ResilientCoasts

FINAL PLAN

November 2025

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Town Neck Beach, Sandwich, MA (Credit: WHG)

NOVEMBER 2025

More than 1,500 miles of coastline in Massachusetts support vibrant communities, a thriving economy, and vital ecosystems. For much of our history, we have looked to the sea. Our ports have welcomed global trade partners for hundreds of years, powering the rapid growth of not just our state, but our entire country. Our fishing industry is one of the biggest in the nation, shaping the lives of generations of families who have fished on our shores. We have brilliant scientists and researchers whose discoveries and innovation are inspired by our waters. Drawn by the opportunity and beauty of our coastlines, Massachusetts families have put down roots in the cities and towns along the Atlantic.

Our coast is changing. As the seas rise, the shore marches inwards and upwards, impacting homes, businesses, roads, trains, ports, energy infrastructure, historic sites, and parks in the ocean's path. Clearly, climate change poses a very real threat to our coastal way of life, but it also presents a unique opportunity for us to build communities that are safer for years to come. Our coastal cities and towns have been weathering erosion, sea level rise, and extreme storms without a holistic state strategy. Homeowners, small businesses, and municipal governments deserve a comprehensive approach to this problem. This is a matter of fiscal responsibility requiring urgent action.

That is why on November 28, 2023, the Healey-Driscoll Administration launched the ResilientCoasts initiative to bring the full powers of the state to deliver real solutions. The goal was to build a bold, long-term plan—together with the people and places most affected. After more than a year of concerted and collaborative efforts with coastal communities, residents, and other partners, I am pleased to present the ResilientCoasts Plan.

This first-ever comprehensive, state-wide strategy provides a 50-year roadmap to strengthen and protect the Massachusetts coastline from the impacts of climate change. The ResilientCoasts Plan assesses the near- and long-term vulnerability of Massachusetts communities, establishes a baseline for the state's efforts to build coastal resilience statewide, and sets the course for how we can best adapt and protect our coast. It is grounded in science, shaped by local voices, and built to guide state and local action over the decades ahead.

A key feature of the plan is the creation of 15 new Coastal Resilience Districts, which will help us better understand and respond to the unique needs of each coastal region—from the North Shore to the South Coast. The plan also provides important tools, data, and guidance to support smart planning and investment at every level.

The stakes are high. If we do nothing, damage to our coastal buildings and infrastructure could cost the state and taxpayers more than $1 billion every year by 2070. But we know that every $1 invested in preparation today can save $13 down the line. By investing proactively in proven strategies, we can avoid far greater future costs—protecting lives, property, and ecosystems while saving taxpayers money. It's about making smart, cost-effective decisions that protect our homes, businesses, and natural resources and ensure that our communities remain strong and livable for generations to come.

Making this vision a reality will take all of us. Implementation will require coordination and commitment. In June, our administration introduced the Mass Ready Act, which will help accelerate our climate resilience efforts and investments and support the implementation of this plan across the state.

To everyone who helped shape this effort—thank you. Your insights and advocacy made this possible. Together, we can build a stronger, safer, and more resilient Massachusetts coast.

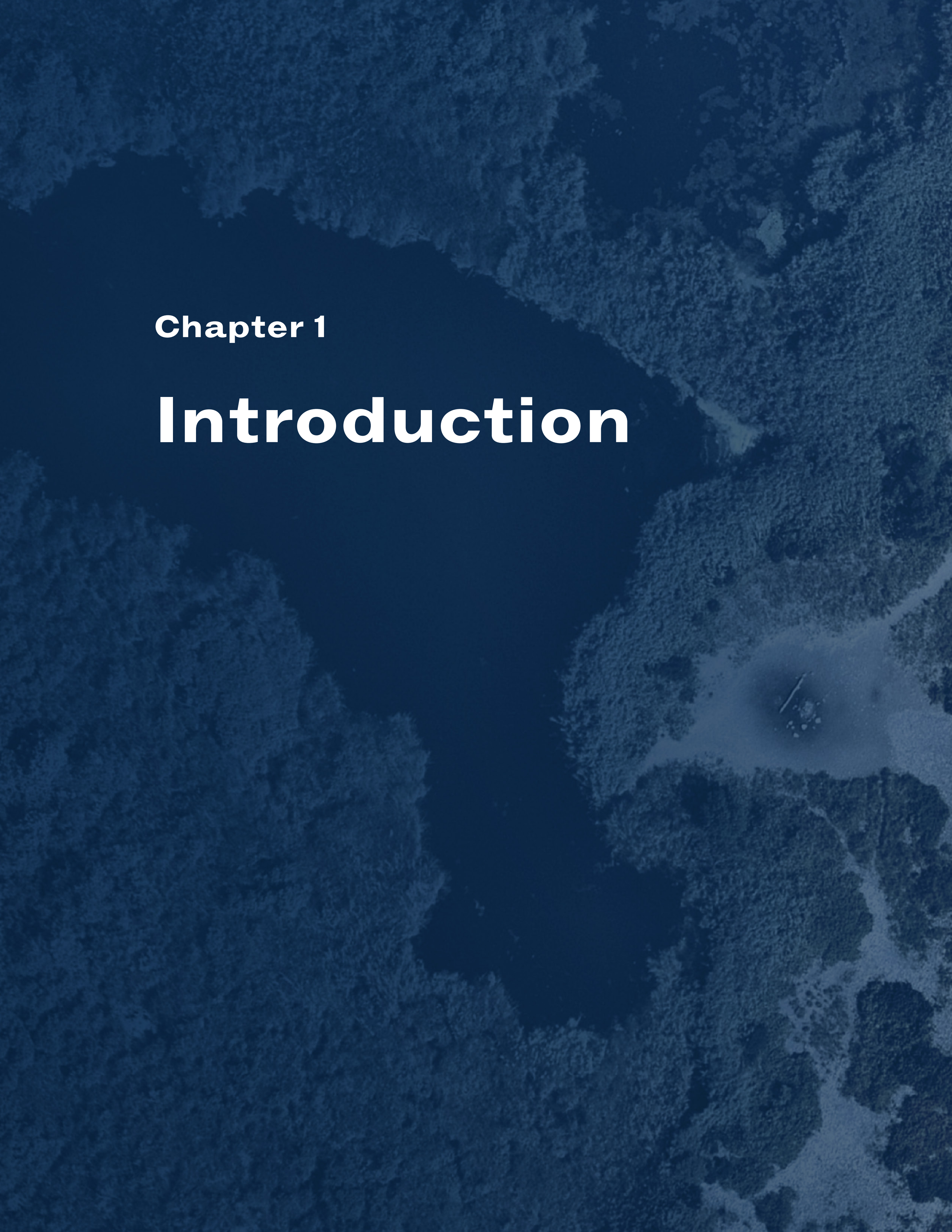
M. T. Healey

Governor Maura Healey

Contents

Chapter 1

Introduction



Our Coast

Over three million Massachusetts residents live in a community expected to experience coastal impacts between now and the end of the century. As climate change increasingly threatens our coastal way of life, it also presents a unique opportunity for us to build communities that are safer and more resilient for years to come.

What's at Risk?

Climate change is already impacting Massachusetts with increased coastal flooding and erosion, putting people, houses, and businesses, as well as significant economic, environmental, cultural, infrastructure, and recreational assets and resources at risk. The best available science shows that, without significant action, the impacts of these hazards on our society, environment, and economy will get much worse over the coming decades due to accelerating sea level rise and intensifying storms. Over three million Massachusetts residents across 98 communities and 8 different counties are expected to experience coastal hazards like storm surge and wave action, sea level rise, and erosion between now and the end of the century.

Coastal hazards are a threat to people's homes, livelihoods, health, and safety. Critical infrastructure providing vital services like police, fire, transportation, power, electricity, water, and other utilities are increasingly exposed to flooding and erosion, compromising access and reliability for thousands of residents. Coastal hazards have the potential to cause injuries, health issues, and even death. They threaten our vast cultural, environmental, and recreational coastal resources that are at the core of the Massachusetts identity – from ports and beaches to historical landmarks and structures. Coastal habitats such as beaches, dunes, and salt marshes are increasingly vulnerable, threatening the vital ecological functions and services these systems provide.

Among the expected economic impacts are damage to residential, commercial and industrial properties, displacement from one's home or community, and lost tourism and impacts to local businesses. Coastal flooding also impacts the ability of people to work (and get to work) and engage in commerce, as well as a range of other day-to-day activities. The Massachusetts marine economy, including tourism, fisheries, aquaculture, and recreation, is estimated to contribute $8.3 billion to the state's gross domestic product (GDP) and $4.1 billion in wages across nearly 6,000 businesses with over 86,000 employees.[1]

Impacts on coastal communities will have ripple effects far beyond the coastal zone. The City of Boston serves as an economic engine and cultural hub for both Massachusetts and the New England region. With a population of over 675,000 people, Boston is the third-largest city in the Northeastern United States, and is an attraction for tens of millions of people each year.[2] Logan Airport, the largest international airport in New England, is located along the Boston Harbor shoreline and serves thousands of residents and visitors a day and employs thousands more. Cape Cod, another popular destination in Massachusetts, is home to over 200,000 year-round residents and is estimated to have 5.5 million visitors annually, the majority during the summer months when they can enjoy the area's beaches and other outdoor recreation.[3] Negative impacts on regional economic centers, pristine beaches and coastal habitats, and critical infrastructure can affect people hundreds of miles from the coast.

The Cost of Inaction

Massachusetts cannot afford the cost of inaction on climate change. Since 1980, weather and climate disasters have cost the state an estimated $10-20 billion.[4] While not all these disasters can be attributed to coastal storms, the frequency of coastal flooding is increasing, and that trend is expected to continue as sea level continues to rise. It's not just the billion-dollar disasters that Massachusetts communities should worry about. Numerous smaller coastal flooding events can also add up. Over the past few years, the coast has experienced significant flood events year-round, including Winter Storm Grayson in 2018 and numerous King Tide flooding events.

The Massachusetts Climate Change Assessment (2022) and the ResilientMass Plan (2023) estimate that future consequences of coastal hazards could be even more severe:

- Coastal property damage could reach **over $1 billion a year**, on average, by the 2070s with over 70% of the damage in the Boston Harbor region.[5]
- Massachusetts municipalities could experience **$104 million in lost revenues** a year by mid-century with 3 feet of sea level rise and **$946 million** per year by end of century with 6 feet of sea level rise.[6]
- Annual expected loss of or damage to state-owned buildings and infrastructure from coastal flooding is estimated at **$8 million today** and may grow to **$36 million by 2050** and over **$52 million by 2070.**[7]

While these are some of the projected economic impacts, the full range of consequences from coastal hazards include loss of life, health-care related costs, damages to ecosystem services, and loss of cultural landscapes and resources. Impacts to natural resources are projected to result in significant changes, including loss of critical habitat and the species that depend on them. Indirect effects resulting from coastal hazards are likely to extend beyond the coast and impact the rest of the state.

Each coastal community faces varying levels of flood exposure, vulnerability to harm or damage, and associated risks due to its unique economic, environmental, and social context. Some coastal communities may have fewer financial resources and less staff capacity to undertake coastal resilience efforts alone, putting them at a disadvantage to other more resourced communities. Within communities, populations that have faced past discrimination, environmental harm, and a lack of investment, are at greater risk from coastal hazards, both at a community and individual level. With limited resources to reduce risks and increase resilience, these populations will continue to face disproportionate burdens.

While the costs of inaction are daunting, preparedness can pay off. By proactively investing in resilience, Massachusetts can avoid the worst impacts and save money doing it. Every $1 invested in resilience and disaster preparedness saves $13 ($7 in economic costs and $6 in cleanup costs).[8] The state can leverage its investment in resilience to simultaneously address existing inequities that place a disproportionate burden on vulnerable and priority populations.

ResilientCoasts

For Massachusetts to continue thriving as the Bay State and providing a safe and high quality of life, our infrastructure, economy, and natural and cultural resources must be made more resilient to climate impacts.

The ResilientCoasts Initiative was announced in November 2023, shortly after it was identified as a priority action in the state's 2023 ResilientMass Plan.[9] Recognizing the significant threat climate change poses to the state's coastal communities and the economy now and in the future, the initiative aims to develop a 50-year comprehensive statewide framework for coastal resilience.

This plan represents an important milestone in advancing the state's broader resilience strategy. It establishes a baseline for the state's efforts to build coastal resilience and sets the course for what we must do to adapt and protect our coast. The plan establishes 15 Coastal Resilience Districts based on shared geography, coastal characteristics, and risks; identifies areas with near-term vulnerability to coastal flooding; provides guidance on place-based strategies for key coastal typologies; and identifies viable and practical state-led coastal resilience strategies to support local and regional efforts and accelerate the pace of resilience coastwide.

The scale of investment needed to achieve coastal resilience cannot be borne by the public or private sector alone. Rather, there is a critical need for public-private partnerships to realize our shared objective.

Broader Resilience Strategy

ResilientCoasts is just one component of the broader statewide approach to resilience in Massachusetts. It is part of ResilientMass, which is the state's umbrella initiative for climate adaptation and resilience programs, policies, and initiatives. Many of the other ongoing initiatives support and integrate with the ResilientCoasts Plan.

Massachusetts has a long history of climate action. In 2008, the Global Warming Solutions Act (GWSA) was signed into law and directed the Executive Office of Energy and Environmental Affairs (EEA) to convene an advisory committee to develop a report analyzing strategies for adapting to the predicted changes in climate.[10] The state's first Climate Change Adaptation Report was released in 2011.[11]

In 2018, the state developed a combined State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), in fulfillment of Executive Order 569 Establishing an Integrated Climate Change Strategy for the Commonwealth.[12] The plan was first of its kind to comprehensively integrate climate change impacts and adaptation strategies with hazard mitigation planning. In 2023, the SHMCAP was updated with the release of the ResilientMass Plan. The 2023 ResilientMass Plan integrates and builds on the impacts identified in the 2022 Massachusetts Climate Change Assessment.

What is "Coastal Resilience"?

Use of the term "resilience" has grown in recent years and has come to mean many different things to different people. Climate resilience, social resilience, and community resilience are all commonly used terms to refer to the ability to overcome and thrive in the face of challenges.

The focus of this plan is "Coastal Resilience," which the state defines as "the capacity of coastal systems and communities to anticipate, prepare for, respond to, and recover from environmental challenges, particularly those related to climate change and natural disasters." Coastal resilience may look different across Massachusetts communities and regions depending on their unique vulnerabilities and exposures of each.

Barrier Beach, Duxbury, MA (Credit: WHG)

5-YEAR CYCLE

INFORMS

August 2008

Global Warming Solutions Act (GWSA)

Signed into law, making Massachusetts one of the first states in the nation to move forward with a comprehensive regulatory program to address climate change.

September 2011

Massachusetts Climate Change Adaptation Report

Released by EEA and the Adaptation Advisory Committee as mandated by GWSA.

September 2016

Executive Order 569

Established an integrated climate change strategy for Massachusetts.

September 2018

State Hazard Mitigation and Climate Adaptation Plan
(later renamed "ResilientMass")

Released as a first-of-its-kind plan to comprehensively integrate climate change impacts and adaptation strategies with hazard mitigation planning.

August 2019

ResilientMass Action Team (RMAT)

An inter-agency steering committee is established to implement, monitor, and maintain the ResilientMass Plan.

April 2021

Climate Resilience Design Standards Tool

Launched to facilitate the application of statewide climate data to the planning and design of physical assets and has been applied annually across municipal grant infrastructure programs and the capital planning process.

April 2021

Massachusetts Coast Flood Risk Model (MC-FRM)

A high-resolution and probabilistic, hydrodynamic model, produced data layers on probability and magnitude (e.g., projected water elevations) of flooding coastwide driven by sea level rise and coastal storms to improve understanding of potential impacts to communities and emergency services during future coastal flood events.

December 2022

Massachusetts Climate Change Assessment

The first statewide assessment detailing how Massachusetts people, environments, and infrastructure may be affected by climate change and related hazards through the end of the century, is released to inform the first five-year update to the State Hazard Mitigation and Climate Adaptation Plan.

October 2023

Office of Climate Science (OCS)

Established to increase state agency, municipal, and public access to and understanding of statewide climate change projections and trends and to provide technical assistance and guidance. They were charged with developing a MA Climate Science report and convening an expert Climate Science Advisory Panel.

2008 … 2011 … 2016 2017 2018 2019 2020 2021 2022 2023

FUNDING & SUPPORT

2013

Dam and Seawall Repair or Removal Grant Program

Launched to provide financial resources for local governments to repair and remove dams, levees, and seawalls to help restore ecological systems, improve public safety, and protect key public assets.

2014

CZM Coastal Resilience Grant Program

Launched to provide financial and technical support for local efforts to increase community understanding of coastal storm and climate impacts, evaluate vulnerabilities, conduct adaptation planning, redesign and retrofit vulnerable public facilities and infrastructure, and restore shorelines to enhance natural resources and provide storm damage protection.

5-YEAR CYCLE

October 2023

ResilientMass Plan

The first five-year update to the State Hazard Mitigation and Climate Adaptation Plan, is released based on the findings, science, and stakeholder engagement of the Massachusetts Climate Change Assessment and identifies, among other hazards, coastal flooding as a key threat to the state.

2028

ResilientMass Plan

Set to be updated in 2028.

INFORMS

5-YEAR CYCLE

RECOMMENDS

November 2023

ResilientCoasts Initiative

Launched to develop a comprehensive, statewide strategy for coastal resilience in Massachsuetts.

November 2025

ResilientCoasts Plan released

2027

Massachusetts Climate Change Assessment

Scheduled to be updated in 2027, will set the stage for the next ResilientMass Plan.

2024 2025 2026 2027 2028

January 2024

Climate Science Advisory Panel

Launched through OCS to provide expertise on statewide climate science and future projections used to inform state and local climate adaptation planning and projects.

January 2024

ResilientMass Metrics Initiative

Launched to develop statewide resilience goals, indicators, and metrics to track progress in implementing the ResilientMass Plan. Metrics will be tracked on resilient.mass.gov and as part of the Massachusetts Climate Chief's annual Climate Report Card.

July 2024

ResilientMass Funding and Finance Strategy

An inter-agency project co-led by EEA and the Governor's Office of Climate Innovation and Resilience is launched to estimate costs needed to invest in statewide key resilience measures and recommend options available to finance and fund climate resilience projects statewide.

2017

Municipal Vulnerability Preparedness (MVP) program

Launched to provide support for cities and towns in Massachusetts to plan for climate change resiliency and implement priority projects.

2023

MVP Planning 2.0

Launched with a pilot of 30 communities that allows communities to both update their resilience priorities through an equitable and inclusive process and build out and implement these priorities through seed project funding.

2025

Resilience Playbook

Set to be released to provide guidance on critical and impactful resilience actions at the local level.

Scope of the Initiative

The Massachusetts coastal zone encompasses 78 coastal communities including those on Cape Cod, Nantucket, Martha's Vineyard, and the Elizabeth Islands. Long-term, 20 additional communities are expected to face coastal impacts from sea level rise and storm surge. Therefore, the geographic planning area of ResilientCoasts includes all 98 of these communities.

The New Coastal Zone

The state's official coastal zone includes lands and waters within an area defined by the seaward limit of the state's territorial sea, extending from the Massachusetts-New Hampshire border south to the Massachusetts-Rhode Island border. It includes 78 communities that are directly served by the Massachusetts Office of Coastal Zone Management (CZM), including all islands, transitional and intertidal areas, coastal wetlands, and beaches.

The Massachusetts Coast Flood Risk Model (MC-FRM) projects that 20 additional communities, primarily located up and along tidal rivers, will be exposed to coastal hazards long-term (2070s).[13] As sea levels rise, the tidal influence will become greater causing coastal flood impacts in these areas and possible erosion of riverbanks. Because the planning time horizon for ResilientCoasts is 50 years, these 20 communities are included in the plan's geographic scope. However, it is important to note that some of these communities are already experiencing impacts from high tides and coastal storms. They may also be uniquely susceptible to risks from compound flooding – flooding that results from multiple drivers like stormwater and groundwater in addition to tidal flooding and storm surge – though that is not the focus of this plan.

Including all 98 communities in the ResilientCoasts Plan helps facilitate more proactive, comprehensive, and long-range planning for coastal hazards. Early coordination on planning, prioritization, and shared solutions can help ensure that investments in resilience are proactive, rather than reactive, and are scaled to be high-impact and cost-effective.

Near- and Long-Term Vulnerability

The ResilientCoasts Plan looks at both near- and long-term vulnerability to coastal hazards. The plan identifies "Near-Term Adaptation Areas" where near-term flood vulnerability intersects with high concentrations of people and housing, built infrastructure, and economic resources at risk. To assess near-term vulnerability, the plan relies on data from MC-FRM that projects the 1% annual chance flood event for the 2030s, based on a sea level rise scenario of 1.3 feet above 2008 levels ("2030s 1% annual chance floodplain"). To assess long-term vulnerability, the plan uses MC-FRM data on the 0.1% annual chance flood event for the 2070s, based on a sea level rise scenario of 4.3 feet above 2008 levels ("2070 0.1% annual chance floodplain.").[14] The effective 0.1% annual chance flood extent used in the ResilientCoasts Plan represents a very extreme event and includes areas with an annual chance flood extent greater than zero (0.1% when rounded up to the nearest tenth percent). This more extreme event was selected over the 1% probability for assessing long-term vulnerability to account for protection of life safety and critical infrastructure.

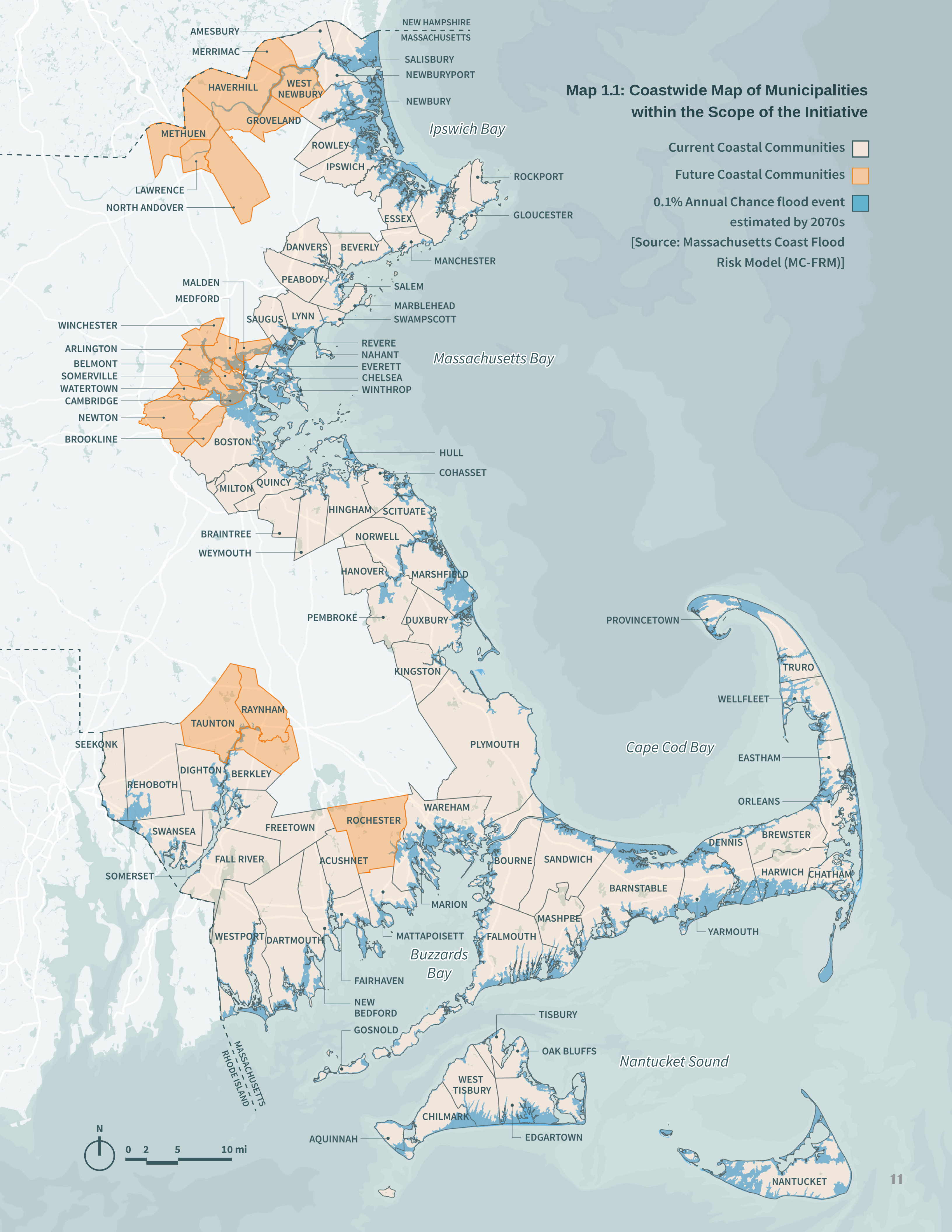
While some areas of the coast may need more urgent action and prioritization, understanding the long-term scale of coastal risk allows communities to plan for coastal resilience over different time scales and coordinate cross-municipally and regionally to identify shared risks and opportunities.

Map 1.1: Coastwide Map of Municipalities within the Scope of the Initiative

Current Coastal Communities

Future Coastal Communities

0.1% Annual Chance flood event estimated by 2070s [Source: Massachusetts Coast Flood Risk Model (MC-FRM)]



Coastal Resilience Framework

ResilientCoasts aims to protect, restore, and responsibly manage the diverse coastal resources along our shorelines and to guide resilience efforts in communities to ensure that our natural and built environments can thrive in the face of current and future climate impacts.

Evolving challenges will require new approaches.

Past approaches to coastal development and floodplain management relied on stable rates of sea level rise and reliable patterns of tides, storms and flooding. With climate change, these approaches are no longer sufficient. At the same time, the coast's natural capacity to absorb and withstand flooding and erosion has been undermined by decades of shoreline armoring and habitat alteration and destruction, impairing coastal ecosystems that help protect people, property, and infrastructure. Development of low-lying, flood-prone areas has put people, property, and infrastructure at risk. We can no longer rely exclusively on hard infrastructure and shoreline structures to block and divert water. While infrastructure like seawalls remain vital to protecting people and critical infrastructure in some places, they are not suitable in all situations. We must restore our coastal ecosystems and implement nature-based approaches where feasible to more sustainably adapt to coastal hazards long-term.

Proactively planning for and investing in coastal resilience will help reduce costs and damage.

Avoiding risk is the most cost-effective approach to coastal resilience. Risk avoidance requires the use of best available science and data to inform decisions about where we build new housing, site new public and critical infrastructure, and make public and private investments. In areas where people, housing, and infrastructure already exist, we must plan for long-term solutions that reduce risk, account for future conditions, and consider the benefit-cost and design life of various resilience measures and other trade-offs. We cannot afford the cost of inaction. Alternatively, investing proactively can pay off - for every $1 invested in resilience measures, the return on investment is $13 during disasters.[15]

Managing the coast requires collective action and planning for a range of scenarios and time horizons.

There is no one-size-fits-all approach to resilience. Different stakeholders will have different needs and risk tolerances requiring interventions at a variety of scales and time horizons. While it is challenging to coordinate resilience efforts among multiple actors at different scales, it presents an opportunity to leverage district and regional scale solutions and investments for greater impact and efficiency. Coordination at these scales will be more cost-effective than focusing efforts at the individual property or community level. Resilience is a collective endeavor, and financial responsibility must be shared among public and private stakeholders.

It will not be possible to completely eliminate all coastal risks, but they can be significantly reduced.

Massachusetts needs bold, innovative solutions that are also equitable, actionable, and forward-thinking. State agencies, municipalities, and other partners have the opportunity to shape a future where the burden of acceptable risk is equitably distributed among communities and residents. Where long-term protection is not feasible, short-term measures may temporarily protect areas most vulnerable to flooding or erosion and buy time to develop more creative, enduring solutions. However, we must acknowledge that some areas face risks beyond our current collective capacity to protect. Shifting toward long-term resilience requires making smart, and often hard, decisions to ensure a more sustainable and prosperous community and coast for tomorrow and future generations.

Vision for a Resilient Coast

ResilientCoasts envisions a **future** where:

- The best available science and data is easily accessible and informs all coastal resilience planning and decision making.
- Actions are proactive rather than reactive, helping to avoid risk and reduce long-term costs and impacts.
- Risk reduction is prioritized for vulnerable populations and, to the maximum extent practicable, coastal resilience strategies are leveraged to address underlying socioeconomic inequities.
- Communities are designed for changing shorelines and floodplains; strategic new development and redevelopment are safe from the impacts of coastal flooding and erosion.
- Coastal communities have the resources, technical expertise, and capacity to increase resilience locally and through regional partnerships.
- Critical infrastructure and services, including transportation, are safe, functional and reliable before, during, and/or after storms allowing residents to safely evacuate and/or shelter in place and quickly recover.
- Essential functions of coastal ecosystems are protected and restored, supporting critical habitat in addition to recreational and economic values and services such as helping protect people, property, and infrastructure from coastal hazards.
- Cultural resources continue to help preserve cultural identity and diversity, allow residents to experience and relate to history, and foster a sense of belonging and community.
- A thriving coastal economy is supported by local tourism and regionally and nationally important water-dependent businesses and industries.
- Access to the coast is protected and enhanced for all residents and visitors.

To achieve this future, coastal resilience efforts in Massachusetts should adhere to the following **guiding principles**:

- Nature-based solutions are prioritized over hard infrastructure where feasible and effective.
- Vulnerable communities, tribal nations, and other priority populations are centered and incorporated throughout the processes of coastal resilience planning, projects, and decision making.
- Not all coastal communities have the same capacity to adapt to coastal hazards, therefore local conditions, including community priorities, health and safety, critical infrastructure, cost-effectiveness, and other characteristics, are considered in assessing risk tolerance.
- Coastal resilience measures that produce environmental and socioeconomic benefits such as enhanced or protected habitat, water quality, coastal access and recreation, green jobs, and environmental education opportunities are prioritized.

Tidal Pond, Thompson Island, MA, 2014 (Credit: CZM)

How to Read this Plan

Collectively, the information, guidance, and strategies in this Plan aim to help Massachusetts achieve its resilience vision through a consistent and comprehensive approach to coastal resilience carried out by the state and coastal partners.

Content and Approach

The ResilientCoasts Plan puts forward a comprehensive and consistent statewide framework for coastal resilience. Planning on a 50-year time horizon, the plan outlines actionable guidance and strategies that address both near- and long-term vulnerability to coastal hazards like sea level rise, storm surge, wave action, and erosion. It identifies specific risks, challenges, and opportunities regionally and coastwide. It also identifies gaps and unmet needs in data and information that can help inform future phases of ResilientCoasts. In addition to the plan, this process has generated data that will be made publicly available through a forthcoming ResilientCoasts Web Viewer. This tool will provide hazard and impact data developed for the plan and can be expanded in future years to include additional information on planned projects and initiatives.

The plan outlines goals and guiding principles that are essential for achieving the state's vision for a resilient coast. The vision, goals, and guiding principles lay the foundation for coastal resilience planning and projects at the state and local level and should inform private efforts as well. In addition, the plan includes the following key components:

ResilientMass Initiative

ResilientCoasts Plan

Coastal Resilience Districts
CHAPTER 5, P. 64

Establishes 15 Coastal Resilience Districts coastwide based on shared near- and long-term coastal hazards and common environmental and physical characteristics of communities along the coast. These districts provide a basis for convening, collaborating, and prioritizing district-scale coastal resilience measures where appropriate and cost-effective. They can also help facilitate peer-learning among communities with similar risks and characteristics and create opportunities to share applicable strategies/measures across similar areas.

Near-Term Adaptation Areas
CHAPTER 6, P. 118

Identifies areas within the Coastal Resilience Districts and typologies where near-term flood risk (between now and the 2030s) intersects with varying concentrations of people and housing, built infrastructure, and economic resources. These areas demonstrate the variability in near-term vulnerability across the coast and can help inform prioritization of resources and intervention.

Coastal Typologies & Coastal Resilience Measures
CHAPTER 7, P. 140

Identifies seven key coastal typologies, representing common coastal environments in Massachusetts and provides a framework for applying resilience measures in different locations based on natural and built characteristics. These coastal typologies are cross-referenced with a shortlist of key resilience measures based on suitability that can be undertaken on different scales and timeframes.

State-led Coastal Resilience Strategies
CHAPTER 8, P. 232

Proposes 10 state-led strategies for coastal resilience and near-, medium-, and long-term state agency actions to ensure a whole-of-government approach to coastal resilience and implementation of the plan.

INTEGRATED INTO

Using the Information in this Plan

How the information in this plan is used may vary depending on the end user. Below are various types of coastal partners, along with descriptions of how they can use the information provided.

Local Governments and Tribal Nations

Many on-the-ground coastal resilience efforts are being implemented at the local level under the leadership of municipal governments and tribal nations who understand the unique vulnerabilities, perspectives, and priorities of their communities. These users can reference the Coastal Resilience Districts to supplement opportunities for district-scale planning, collaboration, and projects. They can use coastal typologies and resilience measures to integrate state guidance on where certain measures are likely to be more or less suitable based on coastal environment, as well as other considerations that should be analyzed locally like population and development density, shoreline condition, costs and difficulty of implementation. Taken together, this information can also help local governments identify cross-municipal resilience measures based on shared risks and physical characteristics.

Local governments can use Near-Term Adaptation Areas to understand how the vulnerability of their communities compares to neighboring communities in their Coastal Resilience District and coastwide. This information can help bring a coastwide perspective to local planning efforts and provide a basis for collaborating and prioritizing efforts across districts. Finally, local governments and tribal nations can reference state-led strategies to understand how the state will approach coastal resilience with its own planning, projects, regulation, and investments; opportunities for partnership and/or replication of state-led strategies at the local level; and what support and funding will be made available for local coastal resilience efforts.

Regional Planning Agencies and Organizations

Regional planning agencies and other regional organizations, like watershed associations, have an important role to play in coastal resilience. They are well positioned to help convene local governments and other coastal stakeholders within the 15 Coastal Resilience Districts to assess, collaborate, and identify joint projects and priorities. They can add needed capacity, bring a broader regional lens to on-the-ground efforts and help disseminate and reinforce place-based guidance on coastal typologies and suitable coastal resilience measures. They may also use information about Near-Term Adaptation Areas to inform prioritization of coastal resilience measures.

State Government

State government has many roles to play on coastal resilience. It supports local efforts through technical assistance and funding, and regulates many local activities related to coastal resilience like development, habitat restoration, and shoreline interventions. State government can also lead-by-example by embedding the ResilientCoasts framework into state planning, projects, investments, and policy decisions. Some state agencies own, operate, and steward coastal properties and public infrastructure while others are responsible for regulating and managing coastal ecosystems and development. Depending on the mission and activities of an individual state agency or secretariat, state government leaders and staff should use place-based guidance on coastal resilience typologies and measures to inform state projects and investments. They can help operationalize Coastal Resilience Districts by providing support, capacity-building, and funding for district-scale projects and collaboration. State agencies are also responsible for implementing the 10 state-led strategies put forward in ResilientCoasts to help achieve resilience coastwide.

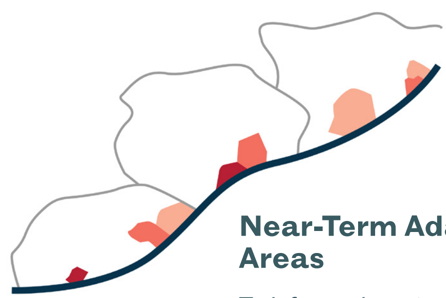
Other Coastal Partners

Numerous other coastal partners have an important role to play in coastwide resilience. Residents, businesses, private property owners, nonprofit and community-based organizations, utility companies and other major infrastructure owners are among those that have a stake in protecting coastal communities and ensuring they can thrive in the face of increasingly frequent and severe coastal hazards. These partners can use the information in this plan to better understand their community's unique characteristics and risk as well as the characteristics and risks of the broader district and coastal region, and help inform actions on coastal resilience, including on their own properties. They can also utilize information on Near-Term Adaptation Areas to understand levels of vulnerability and inform decision-making.

Layers of Information

Coastal Resilience Districts

To inform regional collaboration.



Near-Term Adaptation Areas

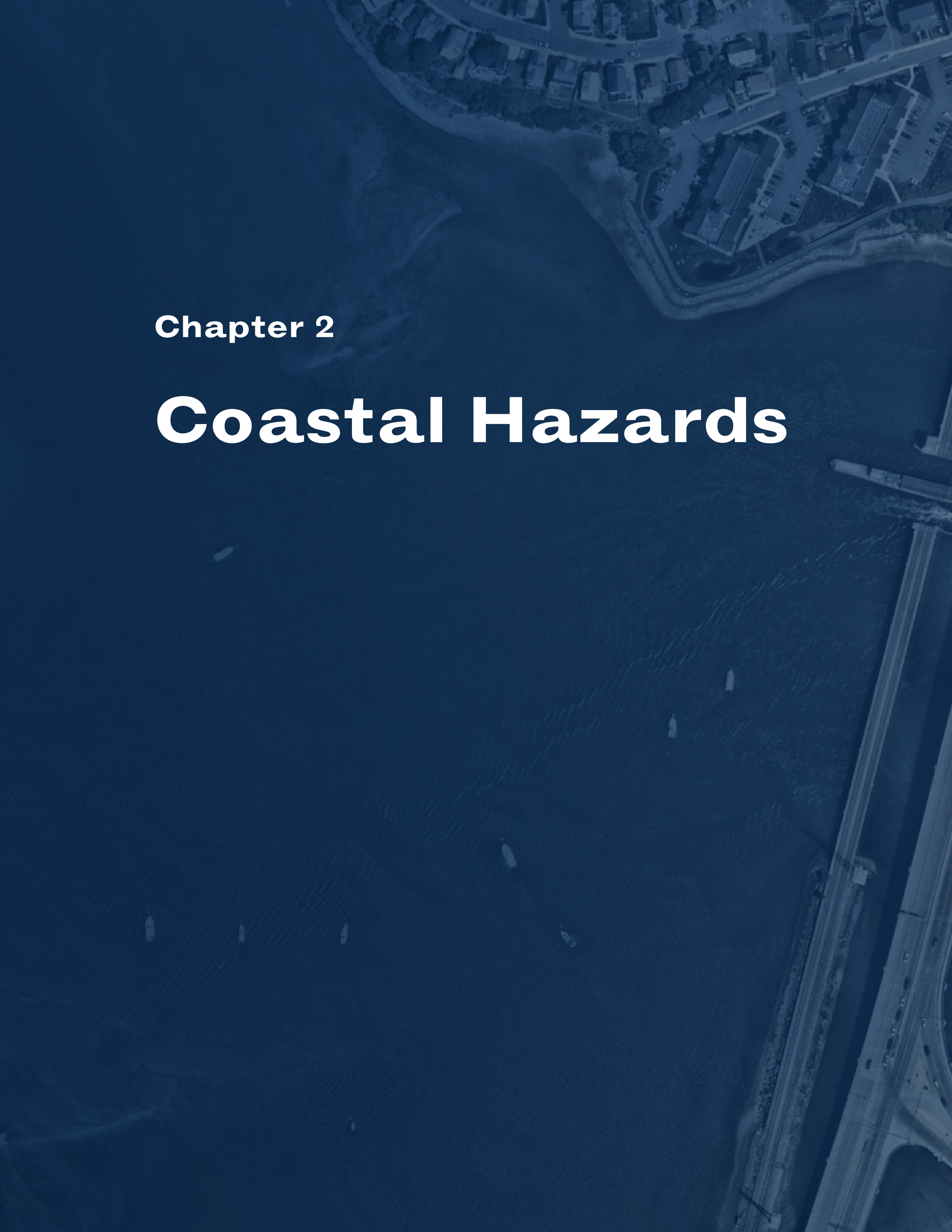
To inform where to prioritize taking action.

Coastal Typologies and Coastal Resilience Measures

To inform how to take action to increase coastal resilience.

Chapter 2

Coastal Hazards



Coastal Hazards

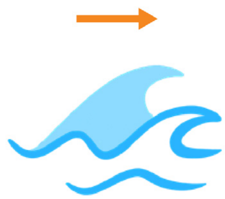
The Massachusetts coastline is highly vulnerable to threats from sea level rise and coastal flooding as well as erosion, hurricanes and winter storms, and other effects of climate change. The focus of the ResilientCoasts Plan is on the coastal hazards of sea level rise, storm surge, wave action, and coastal erosion.

SEA LEVEL RISE

Sea level rise refers to the increase in mean sea level over time. Sea level has been rising in Massachusetts for thousands of years but during the last century, the rate has accelerated due to climate change. Given different future greenhouse gas emissions, the state is planning for sea level rise scenarios above 2008 levels ranging from 1.3 feet in the near-term to 4.3 feet long-term.[16] Sea level rise causes more frequent flooding at high tide on sunny days. Currently, higher than normal tides during full and new moons already cause road closures due to minor flooding. Factors like tidal waters rising up storm drains, land subsidence (sinking), and the loss of natural barriers (beaches/dunes) contribute to high tide flooding. The New England region is expected to see a higher-than-average increase in sea level due, in part, to the fact that the Gulf of Maine is among the fastest-warming regions of the entire global ocean. In Boston, high tide flooding has accelerated by more than triple the national average.[17]

STORM SURGE

Storm surge is the rise in water level caused by storms, such as hurricanes and nor'easters. The geographic location of Massachusetts and the variable orientation of its shoreline make different regions of the coast susceptible to damages from both hurricanes (tropical storms) and nor'easters (extra-tropical storms). Storm surge occurs when low pressure and winds push coastal water landward, flooding normally dry, low-lying land along the ocean, estuaries, and tidal rivers. The combination of storm surge, high tides, powerful winds, and waves can lead to widespread flooding, erosion, and significant storm damages along the coast. Storm surge is expected to intensify as global air and water temperatures rise. Higher sea levels will cause storm flooding to be deeper and extend further inland in low-lying coastal areas.



WAVE ACTION

Nearshore waves are primarily generated as energy is transferred through water often by the ocean and winds. Wave energy and direction contribute to coastal change and impacts. Shorelines that are directly exposed to the ocean can be highly susceptible to wave impacts. Landforms like barrier beaches shelter mainland coastal areas from significant wave forces. Waves are a driver of coastal erosion, property damages, and storm surge overtopping of coastal infrastructure like seawalls and roads.

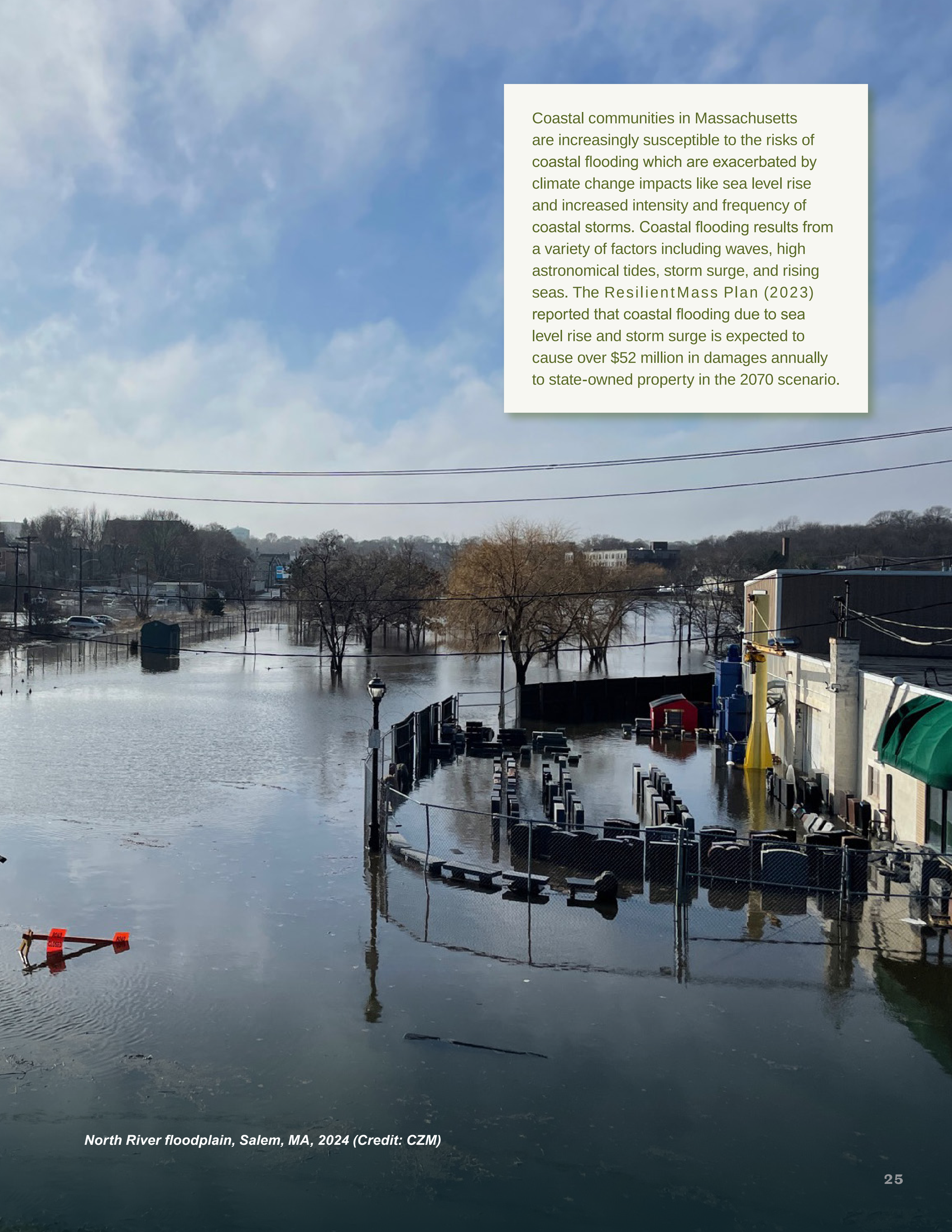
EROSION

Coastal erosion is a process that reshapes shorelines and moves sediment. It is influenced by many factors including tides, storms, waves, development, and shoreline armoring. Accelerated sea level rise and increased intensity and frequency of coastal storms are contributing to increased erosion of the beaches, dunes, coastal banks, and salt marshes of the Massachusetts coast. The undeveloped barrier beaches of Chatham are highly dynamic with some areas experiencing average annual erosion rates over 20 feet per year since the 1970s.[18] The south shores of Martha's Vineyard and Nantucket also experience significant erosion of beach systems and coastal banks. Eroded sediment, such as sediment from coastal banks exposed to waves, benefit the environment in many ways, including enabling coastal wetlands like beaches and salt marshes to shift and build elevation relative to sea level rise. Development along the shoreline and climate change reduce the ability of shorelines to buffer storm impacts. Shorelines armored with seawalls face a unique challenge with the loss of beaches at high tide and structural failures.

Compound Flood Risks

While ResilientCoasts focuses on the coastal hazards of sea level rise, storm surge, wave action, and erosion on Massachusetts coastal communities, compound flood risks must be studied in a future phase to fully understand the magnitude of flood risk to these and other coastal watershed communities. Compound flooding results when multiple drivers of flooding occur together, including higher than normal tides, storm surge, high groundwater, and heavy rainfall. For some areas along the coast, accounting for these compound risks may result in greater flood depths and extents than analyzing sea level rise and storm surge alone. Communities along tidal rivers may be uniquely impacted by compound flood risk, increasing the vulnerability of people and infrastructure along riverbanks. Communities with undersized or outdated stormwater infrastructure are also more likely to be vulnerable to the risks of compound flooding.

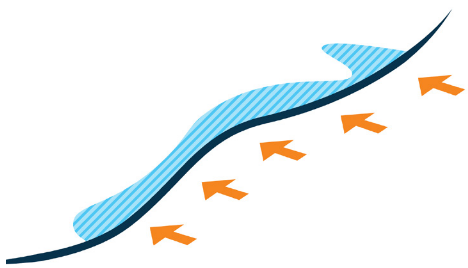
Coastal communities in Massachusetts are increasingly susceptible to the risks of coastal flooding which are exacerbated by climate change impacts like sea level rise and increased intensity and frequency of coastal storms. Coastal flooding results from a variety of factors including waves, high astronomical tides, storm surge, and rising seas. The ResilientMass Plan (2023) reported that coastal flooding due to sea level rise and storm surge is expected to cause over $52 million in damages annually to state-owned property in the 2070 scenario.

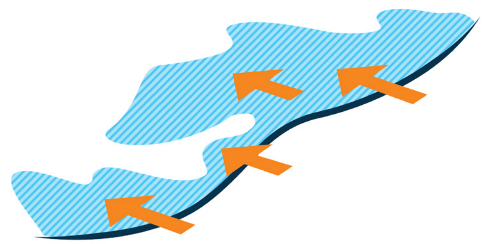


North River floodplain, Salem, MA, 2024 (Credit: CZM)

Patterns of Flood Impacts

Successful measures for addressing coastal flooding depend, in part, on the type of flooding and where it occurs. Flooding can be caused by sea level rise, storm surge, wave action, and erosion.



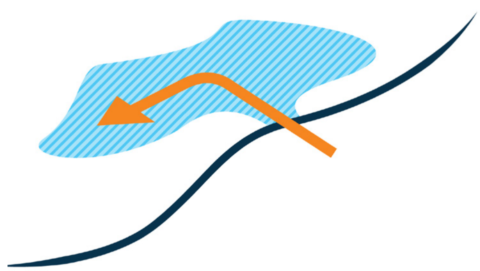


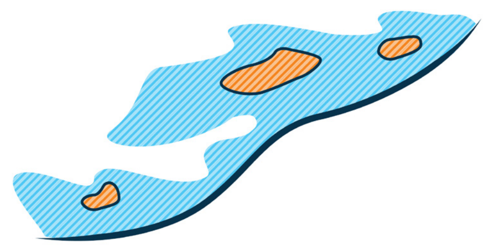
FRINGE FLOODING

Fringe flooding occurs when flood impacts are dispersed along the shoreline and do not propagate much further landward than the coastal edge (for example, in a densely developed context, flooding of first line of waterfront parcels, but not past the first shore-parallel roadway). Where the landform gradually and uniformly rises from the shoreline, flood risk is generally confined to and decreases along the upslope gradient. Waves and wave overtopping may or may not be a factor in these areas, but flooding is generally limited to where the water surface elevation without wave action (stillwater elevation) exceeds local topography. Since fringe flooding is more diffuse in nature, adaptation must occur either at the coastal edge or be applied at the property-scale, depending on the density of development along the coastline.

PROPAGATED FLOODING

Propagated flooding is when flood impacts originate from unconfined shoreline areas and spread significantly landward to the interior floodplain. Past the coastal edge, waves and wave overtopping are generally not a factor unless interior waterbodies or floodplain areas allow for internal wave generation. Where the landform gradually and uniformly rises from the shoreline, flood risk decreases along the upslope gradient and is generally limited to where stillwater elevations exceed local topography. Depending on the patterns and extent of propagated flooding, adaptation may occur either at the coastal edge, at strategic landward locations, or be applied at the property scale.



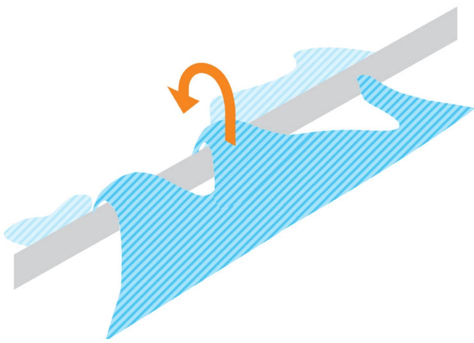


FLOOD PATHWAYS

Flood pathways are areas where propagated flooding is facilitated by a relatively narrow low-lying area near the coast, impacting a much broader landward floodplain. In some cases, these conditions result from existing hydrologic patterns, where a tidal creek opens up to a larger adjacent flood-prone area. More often, however, flood pathways manifest from historical patterns of land alteration (e.g., filled wetlands or buried waterways). This particular pattern of flooding is usually a good candidate for adaptation, either by engineered or nature-based solutions, since the constriction point presents a good opportunity for effective flood mitigation involving fewer landowners. When the landward floodplain is densely developed, these solutions can be efficient and cost-effective.

ISLANDING AND ISOLATED COMMUNITIES

Some communities may be at a slightly higher elevation, protecting them from direct flooding impacts but causing an "islanding" effect during coastal storms, making them vulnerable to coastal flooding by isolating them from access roads. This effect is also increasingly resulting from high tide flooding. Access to developed headlands, nearshore islands, barrier beaches, and glacial hills across coastal Massachusetts is often only via low-lying causeways. These conditions are a concern from an evacuation and emergency access standpoint and, as sea levels continue to rise, present serious issues around the viability of some areas when daily access is lost.



WAVE OVERTOPPING

Along structured shorelines, wave run-up and overtopping contribute to coastal flooding and storm impacts. Overtopping is the conveyance of coastal waters over a seawall, bulkhead, or revetment that occurs when wave run-up exceeds the crest of the structure.[19] When waves break on or over the structure, a continuous flow of water over occurs with each wave. When waves break seaward of the structure or are intercepted by a higher seawall, splash-over can be conveyed landward by momentum or wind. Overtopping volume depends on water levels, winds, and structure geometry. Depending on the landform, overtopping may exacerbate existing flooding, create sheetflow as it drains to other areas, or collect behind the structure. This source of flooding must be addressed by modifications at or seaward of the coastal edge, with adaptation strategies that manage overtopping volumes, redirect energy back to the source waters, or reduce wave energy before the structure.

Marshfield, MA, 2018 (Credit: MyCoast)

Frequency of Flooding

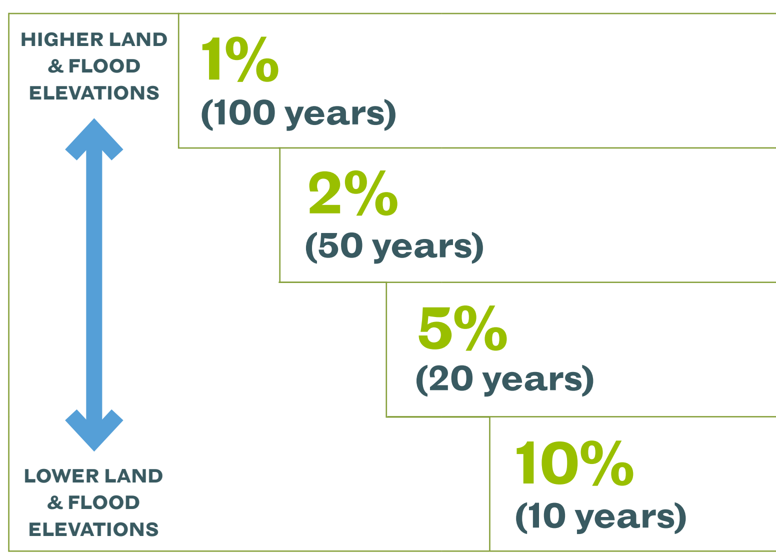
It can be misleading to talk about flood hazards and risk in terms of the average annual return period (or recurrence interval). These values are based on a statistical technique called **frequency analysis**, which estimates the probability a given flood level could be equaled or exceeded in any given year. The occurrence of a “100-year flood” in a coastal town this year does not reduce the probability of the same flood level being equaled or exceeded next year.

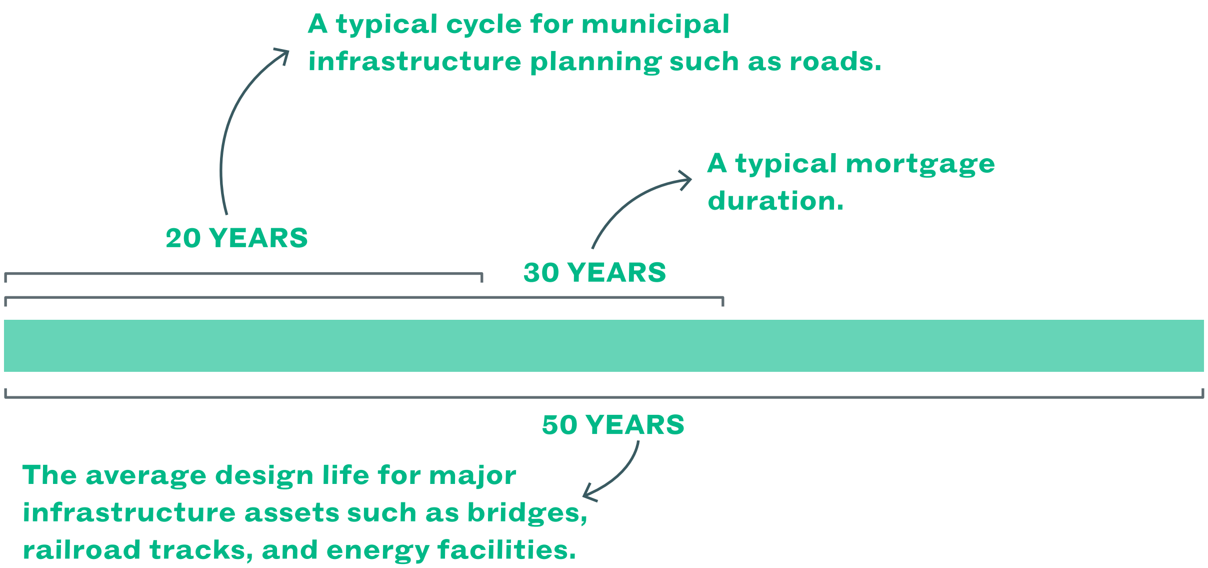
From a purely mathematical standpoint (setting aside the influence of sea level rise), the overall chance of a given flood level occurring at least once accumulates year over year, making flood frequency that is seemingly “rare” in terms of annual probability actually quite likely in the long term. For example, the cumulative frequency of experiencing water levels at or above the 1% annual chance flood at least once in a 20-year period is 18.2%. Cumulative frequency for that same 1% annual chance flood increases to 26% over a 30-year period and almost 40% over a 50-year period. Considering roads (~20-year municipal infrastructure planning cycle), homes (30-year mortgage), and major infrastructure (~50-year design life for bridges, railroad tracks and energy facilities) are located in the floodplain potentially impacted by the 1% annual chance flood, it is important to recognize and plan for the likelihood of flooding over the design life of these assets to reduce vulnerability. Additionally, within the floodplain affected by the 1% annual chance flood level, lower elevation areas along the shoreline have even higher annual and cumulative frequencies of flooding. For example, the cumulative frequency of experiencing water levels at or above the 10% annual chance flood at least once in a 30-year period is nearly 96%. Thus, homes built in these lower-lying areas are virtually certain to be exposed to flooding at least once during the life of a mortgage without intervention. Depending on the type of development across the floodplain, the 1% annual chance flood still represents a higher risk scenario than the 10% annual chance flood due to the larger area flooded and greater depth of flooding.

This is the chance that a flood of a certain size could happen or be surpassed in any given year.

(This doesn’t mean the chance of the same magnitude flood happening the following year are lower!)

ANNUAL CHANCE FLOOD (AVERAGE RETURN PERIOD)





Approximately **1 in 5** chance of flooding from a 1% annual chance flood during a typical planning period (20 years).

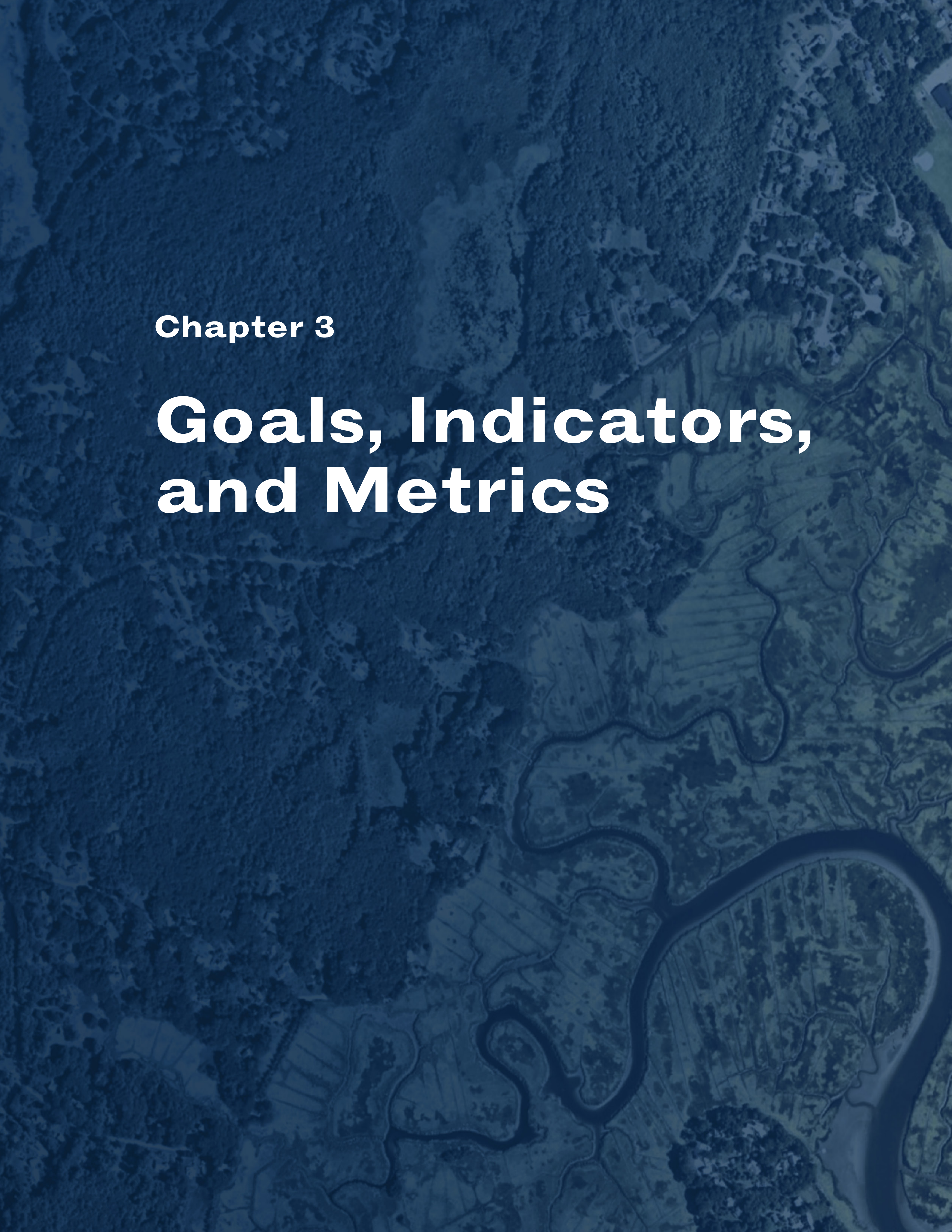
Approximately **1 in 4** chance of flooding from a 1% annual chance flood during the span of a 30-year mortgage.

CHANCE OF FLOODING AT LEAST ONCE DURING:

	A 20-YEAR PERIOD	A 30-YEAR PERIOD	A 50-YEAR PERIOD
	18.2%	26%	39.5%
	33.2%	45.5%	63.6%
	64.2%	78.5%	92.3%
	87.8%	95.8%	99.5%

Chapter 3

Goals, Indicators, and Metrics



Goals, Indicators, and Metrics

The ResilientCoasts Plan is a call to action for Massachusetts, its communities, and many other stakeholders to expand coastal resilience efforts. The goals, indicators, and metrics below align with the state's resilience metrics framework and help lay the foundation for achieving coastwide resilience and tracking the state's progress on implementation.

Goals for a Resilient Coast

ResilientCoasts is a means to effectively, strategically, and equitably coordinate and focus ongoing state engagement on projects, investments, policies, and regulations to make substantial progress on coastal resilience. To guide these efforts, the state has identified the following coastal resilience goals.

These comprehensive goals were developed with the public at the start of the ResilientCoasts planning process. Potential strategies to advance these goals were also identified and evaluated with public input. The guidance and recommendations in this plan are the direct output of this engagement and analysis. For more information about the ResilientCoasts engagement process, see Chapter 4 Engagement and Outreach (page 48).

GOAL A

Improve human health and safety

GOAL B

Protect and enhance the value of natural and cultural resources

GOAL C

Increase resilience of built infrastructure

GOAL D

Strengthen the coastal economy

GOAL E

Advance equity and environmental justice

GOAL F

Support the capacity of coastal communities


Surf Drive, Town of Falmouth, MA, 2023 (Credit: Town of Falmouth)

GOAL A

Improve Public Health and Safety

Sea level rise, coastal flooding, and erosion pose growing threats to the wellbeing of residents, workers, and visitors along the coast. The impacts from these hazards can expose people to unsafe and unhealthy conditions and disrupt access to emergency and health services. Some populations are more vulnerable than others to these impacts, including children, the elderly, people who are socially isolated, racial and ethnic minorities, and people with limited income, limited English proficiency, pre-existing health conditions, or disabilities. Implementing resilience strategies that reduce the impacts of these hazards will improve public health and safety in coastal communities, both in the short- and long-term.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to improve public health and safety to build resilience to coastal climate change impacts:

- CZM Coastal Resilience Grant support for Martha's Vineyard Hospital resilience planning[20]
- MA EEA Office of Technical Assistance and Technology's Chemical Safety and Climate Change Preparedness project to help reduce risk of industrial accidents[21]
- MassDEP updates to the Massachusetts Contingency Plan to require consideration of foreseeable climate change impacts in remediation projects[22]

Indicators

A.1 – Health care, fire, police, and emergency medical services are reliably accessible during and after coastal storms

A.2 – People are able to evacuate or otherwise stay safe during and after a flood

A.3 – Communities have early warning, evacuation, and emergency shelter systems and plans that are accessible to all

A.4 – Exposure to flooding and storm damage health hazards like mold, bacteria, sewage overflows, hazardous waste, and unintentional releases at contaminated sites is limited

GOAL B

Protect and Enhance the Value of Natural and Cultural Resources

Sea level rise, coastal flooding, and erosion pose growing threats to natural and cultural resources and the communities and economic sectors that draw value from them. For example, coastal wetlands have high intrinsic value and provide essential services including wave and erosion reduction, fish and wildlife habitat, carbon sequestration, water filtration, recreational and health benefits, and preservation of Indigenous and cultural practices. Cultural and recreational resources, such as historic landmarks, Indigenous heritage sites, and waterfront parks, contribute to unique character and sense of place, drawing residents and visitors to the coast. While some changes to where these resources are located or how we interact with them are expected, implementing resilience strategies through collaborative and reparative practices help natural systems function and ensure continued access to their benefits. Identification and protection of Indigenous landscapes should be by, with, and for Indigenous communities.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to protect and enhance natural and cultural resources and build resilience to coastal climate change impacts:

- CZM and Massachusetts Board of Underwater Archaeological Resources NOAA-funded Project of Special Merit assessing the vulnerability of the state's coastal cultural resources to erosion, coastal storms, and sea level rise
- EEA Planning Assistance Grants supporting Cape Cod Coastal Resilience model bylaw[23]
- Resilient Lands Initiative[24]
- CZM Coastal Resilience Grant support for House of Seven Gables resilience planning project[25]

Indicators

B.1 – Nature-based solutions are permittable, incentivized, and widely deployed where applicable across the coast, particularly when led by and to benefit priority populations

B.2 – A diverse set of important historical, cultural, and recreational resources are inventoried and prioritized for either preservation or documentation

B.3 – Functions and benefits of salt marshes are understood, protected, and restored

B.4 – Functions and benefits of coastal beaches, dunes, and banks are understood, protected, and restored

B.5 – Impacts of coastal engineered structures on marine environments and other natural resource systems are limited

B.6 – Public access to coastal resources and natural areas is resilient and equitable

GOAL C

Increase Resilience of Built Infrastructure

Sea level rise, coastal flooding, and erosion pose growing threats to critical infrastructure, essential facilities, and residential buildings. When critical lifelines, like transportation, utilities, and housing, are damaged or disrupted, the people and organizations they serve are impacted both immediately and over the longer-term recovery. Lost income and reduced value of damaged assets are coupled with costs to relocate, repair, or rebuild, straining private and public finances and diverting resources from other uses. While it is not possible to eliminate all risks to built infrastructure, the impacts of coastal hazards can be reduced. Implementing resilience strategies will allow these systems to avoid or withstand and recover from chronic and episodic exposure to coastal hazards, minimizing damage and economic impacts, and protecting public health and safety.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to increase the resilience of built infrastructure to coastal climate change impacts:

- CZM Coastal Resilience Grant support for Mattapoisett evacuation road project[26]
- MVP funded Newburyport flood protection/ trail project and Scituate Comprehensive Wastewater Resilience Study[27]
- MBTA Aquarium Station Floodproofing Project, Charlestown Bus Garage Seawall Reconstruction Project, and Blue Line Tunnel Airport Portal Flood Protection Project[28]
- Updates to the Massachusetts State Building Code to include standards for Coastal A Zones and additional freeboard requirements[29]

Indicators

C.1 – Damages to existing essential buildings and structures from coastal flooding and erosion are reduced

C.2 – New housing and structures are not exposed to coastal flooding and erosion

C.3 – Damages to existing housing from coastal flooding and erosion are reduced

C.4 – Public transportation services are reliable before, during, and/or after storms

C.5 – Risks of coastal flooding and erosion to critical transportation infrastructure and evacuation routes (e.g., street, trail, bridge, bus, rail, air, and water) are reduced

C.6 – Access to electricity, cell service, internet, and fuel is reliable during and/or after storms

C.7 – Exposure to coastal flooding and saltwater contamination for water supply and wastewater treatment systems are reduced

GOAL D

Strengthen the Coastal Economy

Sea level rise, coastal flooding, and erosion pose growing threats to the coastal economy and workforce. Historically, centers of industry and commerce were built close to the coast due to its importance for transportation, trade, and natural resource dependent activities. Though many historic downtowns and waterfronts have transitioned to non-water dependent retail and services, their coastal locations make them increasingly vulnerable to coastal hazards. Major water dependent sectors, including tourism, seafood, shipping, energy, marine construction, and research, are important to the current and future economic vitality of coastal communities. Damage and disruptions caused by coastal hazards make it more difficult for small businesses and their workers to continue operating successfully. Natural resource-based sectors are vulnerable to other impacts of climate change, such as changes in water temperature and biodiversity. Implementing resilience strategies that reduce the impacts of these hazards will allow coastal communities and water dependent industries to continue to thrive, while creating new opportunities for workers and businesses to benefit economically from local and regional resilience investments.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to strengthen the coastal economy to build resilience to coastal climate change impacts:

- State supported Island End River project in Chelsea protecting food distribution businesses[30]
- CZM pilot study assessing resilience in the Chelsea Creek and Gloucester Inner Harbor Designated Port Areas[31]
- CZM Coastal Resilience Grant support for Provincetown to address downtown flooding[32]
- Seaport Economic Council grant program supporting working waterfronts, local tourism, coastal resilience, and maritime innovation[33]

Indicators

D.1 – Coastal infrastructure supports the marine economy and water-dependent industries (e.g., fisheries, maritime, offshore wind, research, tourism industries)

D.2 – Commercial and industrial areas and activities maintain operations during King Tides and minor coastal storms

D.3 – Small businesses have access to flood preparedness, mitigation, and recovery resources

D.4 – Community members, particularly priority populations, have skills and access to opportunities to participate in the coastal resilience workforce

D.5 – Coastal economies transition successfully in resilient sectors or alternative locations

GOAL E

Advance Equity and Environmental Justice

Sea level rise, coastal flooding, and erosion pose growing threats to the wellbeing of historically marginalized and socially vulnerable groups. Coastal communities, especially low-income, communities of color, and Indigenous groups, often bear a disproportionate burden of impacts from coastal hazards, yet they may lack the resources and infrastructure to adapt. Implementing targeted resilience strategies will embed environmental justice and equity in climate adaptation, ensuring that these communities are prioritized and empowered to actively participate in decision making, addressing existing disparities, and ensuring the benefits of resilience efforts are shared equitably.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to advance equity and environmental justice to build resilience to coastal climate change impacts:

- MVP 2.0 Planning Grants for municipalities to revisit MVP 1.0 climate resilience priorities with a focus on equity[34]
- CZM Coastal Resilience Grant support for Salem and community groups to undertake Community-Based Participatory Action Research on community resilience in the Point (“El Punto”) Environmental Justice neighborhood[35]
- Executive Order No. 615 to increase language access across state government[36]

Indicators

E.1 – Actions reduce existing inequities in climate change burden

E.2 – Priority populations’ inputs are centered in coastal resilience planning and prioritization of funding and projects

E.3 – Coastal planning respects Indigenous residents’ rights and relationship to nature and incorporates Indigenous knowledge and practices

E.4 – Public conversations on resilience are accessible for all community members

E.5 – Unintended consequences (e.g., displacement due to housing price increases) from resilience improvements are avoided

E.6 – New affordable housing is not exposed to coastal flooding and erosion

GOAL F

Support the Capacity of Coastal Communities

Sea level rise, coastal flooding, and erosion pose growing threats to coastal communities, especially those with extensive vulnerabilities or limited capacity to adapt. To effectively lead efforts to build coastal resilience at the local and regional levels, state agencies, municipalities, tribes, and non-profit organizations need tools, resources, and knowledge targeted to their specific circumstances and priorities. However, staffing, funding, technical assistance, training, and policy supports are currently insufficient to meet the diversity and level of needs. In order to implement resilience strategies, communities first need the resources to build local and regional capacity to assess risks and identify priorities.

Past and Ongoing Initiatives

The following are examples of how Massachusetts has been working to support the capacity of coastal communities to build resilience to coastal climate change impacts:

- Executive Order No. 604 establishing the Office of Climate Innovation and Resilience and a Cabinet-level Climate Chief position[37]
- Establishment of a state Disaster Relief and Resilience Fund[38]
- Expansion of tribal and non-profit eligibility for MVP and CZM grants

Indicators

F.1 – Municipalities, and regional government entities have dedicated staffing capacity to work on coastal resilience issues and access resources

F.2 – Coastal communities receive state financial and technical support on coastal resilience issues

F.3 – State, tribal, and local partnerships prioritize collaboration on regional strategies where needed

F.4 – Funding, financing, and technical assistance from all available sources is sufficient to address the highest state, regional, and local priorities

F.5 – The public has a broad understanding of coastal resilience challenges and opportunities

F.6 – Coastal municipalities have robust strategies to address climate-related impacts to tax bases

F.7 – State and municipal laws, regulations, and policies provide clear, transparent, and predictable frameworks for land use planning, resilient design, and managed retreat

Metrics for Success

Tracking Progress

ResilientCoasts provides a framework for tracking progress on each goal and evaluating the outcomes of implementation. The goals and indicators listed in this chapter provide a broad look at the objectives of the ResilientCoasts Plan. Metrics are a way to track, in more detail, incremental progress (from a known starting point) towards the stated goals. The information provided by metrics can be used to support:[39]

- **Deliberate planning and decision making.** Planners can use metrics to determine where (by geography, hazard, etc.) additional attention is needed to progress towards goals.
- **Resilience funding justification.** Metrics provide quantitative support of the positive impacts of the plan and highlight where further achievement may be hampered by a lack of funding.
- **Accountability and good governance.** Public reporting of metrics on a regular schedule increases transparency and gives all stakeholder access to the same information on the state's progress.
- **Communication and public engagement.** The goals-indicator-metrics framework communicates to the public a clear statewide approach to coastal resilience and can highlight areas where partners in the community, academia, and local governments can contribute to the common statewide goals.
- **Learning and adaptive management.** Planners can use metrics to understand what parts of the plan are working and where adjustments may be necessary to maximize positive impacts of resilience strategies (and minimize any unintended negative impacts).

A set of 24 metrics was selected to be phased in over the next five years to track progress toward the plan's goals. Data are currently available to track and report on a subset of the metrics; however, it will take some time to set up systems for collecting necessary data for the remaining metrics. The selected set of metrics aims to provide coverage across all goals and indicators while ensuring it is feasible to collect data and report within the next five years. The ResilientCoasts metrics were developed concurrently with the statewide ResilientMass Metrics Initiative, which covers all climate stressors and all regions of Massachusetts.

The process of selecting ResilientCoasts metrics began by mapping the ResilientMass metrics to ResilientCoasts goals and indicators. Benefits to aligning statewide metrics with ResilientCoasts metrics include unified planning and communication, and efficient data tracking. The mapping process resulted in three outcomes:

- **ResilientMass metrics that align with ResilientCoasts goals and are specific to coastal hazards.** These metrics were adopted into the ResilientCoasts metric set as is (e.g., *# of acres of coastal resources protected and restored*).
- **ResilientMass metrics that align with ResilientCoasts goals, but have a broader scope than coastal hazards.** These metrics were amended slightly to better fit the scope of ResilientCoasts either geographically or by hazards (e.g., adding 'coastal' to *# of coastal resilience projects planned or implemented in collaboration with tribal and Indigenous organizations*).
- **Gaps in ResilientMass metric coverage of ResilientCoasts goals and indicators.** Given the broader scope of ResilientMass metrics, the statewide metric set does

not cover all important aspects of the ResilientCoasts Plan. Therefore, additional metrics were developed specifically for the ResilientCoasts Plan to address the remaining goals and indicators.

The resulting set of metrics was further refined into a concise set of metrics by selecting those that connect to multiple indicators and goals, provide unique information compared to other considered metrics, address issues of importance to stakeholders, and connect to strategies in the ResilientCoasts Plan.

The final set of metrics is organized in the table that follows by anticipated timeline for tracking and reporting. For each metric, the table identifies the related goals and indicators (as defined earlier in this chapter), as well as flags the metrics that are aligned with an existing statewide ResilientMass metric.

What is ResilientMass Metrics?

ResilientMass Metrics measure and evaluate progress on climate resilience across the state. The metrics assess progress toward building environmental, social, physical, and economic resilience to climate change, with a focus on advancing environmental justice and equity within the process and outcomes. The metrics are designed to track how 2023 ResilientMass Plan actions reduce priority impacts identified in the 2022 Massachusetts Climate Change Assessment. The metrics were developed in 2024 by the MA Executive Office of Energy and Environmental Affairs (EEA) and the MA Emergency Management Agency (MEMA) with input from state agencies, local partners, and an Equity Advisory Group.

Next Steps for Metrics

The metrics framework will be implemented (e.g., data collection processes are finalized, data are collected, metrics are reported) over the next five years. Each metric requires a baseline measurement of where things stand today and a plan for how to update measurements in the future. This process will be done in coordination with the statewide ResilientMass Metrics team. Phasing this work over the next five years allows agencies and programs time to set up data collection systems in response to the metrics.

Another important next step involves breaking down the metrics such that progress can be reported for all communities coastwide. This approach allows the metrics to say something about the equity of resilience improvements. Currently, data availability limits the ability to report in this way across many metrics. Therefore, setting up data collection systems to track information at the appropriate spatial scale, or by categorized demographics, is a critical next step.

Ready to Start Tracking Now

1*	% of state-aided housing developments, identified as highly vulnerable to multiple climate hazards, that have received climate resilience funding
2*	# of coastal resilience projects conducted in collaboration with Tribal Nations and Tribally serving (Native serving) organizations

Develop for Tracking in 1-2 Years

3	% of coastal communities covered by Community Emergency Response Teams (CERTs) that have coastal hazard response plans
4*	# of acres of coastal resources protected and restored (by resource type) (acres or % protected and increased per year)
5	# of beach closures for health reasons
6	% of MA shoreline that is unarmored
7	% of MA shoreline with free public access
8	% of coastal municipalities, RPAs, and counties that have dedicated staff working on coastal resilience, adaptation, coastal hazard preparedness
9*	% of MVP planning and action grant projects and Coastal Resilience Grants that are regional/joint
10	# of coastal municipalities that are addressing climate-related impacts to tax base in MVP plans

* Asterisk indicates that a metric is nested within ResilientMass Metrics Initiative

GOAL A Human Health and Safety	GOAL B Natural and Cultural Resources	GOAL C Built Infrastructure	GOAL D Coastal Economy	GOAL E Equity and Environmental Justice	GOAL F Capacity of Coastal Communities
✓ A.2		✓ C.1, C.3		✓ E.6	
	✓ B.2			✓ E.1, E.2	✓ F.3
✓ A.3					
✓ A.2, A.4	✓ B.3, B.4, B.5	✓ C.1, C.5, C.7	✓ D.1, D.2, D.3		
✓ A.4			✓ D.1	✓ E.1	
	✓ B.1, B.5			✓ E.3	
	✓ B.6			✓ E.1	
				✓ E.3, E.4	✓ F.2
				✓ E.1 E.2	✓ F.3
					✓ F.6

✓ B.1, B.5 — The numbers correspond to the indicators under each goal that this metric satisfies. Refer to pages 36-41 for the indicators under each goal.

Develop for Tracking in 3-5 Years

11*	% of new and existing water and wastewater treatment plants in coastal areas that consider projected flooding, heat, and wind risks throughout the project's lifespan
12	% of miles of evacuation routes that have adequately addressed climate risks (or # miles of evacuation routes that are exposed to the floodplain)
13*	Average annual weather-related electricity outages in the coastal zone, measured with the System Average Interruption Duration Index (SAIDI)
14*	% of new and existing critical facilities in the coastal zone with backup electricity supplies
15*	% of new and existing critical infrastructure facilities in coastal areas that consider projected flooding, heat, and wind risks throughout the project's lifespan.
16	# of residential units constructed or redeveloped in the high hazard floodplain
17*	# of hours of coastal hazard-related transit service disruption (average per event and cumulatively per year)
18	# of contaminated sites in floodplain that have been remediated for projected coastal flood risks
19	# of structures in the coastal floodplain removed via voluntary buyouts
20	# of Orders of Conditions for ecological restoration projects
21	# of publicly funded resilience projects implemented to protect or preserve historic, cultural, or recreational resources in the coastal zone
22*	$ of state funding for resilience improvements for port operators, port business suppliers, and other port-related businesses
23*	$ of state funding for climate resilience improvements for businesses in the coastal zone
24*	# of workers trained in coastal resilience-related skills via MassHire programs

* Asterisk indicates that a metric is nested within ResilientMass Metrics Initiative

GOAL A Human Health and Safety	GOAL B Natural and Cultural Resources	GOAL C Built Infrastructure	GOAL D Coastal Economy	GOAL E Equity and Environmental Justice	GOAL F Capacity of Coastal Communities
✓ A.4		✓ C.7			
✓ A.2, A.3		✓ C.5			
✓ A.2		✓ C.6	✓ D.2		
✓ A.2		✓ C.6	✓ D.2		
		✓ C.6, C.7	✓ D.2		
✓ A.2, A.3		✓ C.2		✓ E.1, E.5, E.6	
✓ A.1		✓ C.4	✓ D.1, D.2	✓ E.2, E.4, E.5	
✓ A.4				✓ E.1	
✓ A.2		✓ C.1, C.2, C.3	✓ D.3	✓ E.5	✓ F.4, F.5, F.7
	✓ B.1				
	✓ B.2				
			✓ D.1, D.2		
			✓ D.3, D.5		
			✓ D.4		

✓ B.1, B.5 — The numbers correspond to the indicators under each goal that this metric satisfies. Refer to pages 36-41 for the indicators under each goal.

Chapter 4

Engagement and Outreach

Engagement Process & Timeline

Stakeholder engagement was critical to shaping the ResilientCoasts strategy, from articulating goals, to identifying coastal resilience measures, to building consensus on policy responses and actions. Engagement was organized around three phases, or “waves”, each with a set of engagement strategies that included public meetings and surveys, smaller group meetings, and other direct engagement opportunities.

Waves of Engagement

Governor Healey formally announced the ResilientCoasts Initiative in November 2023. Given its significance and the need for strong partnership, the engagement process started before this announcement. The State developed a stakeholder engagement plan, compiled contacts from other relevant planning initiatives, and worked to recruit representatives of State agencies and external organizations with active roles and important stakes in coastal resilience. The State also contacted coastal legislators, mayors, and town administrators to share the overall intent of the plan and provide an opportunity to ask questions or request information ahead of time.

The subsequent planning process included the following three waves of engagement, each with distinct objectives:

WAVE 1 – Vision, Goals, and Indicators

In Wave 1, stakeholders were presented with coastal impacts identified in the 2022 Massachusetts Climate Change Assessment and a preliminary set of goals and indicators for the plan.[40] Stakeholders were given the opportunity to rate the importance of draft goals and indicators, describe anything they felt was missing, and help illustrate with greater specificity what the goals mean for their communities. This input helped ensure the process would work toward the most important goals and helped inform a robust set of indicators by which to gauge potential place-based and coastwide strategies. In addition, key stakeholders reviewed preliminary factors under consideration for defining the boundaries of Coastal Resilience Districts and provided input on ways to refine them.

WAVE 2 – Coastal Resilience Districts and Resilience Measures

In Wave 2, stakeholder engagement focused on characterizing the Massachusetts coast into Coastal Resilience Districts and identifying potential coastal resilience measures. Stakeholders were presented with the purpose of Coastal Resilience Districts within the broader ResilientCoasts framework and given the opportunity to provide feedback on draft district boundaries. Discussions were facilitated on projects and issues that would benefit from regional collaboration at the district level and how the State could support such collaboration. An online map and survey were used to crowdsource stakeholder input on coastal resilience problem and opportunity areas in districts. Stakeholders were asked about potential priorities for using state tools, such as regulation, funding, and capital planning, to advance coastal resilience. The State shared plans to provide guidance on applicable place-based coastal resilience measures for types of coastal environments that are common across the coast, as well as identify near-term areas of risk to people and housing, built infrastructure, and economic resources exposed to coastal flooding.

WAVE 3 – State-led Strategies and Near-Term Adaptation Areas

In Wave 3, stakeholder engagement focused on further refining coastwide resilience strategies and priorities for state-led action, as well as reviewing draft "Near-Term Adaptation Areas" (i.e., areas of the coast that will face greatest risk by 2030) and providing input on their application. Stakeholders reviewed a refined set of draft state-led resilience strategies, based on feedback received during Wave 2, encompassing a range of tools that the State could potentially leverage to better facilitate broader and faster implementation of coastal resilience actions coastwide. Stakeholders also reviewed Near-Term Adaptation Areas and gave feedback on the methodology and approach to identifying these areas and ways to most effectively use them for coastwide prioritization and planning.

Equitable Engagement

A layered, adaptive, and flexible approach is critical for effective engagement, especially with vulnerable populations who have historically been less heard in planning processes and who face higher barriers to participation. Barriers may include limited time, language accessibility issues, unclear rationale for or benefit in participating, formats or environments that are culturally unfamiliar and less comfortable, being less likely to receive invitations to participate, and others. Cognizant of these and other barriers, ResilientCoasts followed best practices for equitable engagement, including the following:

- Provided multiple channels for engagement to allow people to participate in the way that works best for them (i.e., virtual meetings, asynchronous channels for comment such as surveys, small-group settings such as focus groups and interviews, and presenting at existing forums).
- Held public meetings during both workday and evening hours.
- Offered opportunities for "office hours" where stakeholders could drop-in informally to discuss the planning process, ask questions, and share concerns.
- Used plain language and visuals to explain concepts.
- Provided compensation for representatives of community-based organizations, Environmental Justice populations, and tribes to participate in focus groups.
- Provided compensation for community liaisons, who helped network with and bridge different constituencies during the planning process.
- Assessed gaps in representation among participants and conducted targeted outreach to address those gaps.
- Provided interpretation and translation of materials for language accessibility.
- Listened to feedback and adapted engagement approaches where needed to reach stakeholders more effectively.

Stakeholder Groups & Activities

The ResilientCoasts Plan was developed through iterative and layered engagement activities involving diverse stakeholder groups and the public.

These included regular meetings of the Project Management Team, and participation from the following groups:

Internal Working Group (IWG)

Representatives from relevant Executive Offices.

External Task Force (ETF)

Representatives from different sectors, including environment, business, real estate, regional planning, academia, philanthropy, insurance, environmental justice, and more.

Focus Groups, Meetings, Briefings

Key stakeholders, such as coastal municipalities and regional planning agencies, or groups whose input may not have been adequately captured in the meetings and surveys, such as Environmental Justice communities, working waterfront stakeholders, and housing advocates.

Broader Public

The broader public and community of coastal stakeholders.

Office Hours

Held by CZM and open to all, to engage the broader public and coastal stakeholders.


WAVE 2
Coastal Resilience Districts and Resilience Measures
WAVE 3
State-led Strategies and Near-Term Adaptation Areas
Environmental Justice Focus Group Meeting 2
Tidal River Communities Convening
External Task Force Meeting 4
Internal Working Group Meeting 4
Coastal Caucus Briefing
Coastal Communities Convening 1
Internal Working Group Meeting 6
External Task Force Meeting 6
November-December 2024 CZM Office Hours
Working Waterfront Focus Group 1
Internal Working Group Meeting 7
External Task Force Meeting 7
Community Liaison Meeting 3
2024
2025
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
Internal Working Group Meeting 3
External Task Force Meeting 3
Regional Planning Agencies Convening
Community Liaison Meeting 2
Internal Working Group Meeting 5
External Task Force Meeting 5
October-November 2024 Public Survey 2
October 21 & 25, 2024
Public Meeting 2
March 2025 CZM Office Hours
March 3 & 4, 2025
Public Meeting 3
Coastal Communities Convening 2
Working Waterfront Focus Group 2
Housing Focus Group

Project Management Team

ResilientCoasts was managed by the Chief Coastal Resilience Officer in collaboration with a project management team of representatives from the Massachusetts Office of Coastal Zone Management (CZM) and the Executive Office of Energy and Environmental Affairs (EEA) Climate Team. The project management team met regularly to steer the project direction, served as subject matter experts, and connected with other agency officials and staff as needed for input, review, and other support.

Internal Working Group

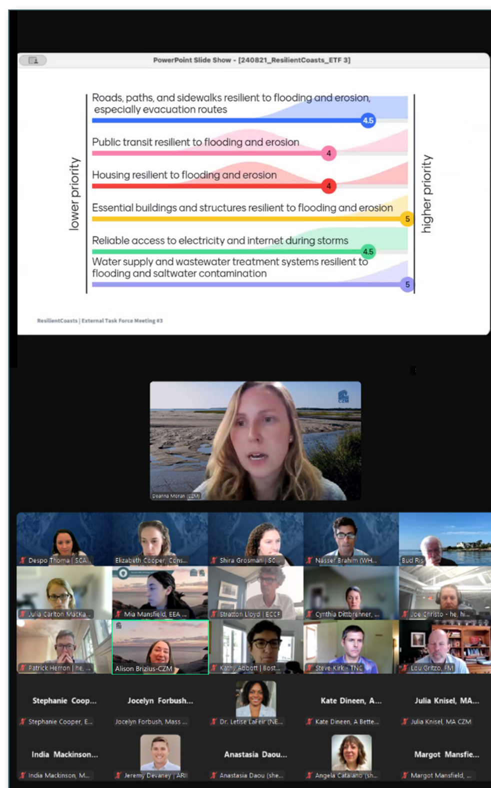
Representatives from relevant Executive Offices participated in the Internal Working Group (IWG). Considering the whole-of-government approach to ResilientCoasts, the IWG provided critical cross-agency input and guidance in the development of all aspects of the plan, both refining principles and strategies and thinking through and addressing potential implications for other State initiatives. The group met seven times over the course of the planning process.

External Task Force

The State formed a task force of external stakeholders from different sectors. The External Task Force (ETF) provided a range of crucial community, stakeholder group, and subject matter expert perspectives to guide and ground truth potential approaches throughout the development of the plan. The ETF met seven times over the course of the planning process, twice in each wave of engagement.

Focus Groups

As part of a layered approach to engagement, the State conducted focus groups with community liaisons and others in each wave of engagement. Focus groups targeted key stakeholders, such as coastal municipalities and regional planning agencies, or those representing groups whose input may not have been adequately captured in the meetings and surveys, such as Environmental Justice populations. The focus groups covered similar topics to those addressed during public meetings but provided additional flexibility to delve deeper into more contextual issues facing specific stakeholder groups. Recruits for Environmental Justice and other priority population focus groups were offered compensation for their participation.



More than **65** hours of community engagement

6 public meetings across **3** waves of engagement

30 focus groups, community consultations, and external task force meetings

47 internal working group members from **18** state agencies

42 external task force members from **27** organizations

Over **190** survey respondents across **2** online public surveys

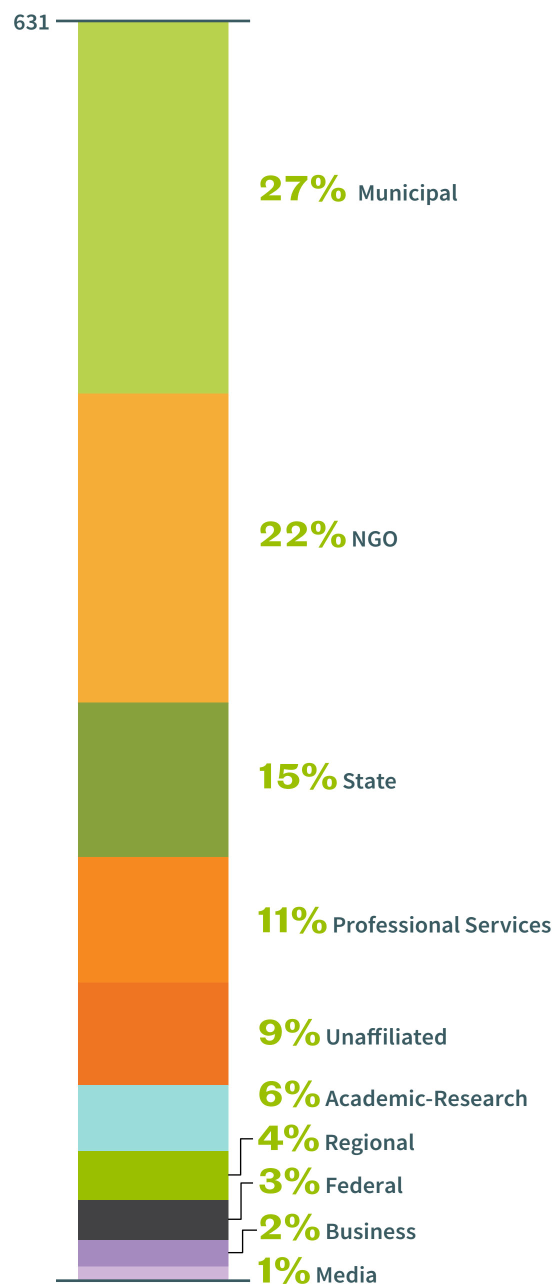
Public Meetings and Surveys

The State engaged directly with the broader public and community of coastal stakeholders through a series of public meetings and surveys during the three waves of engagement.

The State held two public meetings in each wave. Each meeting was 1.5 hours long and held virtually on Zoom. The content for the two meetings in each wave was identical, but the meetings were held at different days and times to accommodate a range of schedules. Meetings included planning updates and draft materials for review, and used interactive tools, including MentiMeter, Zoom chat and Q&A, and spoken public comments, to facilitate discussion and gather stakeholder input and feedback. During the first two waves, the state also issued online public surveys to reach stakeholders and key groups that did not attend the meetings and to collect additional feedback not solicited during the discussion portion of the meetings. In each case, survey content mirrored or expanded upon the discussion questions from the meetings. Online surveys were open for two to three weeks following each wave of meetings.

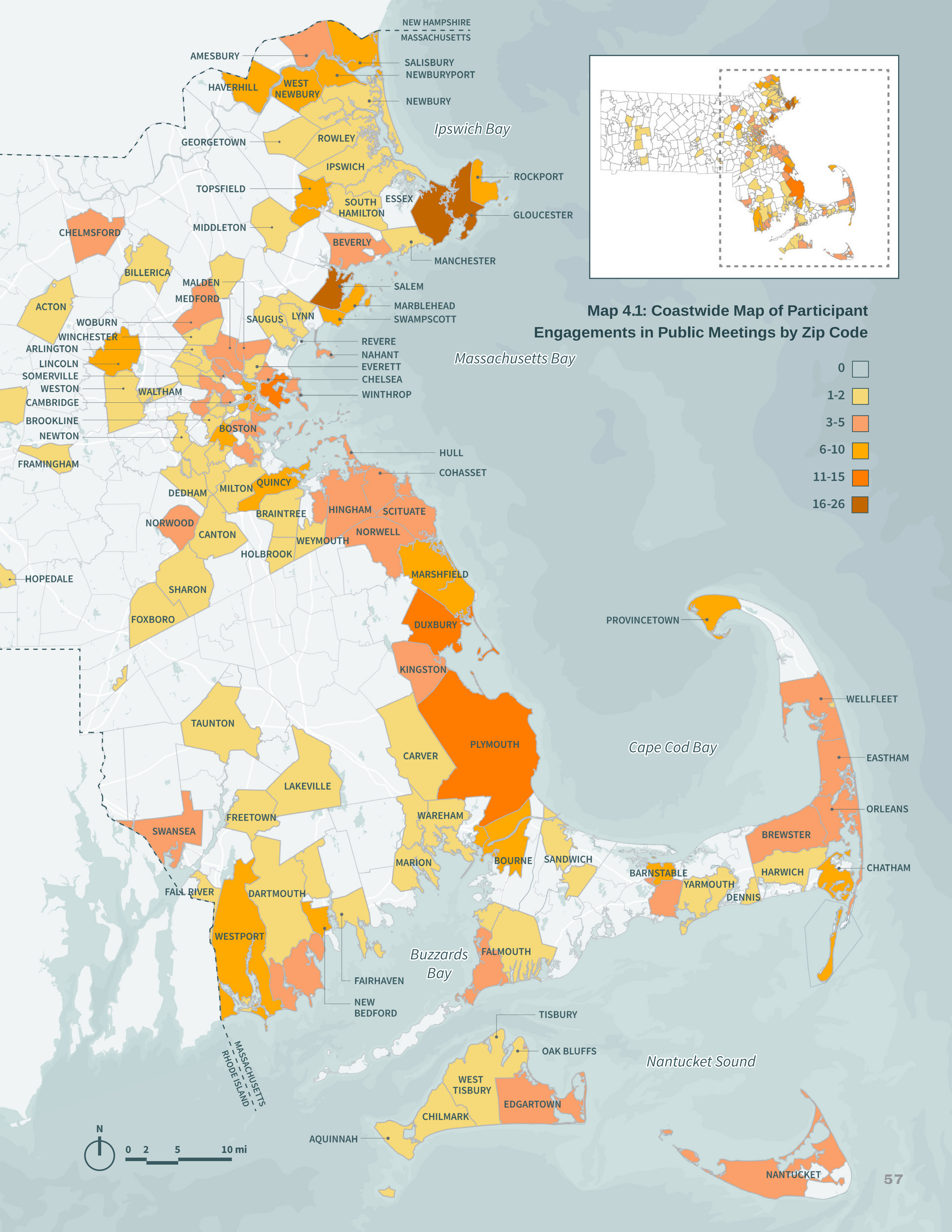
Meeting announcements and notifications were posted on the ResilientCoasts project webpage and sent to the public using email listservs a minimum of two weeks ahead of each public meeting. These communications included instructions in the following seven most common languages in coastal Massachusetts on how to request translation services: Spanish, Portuguese, Mandarin, Cantonese, Haitian Creole, Cape Verdean Creole, and Vietnamese. Interpretation in these seven languages was provided upon request in the first set of public meetings and provided without request in all following public meetings.

Following each wave of meetings, presentation slides, meeting recordings, and online survey links were posted to the ResilientCoasts project webpage. Posted slides were edited to meet EEA accessibility standards, and recordings of public meetings were posted on the ResilientCoasts website and on the EEA YouTube Channel.[41] For the public meetings that took place during waves 2 and 3, recordings of the meetings were posted in each of the seven languages for which live translation was provided. The State then sent notifications via email listservs with links to the project webpage, meeting materials, and online surveys.



Participant Engagements in Public Meetings

Map 4.1: Coastwide Map of Participant Engagements in Public Meetings by Zip Code



Key Feedback

The three waves of stakeholder engagement described above built on each other as well as years of local coastal resilience planning and implementation, engagement, and feedback. A number of themes recurred throughout this process, underscoring issues that were important to many stakeholders. These key topics included the following:

Facilitate regional projects and collaboration.

Stakeholders emphasized the importance of greater collaboration across communities to advance coastal resilience, noting that coastal risks do not respect jurisdictional boundaries, and so more support for regional approaches is needed. Scaling up allows communities to pool resources, address capacity constraints, and pursue more effective strategies. Participants pointed to models such as watershed associations and nonprofit partners working with neighboring municipalities as examples to emulate. Key issues identified by stakeholders as requiring regional collaboration included: salt marsh restoration and migration, coastal erosion, beach and dune nourishment, vulnerable state and regional infrastructure and facilities, and flood control infrastructure and flood pathway mitigation.

"[We need] a framework for regional collaboration, not just funding."

—Public Meeting 2 attendee

Support local capacity.

Stakeholders, particularly municipal representatives, underscored the importance of targeting resources to increase municipal and regional staffing, training, and providing direct technical assistance. A number of comments noted wide-ranging levels of capacity among municipalities and highlighted how constraints in staffing and technical capacity limit communities' ability to access grant funding, perpetuating disparities in risk preparedness. In addition, stakeholders indicated that more support for nonprofits, community-based organizations, and others who are helping to carry out work at the local level is needed.

" Model language for climate zoning could be helpful to smaller municipalities with limited planning staff."

—External Task Force member

Participants noted that these capacity challenges also impact a municipality's ability to participate in regional-scale collaboration and projects. Communities shared varying ideas for how the state can best support needed capacity-building, from direct funding for municipal staff to partnerships with state and regional entities, to funding for circuit riders.

Prioritize support for Environmental Justice and priority populations.

Directing support to vulnerable and underserved communities and ensuring they are included and empowered in resilience planning processes were emphasized as critical goals of ResilientCoasts. Feedback from stakeholders included the importance of ensuring engagement and community partnership is accessible (e.g., provide compensation to participants to recognize the value of their contributions; join meetings and forums that communities are already convening rather than creating a separate meeting, where possible). Participants also highlighted the need to ensure tribes in the state are meaningfully included and that their knowledge of how to steward the land is respected. They also emphasized the value of funding and facilitating community-led planning processes and supporting community-based organizations to increase awareness, education, and involvement of vulnerable populations and to build on the sources of resilience found in these communities.

> ***"Resilience is critical for EJ communities, especially since so much affordable housing is located in flood-prone or vulnerable areas, and residents themselves are more vulnerable to displacement [due to] a variety of factors."***
>
> ***—Nonprofit representative, Public Meeting 1***

Strengthen and align intergovernmental coordination.

Stakeholders highlighted the importance of intergovernmental coordination to support collaboration on planning, policy, permitting, funding, and implementation. In particular, stakeholders noted a need to reduce regulatory barriers and streamline permitting processes and timelines to make it easier to implement resilience actions, particularly for nature-based solutions and new, evidence-based approaches. They noted the importance of harmonizing priorities and plans across agencies to give clear guidance to municipalities and others and called for new and enhanced mechanisms for collaboration and coordination across municipal boundaries and government levels. They also highlighted the need to better understand and document funding needs over time, establish additional criteria for funding priorities, and increase resources in grant programs, particularly to move beyond planning to implementation.

Prioritize critical infrastructure.

Stakeholders called for policies and frameworks to identify, provide, and prioritize funding for relocation and/or adaptation for the most important public infrastructure and facilities. They noted that much of this infrastructure is regional and requires action beyond the scale that any one community can take, will require new or additional funds to adapt, and in some cases will require new governance frameworks to manage. Stakeholders expressed support for limiting the siting of new critical infrastructure in risky locations prone to coastal hazards and highlighted that historically marginalized and communities with fewer resources rely more heavily on public infrastructure, further underscoring the need to prioritize its resilience.

> ***" Prioritize investment in public infrastructure that helps to move development [away from] high-hazard areas."***
>
> ***—Municipal representative, Public Meeting 3***

While many of the state's existing grant programs and other local funding opportunities currently support efforts to retrofit and relocate critical infrastructure, stakeholders emphasized that the scale of funding is not enough to meet the need. They noted that the state could also do more to coordinate efforts on large-scale public infrastructure, especially where a state agency owns, operates, and/or maintains the land or structures.

Educate the public and provide actionable, clear communication about risks and strategies to improve resilience.

Stakeholders underscored the need to provide public education about flood risk and resilience strategies, directly and through support of local/regional and community-based organization partners. They also pointed out that clear information supports the important step of communities having crucial conversations about values and priorities to guide planning decisions and weigh tradeoffs. Stakeholders highlighted the importance of clear information about issues such as near-term vs. long-term risks, insurance, funding pathways, and public and private landowner tools, among others.

> ***" [The] state can provide support by providing tools and resources to facilitate difficult and confusing conversations."***
>
> ***—Public Meeting 2 attendee***

Prioritize and protect natural resources.

The important value of natural resources on the coast was emphasized throughout the process, both for the resilience benefits they provide as well as their intrinsic value. Stakeholders pointed to the critical need to accelerate conservation, restoration, and protection of numerous natural resources such as salt marshes, eelgrass, and critical habitats for biodiversity, highlighting their connections to coastal resilience, the health of the coastal economy, opportunities for recreation and tourism, public and environmental health benefits, and the sustenance of complex coastal ecosystems.

> ***"State funds for projects should consider public access and minimize impacts to natural resources."***
>
> ***—Climate resilience professional, Public Meeting 2***

While nature-based solutions to coastal hazards will not necessarily address all risks in all areas of the coast, they should be prioritized where they make sense and will be effective at achieving coastal resilience goals.

Manage coastal development for resilience.

Managing development to account for long-term risk was a recurring theme with stakeholders emphasizing the need to discourage and direct public resources away from risky new development, reduce risk to existing structures, and facilitate a strategic and coordinated approach to managed retreat. Many comments underscored the need for state-level guidance on both limiting new development in high-risk areas and resources for managed retreat where risks are too great. Stakeholders noted that it is difficult for municipalities to manage these processes on their own, especially when it comes to managed retreat. At the same time, they emphasized that solutions need to be tailored to the local context rather than a one-size-fits-all approach. Stakeholders called for model zoning codes and better building codes and design standards to address resilience to coastal risks and help communities develop more responsibly in areas where it is possible to avoid and reduce risks. Feedback also included ideas on how land should be used after retreat, including for ecological restoration, to enhance resilience of nearby properties, and for public access and benefit.

> ***"[The state should] support proactive resilience (including buyouts) to protect people from flooding rather than needing to wait for major losses to act."***
>
> ***—Nonprofit representative, Public Meeting 3***

> ***"Current land use regulations [are] inconsistent with resiliency goals. Policy and regulatory guidance from the state would be extremely helpful."***
>
> ***—Municipal representative from the North Shore, survey 2 respondent***

> ***"Communities need help with managed retreat."***
>
> ***—Public Meeting 3 attendee***

Increasing the Visibility of Existing State Resources and Initiatives

One goal coming out of the ResilientCoasts process is to increase the visibility of existing resources — from the state and partners — to address the topics highlighted in this chapter. More work is needed to develop additional guidance and resources to advance coastal resilience, but feedback from stakeholders during this process has also underscored the need to better promote existing resources so they are reaching a wider audience. A few of these such resources that are responsive to feedback noted above are highlighted below.

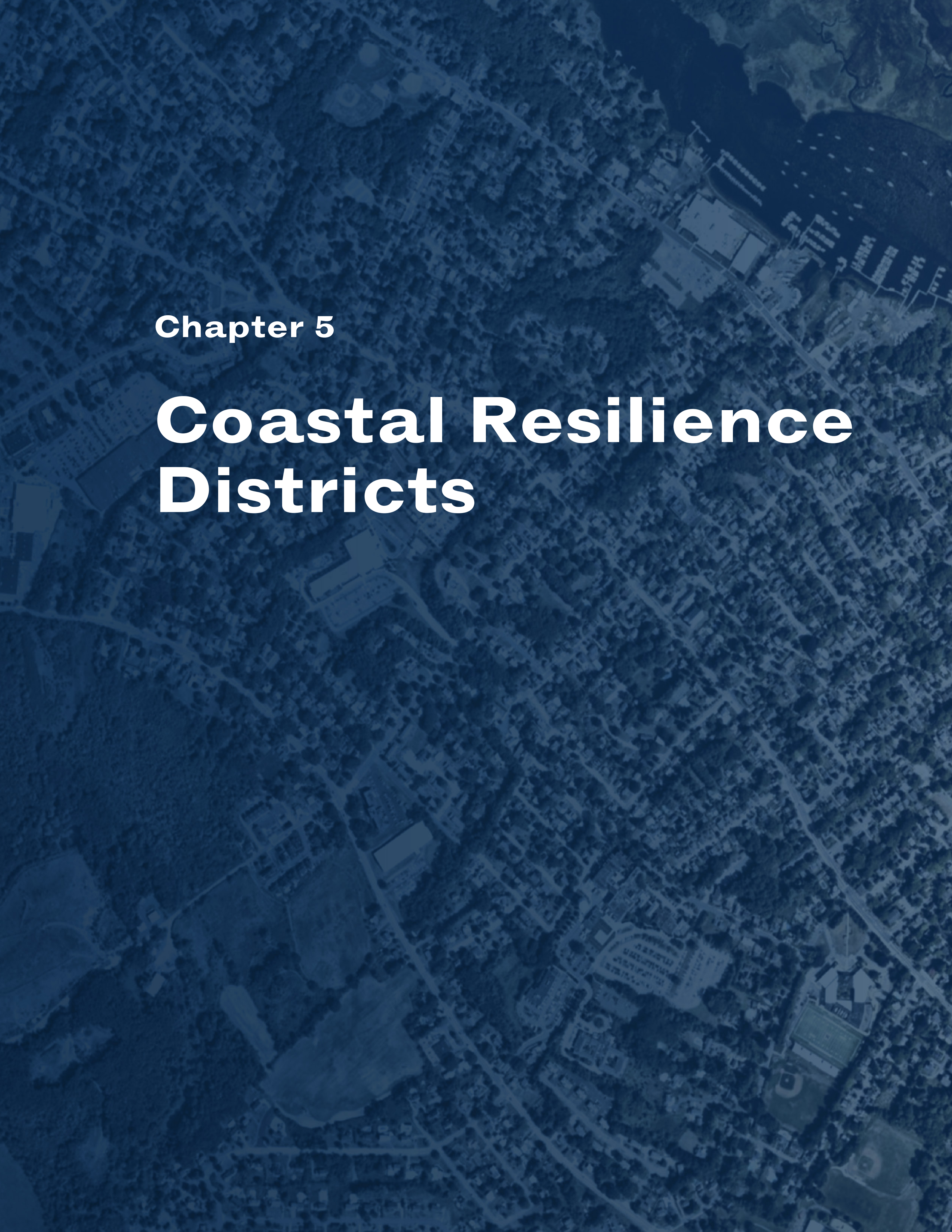
Coastal Development

The state, as well as several regional planning agencies, currently offer resources on how to build for climate resilience and avoid development in high-risk areas. For example, the Cape Cod Commission developed a model coastal resilience bylaw that can be used to promote natural resource migration and reduce risk in the floodplain due to sea level rise.[42] Similarly, the Metropolitan Area Planning Council (MAPC) maintains a database of climate resilient land use strategies including examples of regulatory language and policies used by various communities across the state to promote resilience.[43] CZM's StormSmart Coasts Program has developed and published a series of fact sheets for property owners on reducing coastal erosion and storm damage.[44] The fact sheets provide information on a range of measures that can effectively reduce erosion and storm damage while minimizing impacts to shoreline systems.

Education and Communication

The state currently provides several tools and other resources to help communicate risk and share case studies and best practices. For example, CZM's "MyCoast" is a portal used to collect and share photos and observations of coastal flooding, coastal storm impacts, and shoreline adaptation.[45] MyCoast reports help increase awareness of coastal hazards and inform coastal management. The state also maintains a Massachusetts Sea Level Rise and Coastal Flooding Viewer that supports the assessment of coastal flooding vulnerability for community facilities and infrastructure.[46] The viewer includes interactive maps of flooding associated with static sea level rise scenarios, dynamic future storm surge, current worst-case hurricane surge, and areas within the Federal Emergency Management Agency (FEMA) coastal flood zones.[47] Through ResilientMass, the state also hosts resources that support local resilience planning conversations including a map and data center, a resilience design tool, and Guides for Equitable and Actionable Resilience.[48]

Revere, MA (Credit: WHG)



Chapter 5

Coastal Resilience Districts

Purpose and Function

Coastal Resilience Districts encompass areas along the Massachusetts coastline that are currently experiencing or expected to experience coastal flooding and/or erosion due to climate change.

Understanding Coastal Resilience Districts

Coastal Resilience Districts (CRDs) are delineated to group together areas that share common characteristics like geomorphology, natural environment, built infrastructure, population and development character, and coastal hazards. The goal of identifying CRDs is to highlight regional differences in coastal areas, help facilitate district-scale coordination on coastal resilience, identify opportunities for integrated management, and appropriately scale projects and strategies for greater impact and efficiency.

Working on coastal resilience within and across districts can help manage the physical and jurisdictional complexity and diversity of the Massachusetts coastline. CRDs cross traditional jurisdictional boundaries of cities and towns, adhering instead to the boundaries of natural features and processes like resource areas and watersheds. While CRDs are not regulatory in nature, they can help set the stage for district-scale funding solutions and regulatory tools. As a whole, CRDs encompass the area of the Massachusetts coast that will experience growing risk from sea level rise, storm surge, and erosion over the next 50 years.

The Case for a Regional Approach

The ResilientMass Plan, the state's State Hazard Mitigation and Climate Adaptation Plan, calls for a statewide approach to coastal resilience that considers climate-resilient development and standards in vulnerable areas, develops best practices for coastal adaptation, and explores managed retreat. One important component of a statewide approach to coastal resilience is scaling up and accelerating efforts for regional scale collaboration.

Many coastal communities are already diligently planning and implementing coastal resilience projects at the local level. However, coastal flooding and erosion do not respect municipal boundaries, and it is increasingly clear that the scale and complexity of addressing coastal hazards will require greater local, state, and regional collaboration. This is particularly true for smaller communities that often face funding and staffing constraints and/or lack technical capacity. The need is urgent, but resources are limited. To advance toward coastal resilience in the most cost-efficient and effective manner, the state must coordinate investments strategically across regions.

Massachusetts has expanded its support of regional resilience efforts in recent years including using two existing grant programs (EEA's Municipal Vulnerability Preparedness program and CZM's Coastal Resilience Grant Program) to incentivize regional partnerships. The Municipal Vulnerability Preparedness program's prioritization of regional projects encourages the identification of high-impact projects across a broader geographic area.

This allows the program's resources and funding to go further, delivering greater resilience benefits than projects focused on individual communities. Similarly, the Coastal Resilience Grant Program encourages multi-community projects that address coastal flooding, erosion, and sea level rise issues across coastal systems and landscapes. Municipalities and other partners are able to leverage resources and maximize grant funding to provide greater flood and erosion control benefits to broader areas and populations.

To help facilitate greater regional collaboration, each CRD has shared natural features and development characteristics that lends itself to managing the area as a coherent unit for coastal resilience planning and can help inform the selection of measures that are most suitable for each area. By grouping together areas that share coastal characteristics and face common challenges and risks, CRDs provide a spatial scale that can support more cost-efficient and effective development and implementation of coastal resilience measures. CRDs can also be helpful for cross-municipal data sharing, assessing risks, identifying needs and priorities, and tracking progress on coastal resilience.

Not all coastal hazards will require district-scale measures. Interventions at a smaller scale will continue to be needed in coordination with larger scale projects. However, CRDs can help coordinate even smaller scale interventions to avoid redundancies and conflicts across municipal jurisdictions.

Periodic Review and Updates

While ResilientCoasts sets out a 50-year strategy for coastal resilience, it also requires decision making in the face of ongoing variability, particularly regarding human responses, rates of sea level rise, and magnitude of flooding and erosion. To respond to changing economic, social, environmental, and climatic conditions, the boundaries and function of the CRDs will need to be periodically reviewed and updated. The latest advances in science, modeling, and engineering will be used to account for the coastal landscape, sea level rise, land loss, shoreline changes, and construction of restoration and risk reduction projects. Further, ResilientCoasts focuses on coastal hazards, defined as storm surge, sea level rise, wave action, and erosion. The Plan does not assess the risks of compound flooding. Compound flooding results when multiple drivers of flooding occur together, including higher than normal tides, storm surge, high groundwater, and heavy rainfall. Future phases of ResilientCoasts will integrate data on compound flood risk, as it is developed, to more comprehensively assess flood risks in communities coastwide.

How to use Coastal Resilience Districts

CRDs provide a coastwide framework for identifying and implementing coastal resilience measures at a district-scale by highlighting areas with shared coastal risks and opportunities. Note that some communities are split between more than one district based on distinct differences in coastal environment or hazard exposure within the municipality. The information can help facilitate more regional collaboration and partnerships. CRDs are not intended to limit communities in their ability to work cross-district (e.g., working with municipalities that are not within the same CRD) or to discourage individual municipalities from pursuing coastal resilience projects within their own municipal boundaries. Some coastal resilience projects and measures may be better suited to district-scale planning and implementation than others. Individual communities should continue planning and implementing coastal resilience measures at the municipal level in addition to pursuing opportunities for cross-municipal collaboration. Communities within the 15 CRDs may choose to work within their CRD and/or across CRDs to collaborate on and scale up projects.

It is important to note that there are limitations to the CRD framework. The delineation of these areas does not currently take into consideration regional linear assets like state and interstate highway systems or regional or interstate public transportation (like Amtrak). It also does not take into consideration how neighboring states like Rhode Island or New Hampshire are approaching coastal resilience along the Massachusetts border. These considerations were outside of the scope of the ResilientCoasts Plan but should be considered in future phases.

This framework for coastal resilience should not be used in isolation from other state initiatives such as ResilientMass, Resilient Lands, or the Commonwealth's Biodiversity goals.[49] Not all coastal resilience measures will be appropriate for all CRDs or coastal environments therein, including where they conflict with vulnerable and critical habitats.

Potential Use Cases:

- **Cross-municipal projects:** Communities within a CRD may choose to target shared areas of risk, like existing deteriorating infrastructure or shared flood pathways—narrow, low-lying areas through which entering floodwaters affect large areas of floodplain —that have cross-municipal impacts and require an approach that is not confined to one municipality. Working within the CRD and leveraging the resources and capacity of multiple communities, while reducing the duplication of efforts and costs associated with a community-by-community approach, can help maximize benefits of a project.

- **District-wide prioritization and planning:** Communities within a CRD may choose to supplement existing community-specific vulnerability assessments and implementation plans to set broader, district-wide policies and priorities based on asset types, criticality, and risk. Agreeing on shared district-wide priorities can position communities within a CRD to jointly undertake burdens of costs, administration, and technical capacity to jointly implement coastal resilience projects.

- **Working across CRDs:** Communities may work across CRDs on projects that require a different scale of collaboration. For example, Boston Harbor communities are split into three CRDs: Saugus Watershed, Mystic-Charles Watersheds, and Neponset-Weir Watersheds. These delineations are based on some distinctions in land use and development patterns, prevalence of different coastal resource areas, and other factors. However, these communities may choose to collaborate across CRDs with State and Federal partners on Boston Harbor-wide coastal resilience projects like vulnerable transportation infrastructure. Similarly, Cape Cod is split into four districts, but these communities may choose to collaborate across one or all of these CRDs on planning projects with the assistance of regional partners. Other projects, like beach nourishment, salt marsh restoration, district-scale seawall replacement, construction of berms, and other shoreline measures may be more conducive to working within the CRD.

CRDs are not regulatory in nature. Rather, the near-term focus of CRDs is to facilitate district-scale and regional prioritization and implementation of effective, priority projects. Future phases of ResilientCoasts will undertake a deeper analysis of the challenges associated with district-scale collaboration, and opportunities for the state to better support it including identifying existing regional- or district-scale conveners and gaps in capacity.

Factors and Overlays

Three primary data sources were used to identify the geographic traits and differences of each CRD: coastal wetland resources, major watershed basins and sub-basins, and modeled future coastal flood risk.

Landward, Seaward, and Inter-District Boundaries

The delineation of CRDs was divided into three components: landward boundary, seaward boundary, and inter-district boundaries. Each component was built upon the previous, resulting in a single data layer representing 15 distinct CRDs.

The **landward boundary** of the CRDs is primarily defined by the Massachusetts Coast Flood Risk Model (MC-FRM) 2070s extent for the 0.1% annual chance storm event, modeled assuming 4.3 feet of sea level rise (from a 2008 baseline).[50] The effective 0.1% annual chance flood extent used in the ResilientCoasts Plan represents a very extreme event and includes areas with an annual chance flood extent greater than zero (0.1% when rounded up to the nearest tenth percent). However, in areas with elevated coastal banks, buffer areas between 100 and 400 feet were added depending on whether the bank was consolidated or unconsolidated to account for future vulnerabilities due to weathering and erosion. The coastal banks define the landward extent of the CRDs only where they reach inland of the MC-FRM boundary.

The **seaward boundary** of CRDs is primarily defined as the nearshore extent of the Massachusetts Ocean Management Planning Area (planning area) with some exceptions.[51] The planning area generally begins 0.3 nautical miles offshore but excludes Boston Harbor. Therefore, a 0.3 nautical mile buffer was manually added to Boston Harbor as well.

The **inter-district boundaries** are primarily defined by drainage sub-basins as previously mapped by the USGS Water Resources Division and the Massachusetts Water Resources Commission, with modifications by state agencies. Coastal sub-basins were aggregated into 15 distinct CRDs, primarily based on geographic region and dominant landforms, including coastal wetland resources. The drainage sub-basin delineations do not extend into coastal waters, therefore the inter-district boundaries defined by the drainage sub-basins were manually extended to the CRD seaward edge. Additional modifications were made to the aggregated drainage sub-basins, as necessary to account for other factors like shared flood pathways.

For areas that were excluded from the CRDs (e.g., high-elevation areas outside of the MC-FRM 2070 floodplain), but were completely surrounded by one or more CRDs were either: (1) added to the CRDs if they were less than three acres, or (2) classified as **"evacuation and isolation risk areas"** if they were at least three acres. These remain outside of the CRDs; however, they are important to consider in developing and undertaking coastal resilience planning and projects. See more on page 76.

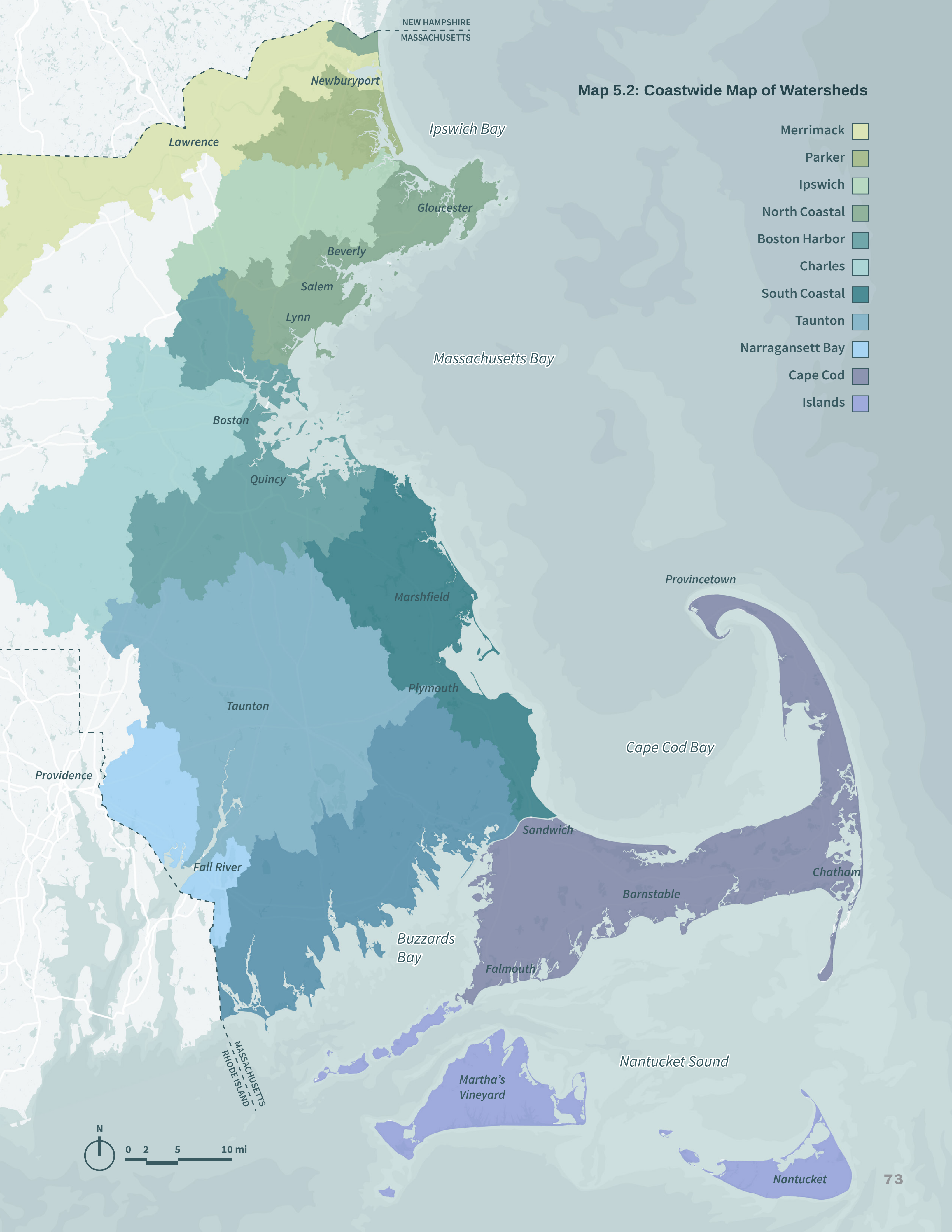
Map 5.1: Coastwide Map of Projected Coastal Flood Extents

Watersheds and Sub-Basins

To the extent possible, inter-district boundaries were drawn to align with major watershed or sub-basin boundaries. A watershed, or drainage basin, is the area of land that drains or flows into a specific body of water. Watersheds are divided by high points in the landscape, like ridges and hills, where areas on opposite sides of the high points drain to different water bodies. Major coastal watersheds ultimately drain into the ocean and can be made up of multiple sub-basins. For example, a major watershed may contain the sub-basins of several streams that drain to the same tidal river, or the sub-basins of several tidal rivers that drain to the same bay.

Watersheds and sub-basins are relevant for defining CRDs for several reasons. First, the areas that drain to a given water body, especially the lowest areas, are typically the same areas that will flood when that body of water is elevated by sea level rise or storm surge. If a major flood pathway crossed watersheds or sub-basins, the inter-district boundary was shifted to contain the flood pathway in one CRD. Second, some of the most successful regional collaborations on coastal resilience in Massachusetts are happening at the major watershed level, often facilitated by watershed organizations.

Finally, using watershed and sub-basin boundaries to delineate CRDs will make it easier to expand the scope of flood risk in future phases. Specifically, it will allow for the incorporation of new maps that the State is developing to identify areas along rivers and streams facing increased exposure to flooding. These risks result from the combined effects of extreme rainfall and coastal flooding due to climate change.

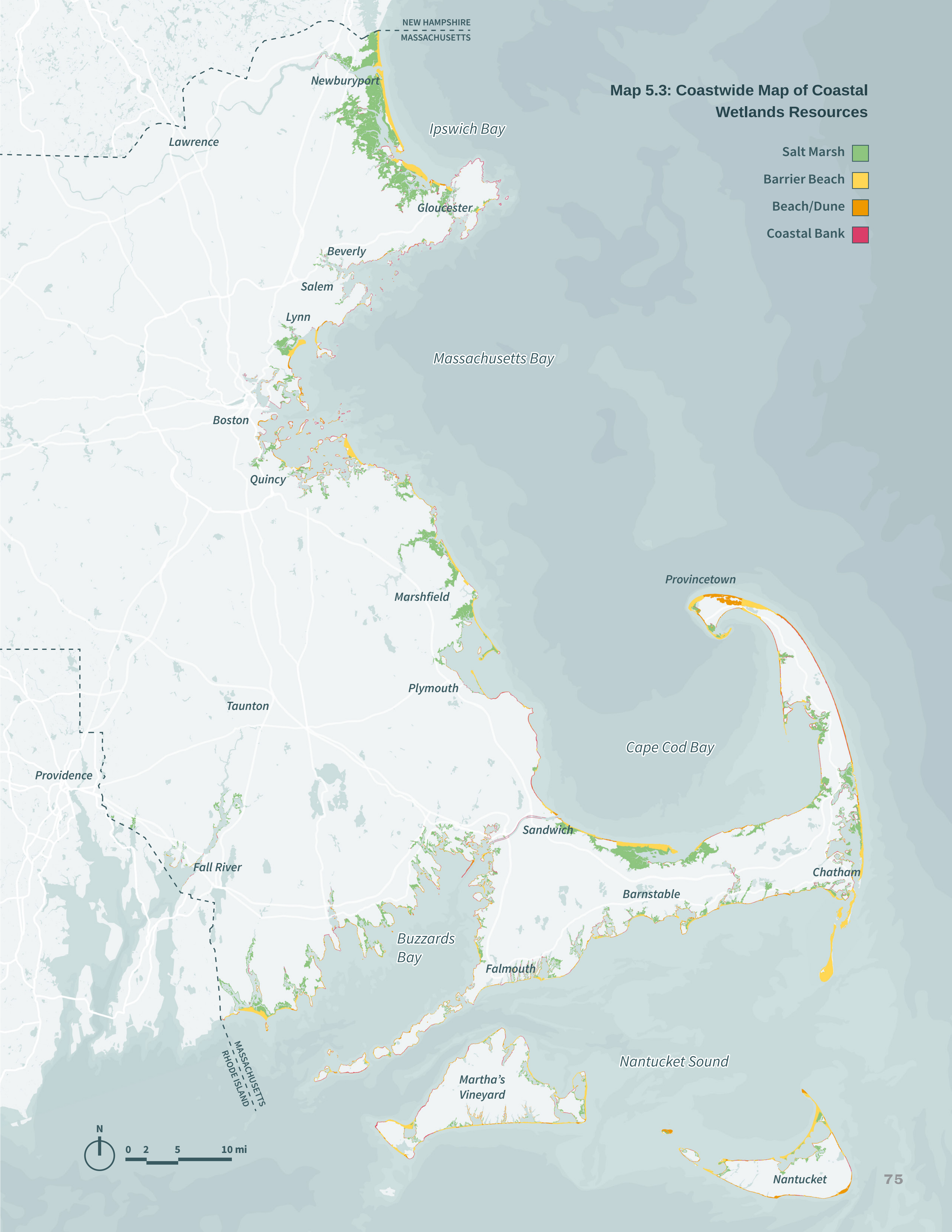

Map 5.2: Coastwide Map of Watersheds
Merrimack
Parker
Ipswich
North Coastal
Boston Harbor
Charles
South Coastal
Taunton
Narragansett Bay
Cape Cod
Islands
NEW HAMPSHIRE
MASSACHUSETTS
Newburyport
Ipswich Bay
Lawrence
Gloucester
Beverly
Salem
Lynn
Massachusetts Bay
Boston
Quincy
Marshfield
Provincetown
Plymouth
Taunton
Cape Cod Bay
Providence
Sandwich
Fall River
Chatham
Barnstable
Buzzards
Bay
Falmouth
MASSACHUSETTS
RHODE ISLAND
Nantucket Sound
Martha's
Vineyard
Nantucket
N
0
2
5
10 mi

Coastal Wetlands Resources

Coastal wetlands resources, as defined by the state Wetlands Protection Act, are areas directly adjacent to the ocean including beaches, barrier beaches, salt marshes, dunes, coastal banks, and rocky intertidal shores. They provide significant storm damage prevention and flood control functions, serve as buffers for impacts like coastal erosion, wave damage, and coastal flooding, and provide many other benefits for people, fish, and wildlife. They are often the main interface between waterbodies that are the source of coastal flooding and upland areas occupied by people, buildings, and infrastructure. Because of their proximity to the water, they have historically been developed and armored with engineered shoreline stabilization and flood control structures, like revetments and seawalls.

Coastal wetland characteristics informed which major watersheds or sub-basins to group together into CRDs. The intent was to group together areas with similar coastal wetlands resources. This process included analyzing coastal wetlands resources that are common across the Massachusetts coast, namely salt marshes, barrier beaches, coastal beaches, coastal dunes, coastal banks, and coastal and tidal river floodplains, using approximate locations and extents of these wetlands as mapped by the Massachusetts Department of Environmental Protection (MassDEP).[53]

Considering coastal wetlands resources in the districting process helps make CRDs a platform for building regional understanding of common resources and threats posed by climate change and encourages regional collaboration and coordination on implementing measures to maintain or ideally improve the function of coastal wetlands resources. These resources can impact the extent and type of coastal hazards different areas of the shoreline face and the types of coastal resilience measures that will be effective (or permitted) to address those hazards. Modern laws and regulations put guardrails on the construction of new or modified coastal engineering structures, nature-based strategies, and other development activities to protect the public interest in healthy and well-functioning wetlands.[54] At a high level, this component of the CRDs can help inform what types of coastal resilience measures are generally more suitable, considering legal and regulatory protections of wetlands.



Map 5.3: Coastwide Map of Coastal Wetlands Resources

Refinements and Overlays

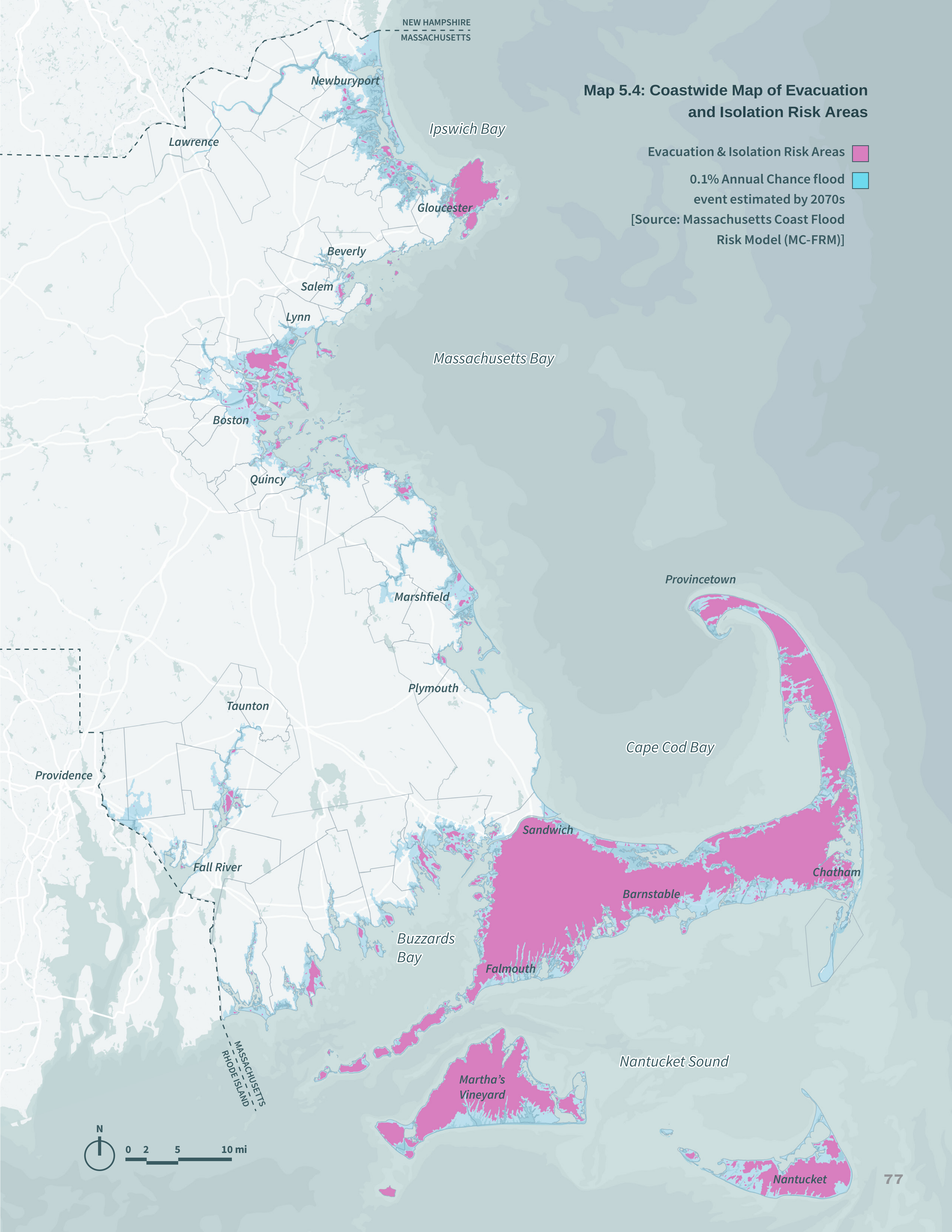
A few additional refinements were made to the CRD delineation methodology described above, including modifications to avoid, where possible, splitting areas where stakeholders have already begun collaborating and coordinating on shared systems and risks. In some cases, CRDs were also adjusted to account for distinct changes in population and development density. Finally, feedback from stakeholders, including a public survey on draft CRDs, was used to further refine CRD boundaries and names where it aligned with the overall delineation approach.

Evacuation and Isolation Risk Areas

High elevation areas within CRDs face unique challenges. Because the inland extent of the CRDs is primarily driven by MC-FRM data, there are areas of varying sizes excluded from the CRD boundaries. These areas are not directly exposed to flooding based on the MC-FRM projection for the 2070s 0.1% annual chance storm event but are surrounded on two or more sides by current or projected flooding.[55] For example, areas of South Boston, Marblehead Neck, Lafayette Street in Salem, and Strawberry Hill in Hull all fall into this category. While the boundaries of the CRDs are intended to portray long-term coastal hazard risk and therefore exclude these high elevation areas, they are nonetheless important to consider when devising district-scale strategies for coastal resilience.

In most cases, high-elevation areas will face ingress and egress challenges related to evacuation and isolation during major coastal flood events. Depending on the size of these areas, the vulnerability of critical infrastructure serving them, and the available access routes, flooding may damage utility and road infrastructure making it difficult or impossible for residents to leave or receive essential supplies or services.

While many of these evacuation and isolation risk areas range in size –anywhere from slightly more than 3 acres to neighborhood-size– there are also large areas of Gloucester and Rockport, as well as most of Cape Cod, included. Because these areas are much larger, they may need a different approach than smaller, isolated areas. In addition, the entirety of the Islands CRD (see page 106) meets this criterion; however, these communities already face transportation and supply distribution challenges given the nature of their communities. Coastal hazards like sea level rise will exacerbate these existing challenges and likely require a tailored approach.



Map 5.4: Coastwide Map of Evacuation and Isolation Risk Areas
Evacuation & Isolation Risk Areas
0.1% Annual Chance flood event estimated by 2070s [Source: Massachusetts Coast Flood Risk Model (MC-FRM)]
NEW HAMPSHIRE
MASSACHUSETTS
Newburyport
Lawrence
Ipswich Bay
Gloucester
Beverly
Salem
Lynn
Massachusetts Bay
Boston
Quincy
Marshfield
Provincetown
Plymouth
Taunton
Cape Cod Bay
Providence
Sandwich
Chatham
Fall River
Barnstable
Buzzards Bay
Falmouth
MASSACHUSETTS
RHODE ISLAND
Nantucket Sound
Martha's Vineyard
Nantucket
N
0 2 5 10 mi

The Districts

A total of fifteen Coastal Resilience Districts, encompassing land across 98 communities, were delineated coastwide. The predominant characteristics for each district, including coastal environments and population and development patterns, are described below.

Coastal Typologies

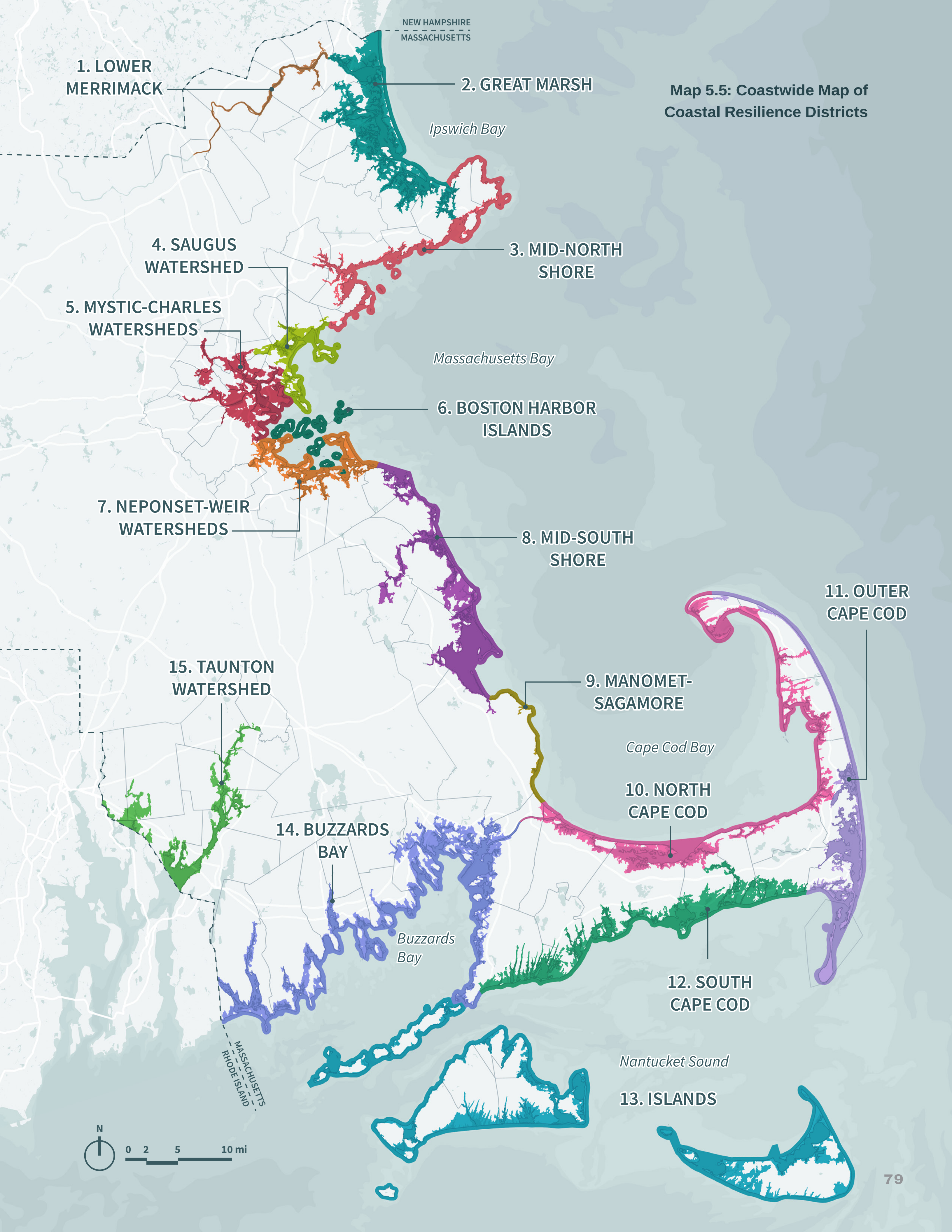
Each CRD has one or more predominant coastal environment or "coastal typology" that will likely guide the selection of suitable coastal resilience measures within the district. These coastal typologies, which include many of the previously described coastal wetlands resources, are not an exhaustive list of coastal environments in Massachusetts but represent a common and relevant subset, primarily along the immediate shoreline and within the floodplain where the highest risks for coastal hazards coincide the vulnerable development. These typologies are described in more detail in Chapter 7.[56]

In many cases, the types of coastal typologies in a district influence the kinds of hazards the district faces. For example, areas with salt marshes may experience fringe flooding along the edges of the resource area, while low-lying coastal floodplains, especially those made up of historically filled wetlands, may have discrete flood pathways that enter from a low-lying section of the shoreline. Many districts also experience coastal erosion, which is exacerbated in some cases by interruptions of sediment transport, often due to the presence of coastal engineering structures.

The coastal environment may be influenced by the existence of certain limitations or restrictions. Several data overlays were used to analyze and summarize key characteristics of each CRD, including sensitive and/or regulated environmental areas like Areas of Critical Environmental Concern (ACEC), Coastal Barrier Resource System Units (CBRS), Designated Port Areas (DPAs), and federal and state conservation lands. Demographic and development data including U.S. Census data on population and housing, Environmental Justice Populations, land uses, shoreline character, and community type were also analyzed.

- **ACECs** are areas designated by the Secretary of the Executive Office of Energy and Environmental Affairs that receive special recognition because of the quality, uniqueness, and significance of their natural and cultural resources. ACEC designation creates a framework for local and regional stewardship of these critical resource areas and ecosystems and requires stricter environmental review of certain kinds of proposed development under state jurisdiction within the ACEC boundaries.[57]

- **CBRS** are portions of relatively undeveloped (at the time of designation) barrier beaches that the U.S. Fish and Wildlife Service has identified as storm-prone and dynamic coastal barriers. They serve as important buffers between coastal storms and inland areas, often protecting properties on land from serious flood damage. As such, these areas are subject to the Federal Coastal Barrier Resources Act, which discourages development and encourages conservation


Map 5.5: Coastwide Map of Coastal Resilience Districts
NEW HAMPSHIRE
MASSACHUSETTS
1. LOWER MERRIMACK
2. GREAT MARSH
Ipswich Bay
3. MID-NORTH SHORE
4. SAUGUS WATERSHED
5. MYSTIC-CHARLES WATERSHEDS
Massachusetts Bay
6. BOSTON HARBOR ISLANDS
7. NEPONSET-WEIR WATERSHEDS
8. MID-SOUTH SHORE
11. OUTER CAPE COD
9. MANOMET-SAGAMORE
15. TAUNTON WATERSHED
Cape Cod Bay
10. NORTH CAPE COD
14. BUZZARDS BAY
Buzzards Bay
12. SOUTH CAPE COD
MASSACHUSETTS
RHODE ISLAND
Nantucket Sound
13. ISLANDS
N
0 2 5 10 mi

by withdrawing the availability of federal funding and financial assistance in an effort to protect the barrier system and prevent future flood damage.[58]

- **DPAs** are land and water areas with certain physical and operational features that have been identified to have state, regional, and national significance with respect to the promotion of water-dependent industrial uses and commercial activities. State policy seeks to preserve and enhance the capacity of these areas to accommodate water-dependent industrial uses.[59]

- **Federal and State Conservation Lands** are areas within the district that are subject to federal and/or state restrictions for development and held for conservation purposes. These areas may include wildlife refuges, state park land, National Park Service properties, and others.

Population and Development

In addition to shared coastal environments, each district has shared population characteristics and development patterns. The summary of population and development characteristics for each district includes population size and housing units, Environmental Justice (EJ) Populations, and an overview of key land uses within a district including ports and working waterfronts, agricultural, open space, residential, and commercial/industrial land uses. Structures and land exposed to flooding are also summarized.

- **EJ Populations** in Massachusetts are defined as a neighborhood where one or more of the following criteria are true:
    - The annual median household income is 65 percent or less of the statewide annual median household income,
    - Minorities make up 40 percent or more of the population,
    - 25 percent or more of households identify as speaking English less than 'very well,'
    - Minorities make up 25 percent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income.[60]

  Identifying EJ areas within CRDs is crucial, as these populations are more likely to experience disproportionate impacts from climate change. This vulnerability arises from factors such as economic disparities, limited access to resources, and systemic challenges like racial discrimination, which can increase their exposure to climate hazards or impede their ability to adapt. Notably, the EJ designation is made at the Census Block Group level. As a result, some municipalities may have EJ Block Groups within their boundaries, but not within the portion of the community that is within the CRD boundary. EJ Populations are only noted where the Block Group intersected with the CRD boundary.

- **Community Types** are described using a classification system developed by the Metropolitan Area Planning Council (MAPC) that identifies five basic community types across the state: rural towns, developing suburbs, maturing suburbs, regional urban centers, and inner core communities. These are further subdivided into nine sub-types. The criteria used to define community types include land uses and housing patterns, recent growth trends, and project development patterns. A summary chart of each community type and sub-type is included in the Massachusetts Community Types document[61]. Notably, these designations are at the municipal level. The character of the municipality as a whole does not necessarily reflect the character of the shoreline or the portion of the community that is within the CRD. However, understanding the characteristics of the entire community, even if only a portion of it is within the CRD, is important for identifying and assessing coastal resilience measures.

- **Population and Housing** in the floodplain are summarized for each CRD using 2020 Decennial Census Block data from the U.S. Census Bureau. It is important to note that any Census Block that had an intersecting boundary with the CRD was included for the purposes of estimating population and housing at risk. In some cases, a very small portion of the Census Block may intersect with the CRD, but the entire population and housing of that Census Block is attributed to the CRD. Therefore, population and housing estimates may be overestimated in some cases.

- **Structures and Assessed Value** in the floodplain are summarized for each CRD and derived from a combination of structure assessment data from the 2022 Massachusetts Climate Change Assessment (derived from U.S. EPA's National Coastal Property Model) and the 2-D building structures dataset available through MassGIS.[62] [63] Structure value within the MC-FRM 2070s extent for the 0.1% annual chance storm event was calculated for each CRD across residential, commercial, industrial, and other uses. In addition, the total number of 2-D building structures were calculated within the MC-FRM 2030s extent for the 1% annual chance storm event and the 2070s extent for the 0.1% annual chance storm event.[64]

- **Open Space** land use is summarized for each CRD derived from the Protected and Recreational Open Space dataset available on MassGIS.[65] This data includes the boundaries of conservation lands and outdoor recreational facilities in Massachusetts owned by federal, state, county, municipal, and nonprofit enterprises. Each area is classified by its level of legal protection. Notably, these open spaces often include protected coastal wetlands resources like salt marshes and other wetlands.

- **Shoreline Characterizations** are derived from a dataset previously developed by CZM to describe lands potentially at risk from coastal erosion for the Massachusetts Coastal Erosion Commission.[66] That work identified the occurrence and distribution of coastal landforms (e.g., dune, beach, and bank), habitats (e.g., forest, salt marsh, and rocky intertidal shore), developed lands (e.g., residential, commercial, and industrial), and shore parallel coastal engineering structures (e.g., bulkheads/seawalls and revetments) at the immediate, exposed ocean-facing shoreline that encompasses 57 Massachusetts communities.[67] Shoreline characterizations do not exist for the Lower Merrimack and Taunton Watershed CRDs as they lack an exposed, ocean-facing shoreline. Characterizations for the Mystic-Charles Watersheds CRD were omitted since only a small percentage of the shoreline is exposed or ocean-facing.

Each district also has a summary of the projected area, in square miles, exposed to coastal flooding through midcentury as modeled by the MC-FRM. Understanding the interaction between coastal processes and climate-induced coastal impacts in a district is critical for understanding and assessing coastal resilience options.

DISTRICT 01

Lower Merrimack

The Lower Merrimack district includes areas of the Merrimack River watershed, from upstream of Whittier Bridge (I-95) in Newburyport and Amesbury, through West Newbury, Merrimac, Groveland, Haverhill, North Andover, Methuen, and Lawrence.

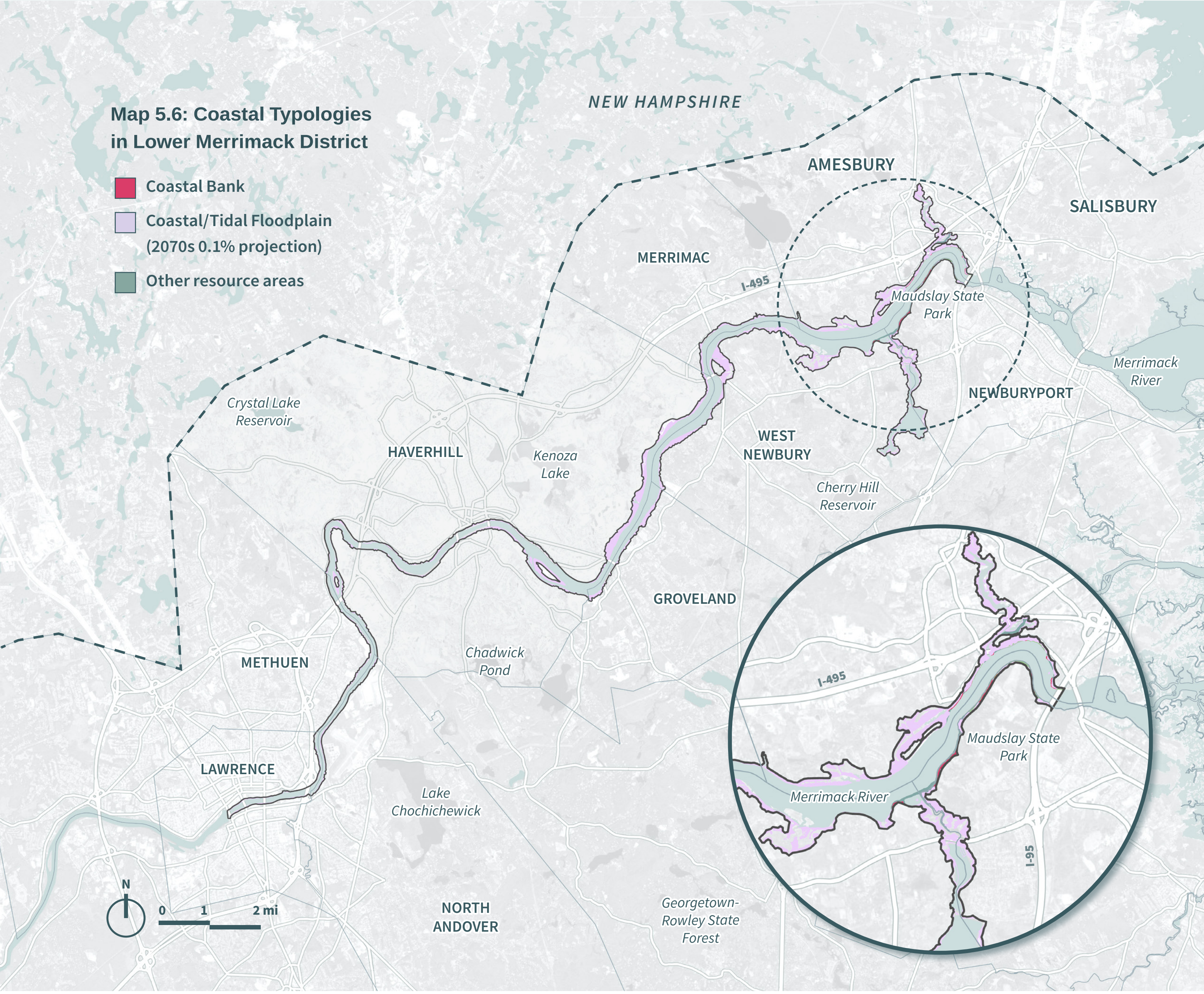
Coastal Environment

Coastal flood exposure is concentrated within and around the banks and wetlands of the Merrimack River and its tributaries, such as the Artichoke River in Newburyport and West Newbury, and Powwow River in Amesbury. These areas face increasing exposure to coastal flooding and erosion of wetlands including riverbanks. This district is expected to be impacted by increased tidal influence from sea level rise and communities are likely to face compound risks of coastal flooding and stormwater flooding. While stormwater flooding was not incorporated in the current analysis, it should be a consideration for communities within the district and could make flood exposure more pronounced. From a coastal perspective, this district faces primarily fringe flooding in the near- and long-term but has slightly more expansive flood exposure in the lower reaches of the river that are expected to moderately increase by the 2070s. The shoreline currently has large swaths of fringing wetlands along the river edge, which will serve as important locations for future salt marsh migration.

Population and Development

This district encompasses a smaller number of people and housing units as compared to other districts with a little over 15,000 people (973 people per square mile) living in affected Census Blocks and almost 7,000 housing units. The district includes mapped EJ Block Groups in Amesbury, Haverhill, North Andover, Methuen, and Lawrence. It has a diverse mix of communities ranging from developing suburbs (like West Newbury) to maturing suburbs (like Groveland) and regional urban centers (like Amesbury and Lawrence). Development character varies from low density communities with vacant land available for development to small mid-sized urban downtowns and large, high-density urban centers. However, by land area, the flood extent in this district is primarily in Amesbury, Newburyport, and West Newbury. Land uses along the riverbank are more residential (28%) than commercial/industrial (6%). The value of structures at risk in the district is estimated at $350 million (68% residential, 19% commercial/industrial). There are also some areas of agricultural use exposed to coastal flooding. While population and housing density is generally low in exposed areas, there are higher density residential and commercial areas exposed in Amesbury, Haverhill and Lawrence.

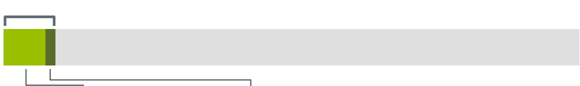
Note: The effective 0.1% annual chance flood extent used in the ResilientCoasts Plan represents a very extreme event and includes areas with an annual chance flood extent greater than zero (0.1% when rounded up to the nearest tenth percent).



3 sq mi	302 structures	Exposed to near-term (2030s) 1% AEP flooding
4 sq mi	648 structures	Exposed to long-term (2070s) 0.1% AEP flooding[68]

Note: AEP = Annual Excedence Probability

9% of the district is open space



84% permanently protected

16% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

What characterizes the shoreline of the Lower Merrimack district?

The shoreline is largely dominated by industrial and commercial land and high-density residential housing from Lawrence to Haverhill and Groveland with varying degrees of armoring, interspersed with agricultural lands. The shoreline shifts to low-density residential housing with large swaths of forest, tidal freshwater, tidal swamp, and brackish marsh through West Newbury to Interstate 95, where it borders the Great Marsh CRD.

DISTRICT 02

Great Marsh

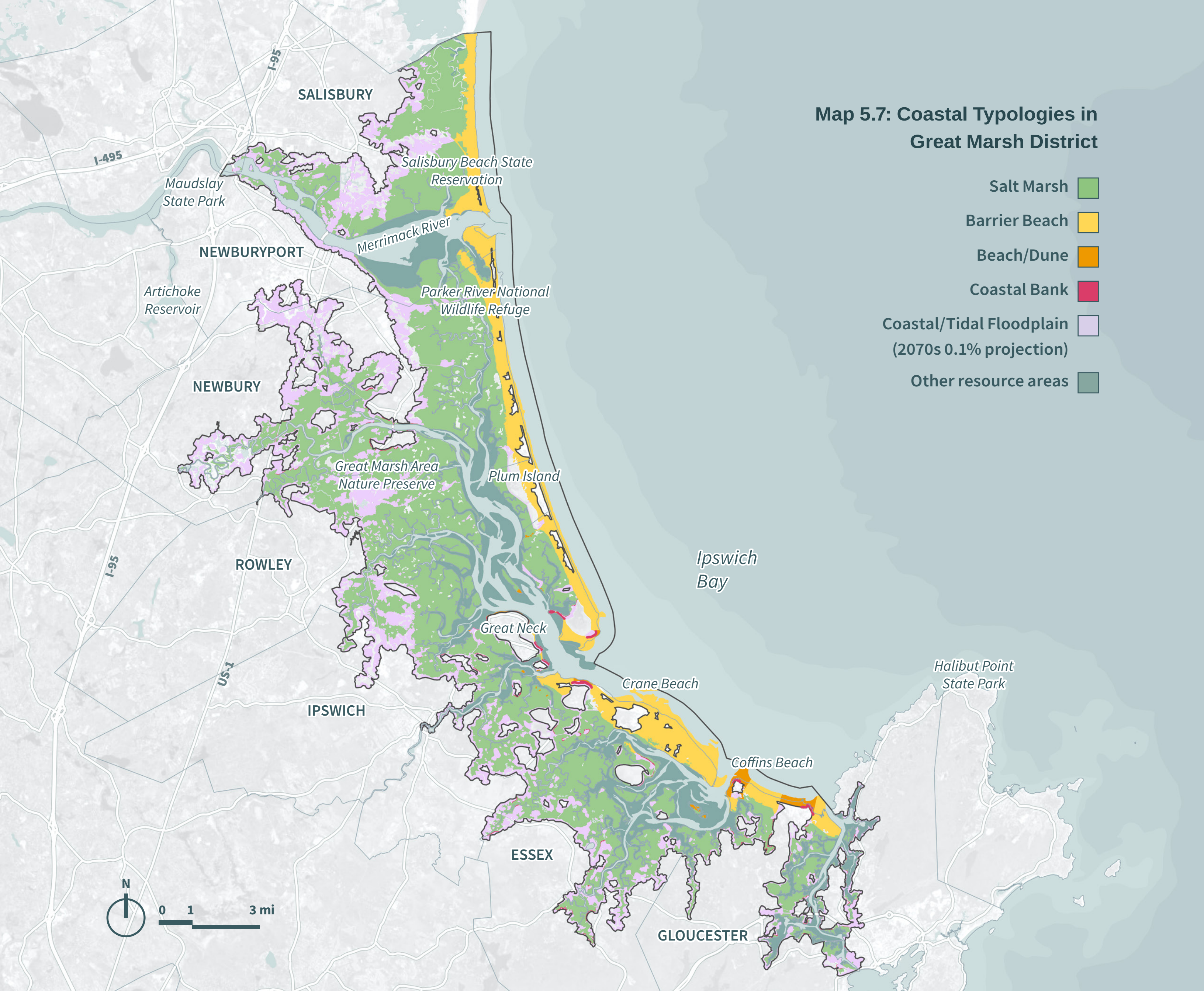
The Great Marsh district extends from the Massachusetts state line in Salisbury, south through Newburyport, Newbury, Rowley, Ipswich, Essex, and the Annisquam River watershed in Gloucester.

Coastal Environment

Coastal flood exposure is widespread within and around the fringes of the district's large and mostly unarmored barrier beaches, salt marshes, and tidal rivers. Ocean-facing shores are exposed to high wave energy during coastal storms, causing beach and dune erosion, with beach lowering seaward of coastal armoring structures. Lack of sediment supply in this district is also contributing to beach and dune erosion. Models suggest that beach areas that are dry at high tide will narrow with long-term sea level rise beyond 2070. Changes will also occur within the salt marsh, including more regular inundation of areas within the marsh platform. Salt marsh and undeveloped barrier beaches have the potential to migrate landward in some areas, especially in protected conservation land and areas where development is setback from the shoreline, and into other wetlands. This district contains the state-designated Great Marsh ACEC, which is the oldest and largest coastal ACEC in Massachusetts. The Great Marsh is the largest contiguous salt marsh in New England. It also contains several federally designated CBRS units and the Parker River National Wildlife Refuge, which is a federally managed conservation area, along with several state wildlife management areas and reservations.

Population and Development

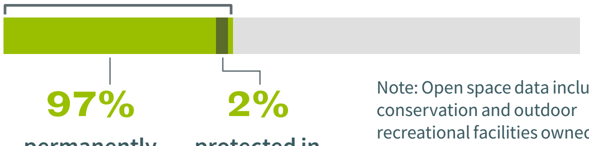
The district has just over 30,000 people (374 people per square mile) living in affected Census Blocks and just under 16,000 housing units. This district includes mapped EJ Block Groups in Newburyport and Gloucester. Communities within the district range from developing suburbs (like Essex and Rowley) to regional urban centers (like Newburyport). The development character of these communities varies between very low density with owner-occupied single-family homes to small/mid-sized urban downtowns. Population and housing density is generally low in exposed areas. However, there are higher density residential or commercial/industrial areas exposed in Salisbury, Newburyport, Newbury, Ipswich, Essex, and Gloucester. The value of structures at risk in the district is estimated at $2 billion (87% residential, 7% commercial/industrial). Working waterfronts in Salisbury, Newburyport, Newbury, Rowley, and Essex are among the exposed areas as well as some agricultural land. There is a larger amount of natural resource, conservation land, and protected open spaces compared to other districts.



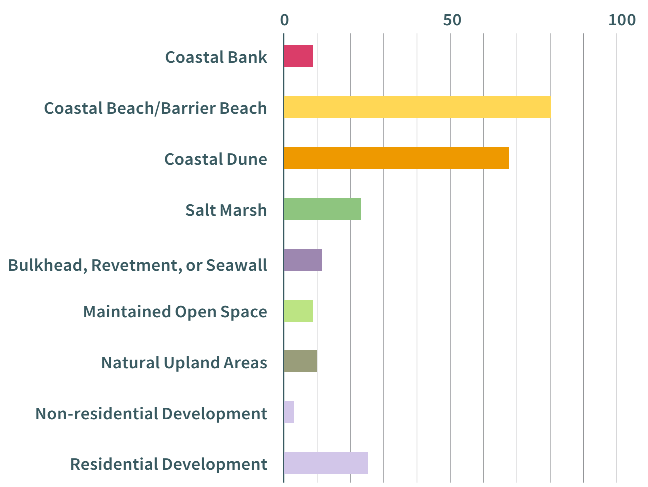
23 sq mi	**3.9K** structures	Exposed to near-term (2030s) 1% AEP flooding
32 sq mi	**7.4K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

36% of the district is open space



Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 03

Mid-North Shore

The Mid-North Shore district extends from Gloucester's rocky northern shore, through Rockport, Manchester-by-the-Sea, Beverly, Danvers, Peabody, Salem, Marblehead, and ends at Blaney Rock in Swampscott.

Coastal Environment

Coastal flood exposure is concentrated within and around the fringes of the district's rocky or largely armored coastal banks, where high-energy waves run up and overtop the shores, which rise rapidly in elevation. There is also exposure within and along the district's pocket beaches, salt marshes, and tidal rivers. Many of the district's beaches are sediment starved, particularly where armored banks provide limited sediment supply. Some of its barrier beaches have relatively small, and in some cases densely developed, coastal dunes. Gloucester and Rockport have barrier beaches with larger dunes.

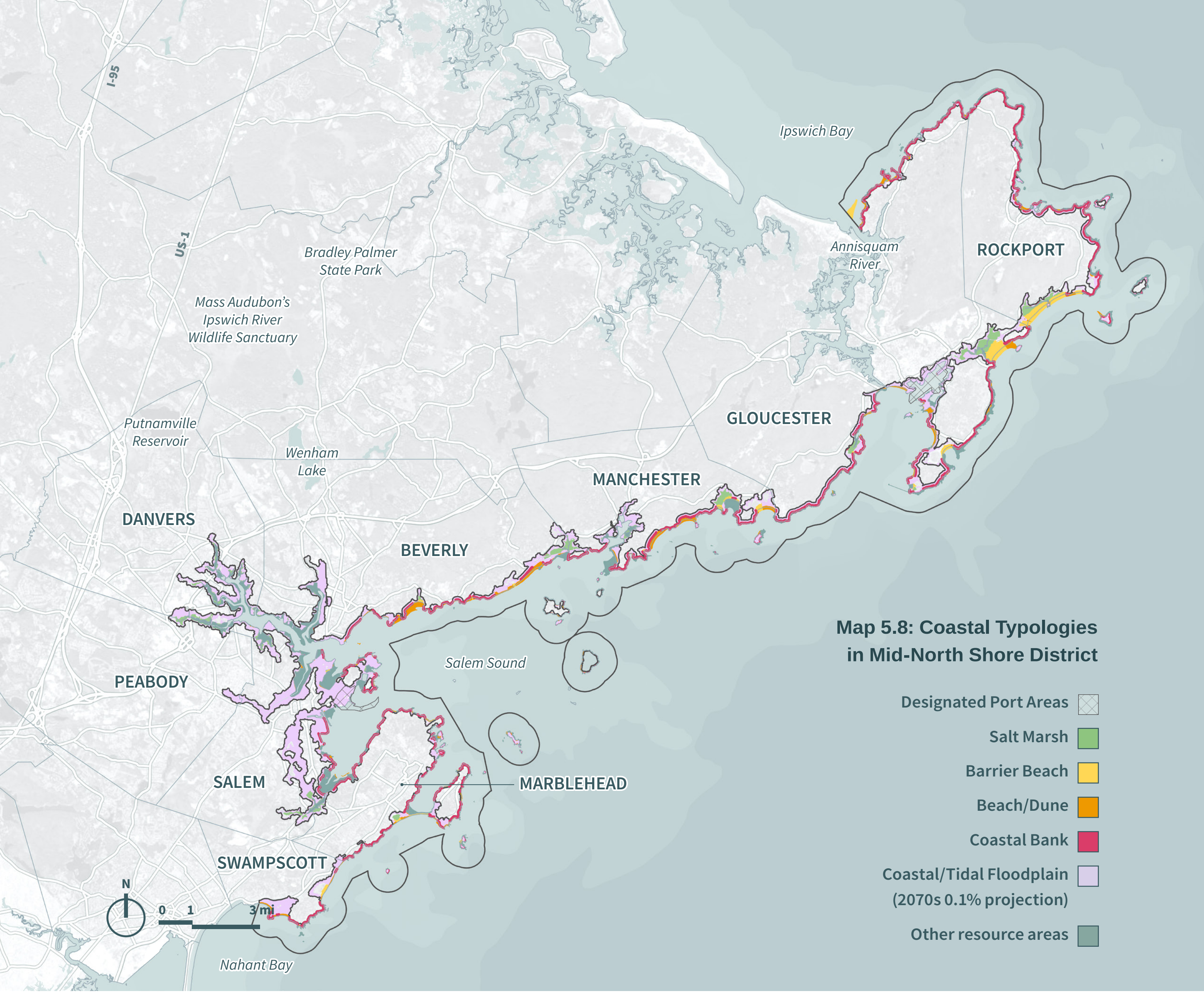
Limited sediment availability, combined with high wave energy along ocean-facing shores, leads to coastal erosion during storms and lower beach elevations, especially seaward of coastal engineering structures. Narrow beach areas that are dry at high tide today are susceptible to further narrowing and drowning due to long-term sea-level rise if the landforms behind the beaches can't shift landward.

Coastal flood exposure is widespread within and around previously filled tidelands and other historical wetlands, including low-lying working waterfronts and densely populated areas. Flood pathways, or narrow, low-lying areas through which entering floodwaters affect large areas of floodplain, are evident in some of these locations. Salt marsh will face more regular inundation with sea level rise, resulting in conversion of some existing regularly flooded areas to open water. Marsh migration potential exists in limited areas of the undeveloped upland/marsh border. This district also contains several federally designated CBRS units.

Population and Development

This district has just over 64,500 people (2,143 people per square mile) living in affected Census Blocks and just under 31,000 housing units. Communities in this district range from developing (like Rockport) and maturing suburbs (like Marblehead) to regional urban centers (like Salem and Beverly). Developing and maturing suburbs include mixed-use town centers, moderate density, and single-family homes, while regional urban centers typically have small to mid-sized urban downtowns surrounded by more suburban residential neighborhoods. There are EJ Block Groups in Salem, Beverly, Rockport, Gloucester, Peabody, and Danvers. Marblehead and Swampscott have EJ Block Groups, but they are inland of the long-term modeled flood risk (MC-FRM 2070 0.1% annual chance).[68]

Most ocean-facing shorelines in this district are armored or naturally occurring ledge and development is minimally setback from the shoreline. This results in flood exposure for dense residential and commercial/industrial areas, including the Gloucester Inner Harbor and Salem Harbor DPAs and other smaller working waterfronts. While some communities, like Marblehead and Swampscott, have primarily single-family residential land uses exposed, areas in Beverly, Danvers, Peabody, and Salem have multi-family, mixed-use and commercial/industrial land uses exposed. The value of structures at risk in the district is estimated at $5.1 billion (82% residential, 12% commercial/industrial).



3 sq mi	**2.9K** structures	Exposed to near-term (2030s) 1% AEP flooding
7 sq mi	**8.6K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

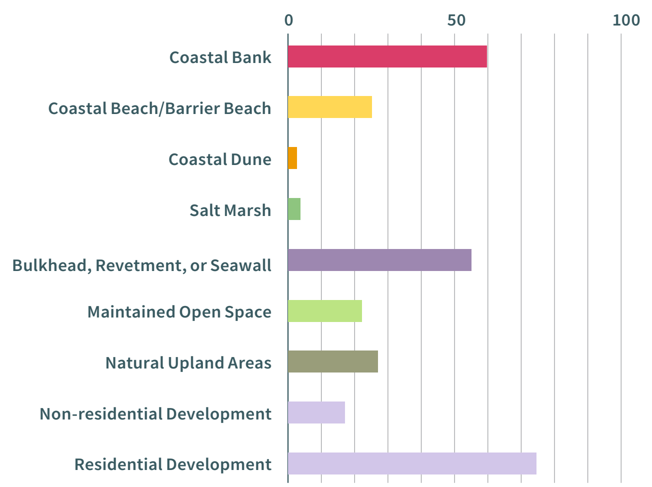
4% of the district is open space

81% permanently protected

15% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 04

Saugus Watershed

The Saugus Watershed district extends from King's Beach in Swampscott and Lynn, through Nahant, Saugus, Malden, Revere, and Winthrop, ending at Constitution Beach in Boston.

Coastal Environment

Coastal flood exposure is widespread within and around the district's large salt marshes, tidal rivers and beaches which are mostly armored. The district's barrier beaches have relatively small coastal dunes, all of which are highly developed with buildings or roadways. The small dunes and developed character, combined with exposure to high wave energy along ocean-facing shores, lead to erosion during coastal storms and lower beach elevations, especially seaward of coastal armoring structures.

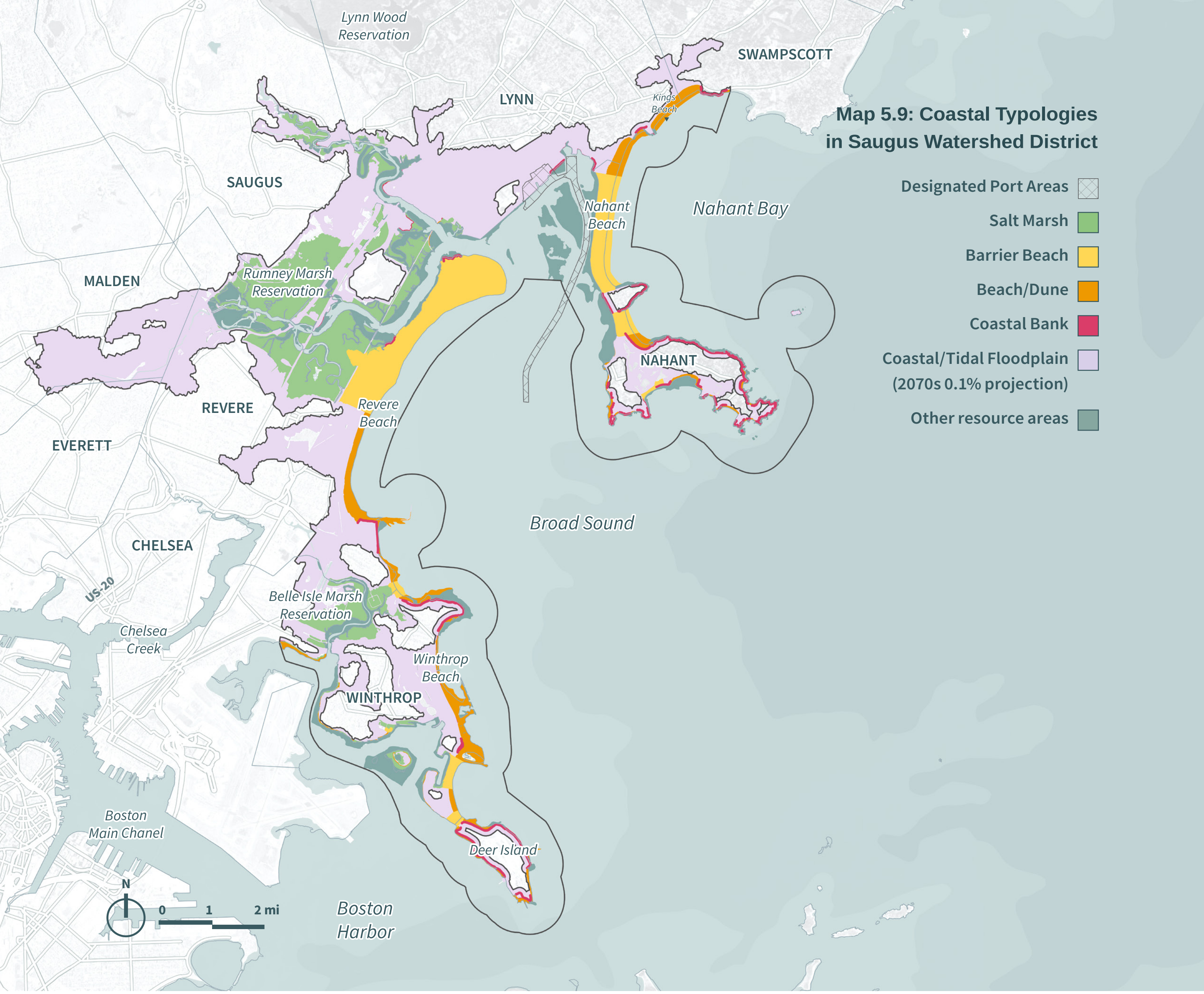
Narrow beach areas that are dry at high tide today are susceptible to further narrowing due to long-term sea-level rise if the landforms behind the beaches are unable to shift landward. A large-scale beach nourishment project conducted at the DCR Reservation in Revere in the 1980's has been successful in maintaining a wider dry beach and providing more shore protection. Models suggest that changes will occur within the salt marsh as sea level rises, such as more regular inundation of the marsh, and some conversion of existing regularly flooded areas to open water. The potential for salt marsh and barrier beaches to migrate landward is severely restricted in most places by existing and new development.

This district contains the state-designated Rumney Marshes ACEC as well as one federally designated CBRS unit, and state reservation areas. Coastal flood exposure is also widespread within and around previously filled Tidelands and other historically filled wetlands, including low-lying working waterfronts and densely populated areas. Flood pathways, or narrow, low-lying areas through which entering floodwaters affect a large floodplain, are evident in many of these areas.

Population and Development

This district is the second most populous and densely developed with just over 95,000 people (7,317 people per square mile) living in affected Census Blocks and just under 41,000 housing units. Most of the district is within a mapped EJ Block Group, including parts of all communities except Swampscott. Swampscott has an EJ Block Group, but it is inland of the long-term modeled coastal flood risk (MC-FRM 2070 0.1% annual chance flood extent).

The district includes maturing suburbs (like Nahant and Swampscott), regional urban centers (like Lynn), and inner core communities (like Boston, Everett, and Revere). These communities range from moderate density suburbs to high-density suburbs and inner cities. Small portions of East Boston and Swampscott are encompassed within this district, but the majority of land area is within Nahant, Lynn, Saugus, Winthrop, Revere, and Malden. In general, large portions of the ocean-facing shorelines are armored and development is minimally setback from the shoreline resulting in a mix of dense residential and commercial/industrial areas exposed, including the Lynn DPA and other smaller working waterfronts. The value of structures at risk in the district is estimated at $6.4 billion (81% residential, 12% commercial/industrial).



Map 5.9: Coastal Typologies in Saugus Watershed District

5 sq mi	**6.8K** structures	Exposed to near-term (2030s) 1% AEP flooding
8 sq mi	**14.4K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

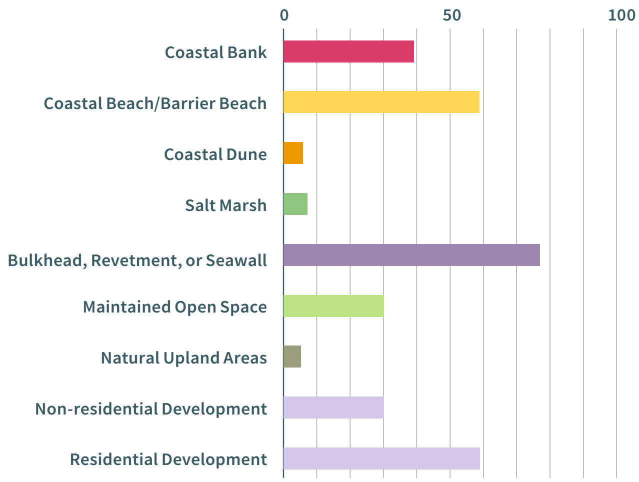
15% of the district is open space

89% permanently protected

10% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 05

Mystic-Charles Watersheds

The Mystic-Charles Watersheds district extends from Constitution Beach in Boston, through the Mystic and Charles River watershed communities of Revere, Chelsea, Everett, Malden, Medford, Winchester, Arlington, Belmont, Cambridge, Somerville, Watertown, Newton, Brookline, and Boston, ending just south of the Dorchester Bay Basin in Boston.

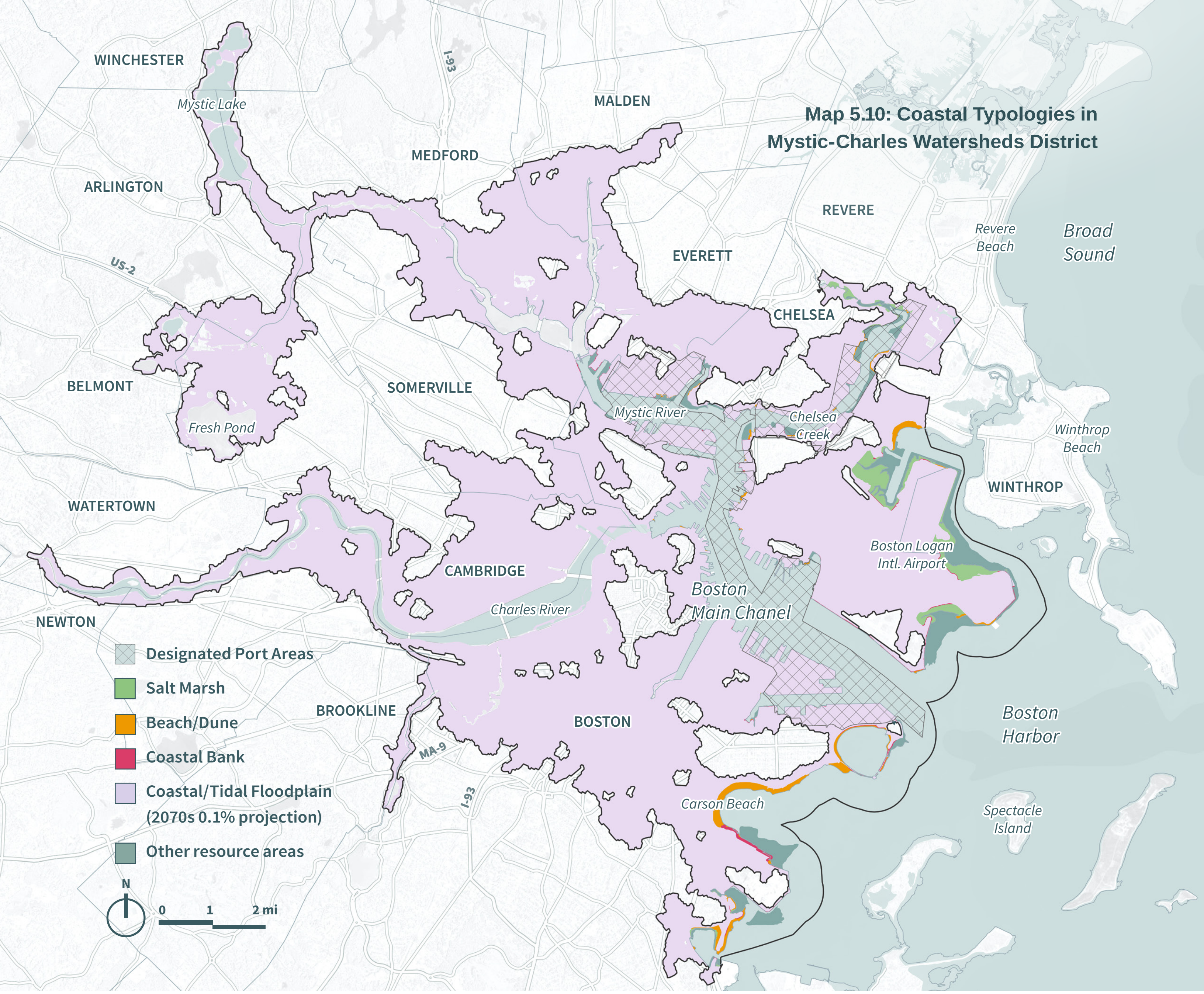
Coastal Environment

Coastal flood exposure is widespread within and around previously filled Tidelands and other historically filled wetlands, including low-lying working waterfronts and densely populated areas. This includes expansive areas along the Mystic and Charles rivers and their tributaries, upstream of the Amelia Earhart and Charles River dams, that are currently protected from storm surge. With sea level rise and more intense coastal storms, flooding is increasingly likely to flow around and over these dams, exposing "non-coastal" communities to coastal flooding. This district is dominated by coastal floodplain with smaller pockets of coastal beach and salt marsh. It also encompasses the greatest amount of DPA with the entirety of four DPAs within its boundaries – Mystic River, Chelsea Creek, East Boston, and South Boston. Flood pathways, or narrow, low-lying areas through which entering floodwaters affect a large floodplain, are evident in these areas. The Boston Harbor Islands provide some sheltering from storm surge and wave action, though overtopping and erosion still occur. This district also contains several state reservation areas.

Population and Development

This district is the most populous and densely developed of the fifteen CRDs, with over 400,000 people (13,559 people per square mile) living in affected Census Blocks and more than 200,000 housing units. Most of the district is either fully or partially within mapped EJ Block Groups, except the communities of Winchester and Newton. The municipalities within this district range from high density inner core communities (like Boston and Cambridge) and historic, high-density suburbs near the urban core (like Newton and Medford) to moderate-density, maturing suburbs (like Winchester). Many of the communities within this district are nearing or are completely built out with new growth opportunities largely limited to redevelopment and infill.

This district has a highly developed and mostly altered shoreline. Dense residential or commercial/industrial areas in each community in the district are exposed to coastal flooding, except in Winchester and Newton. This includes the four DPAs within the district as well as other smaller working waterfronts. The district has a greater percentage of commercial/industrial land exposed to flooding (19%) than other districts and is distinguished by its high concentration of multi-family, versus single-family, housing. Shorelines are generally armored, and development is minimally setback from the shoreline, except where there are coastal parks and along upstream river shorelines where the presence of U.S. Army Corps of Engineers and Massachusetts Department of Conservation (DCR) land and structures serve as a wider buffer to development. The value of structures at risk in the district is estimated at $135 billion (49% residential, 30% commercial/industrial).



10 sq mi	**4.6K structures**	Exposed to near-term (2030s) 1% AEP flooding
27 sq mi	**37K structures**	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

11% of the district is open space

91% permanently protected

4% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

What characterizes the shoreline of the Mystic-Charles Watersheds district?

The shorelines of Boston Inner Harbor, the Charles and Mystic Rivers, and Chelsea Creek are heavily urbanized, dominated by industrial and commercial land (including land for water-dependent industrial uses), high-density residential housing, and transportation infrastructure. Shorelines are heavily armored with bulkheads and revetments. Countless wharves dot the Inner Harbor. The few natural areas, including beaches and salt marshes, are mostly backed by seawalls or other hardened infrastructure.

DISTRICT 06

Boston Harbor Islands

The Boston Harbor Islands district includes islands in Boston Harbor and Hingham Bay, within the communities of Boston, Hull, Quincy, Weymouth, and Hingham.

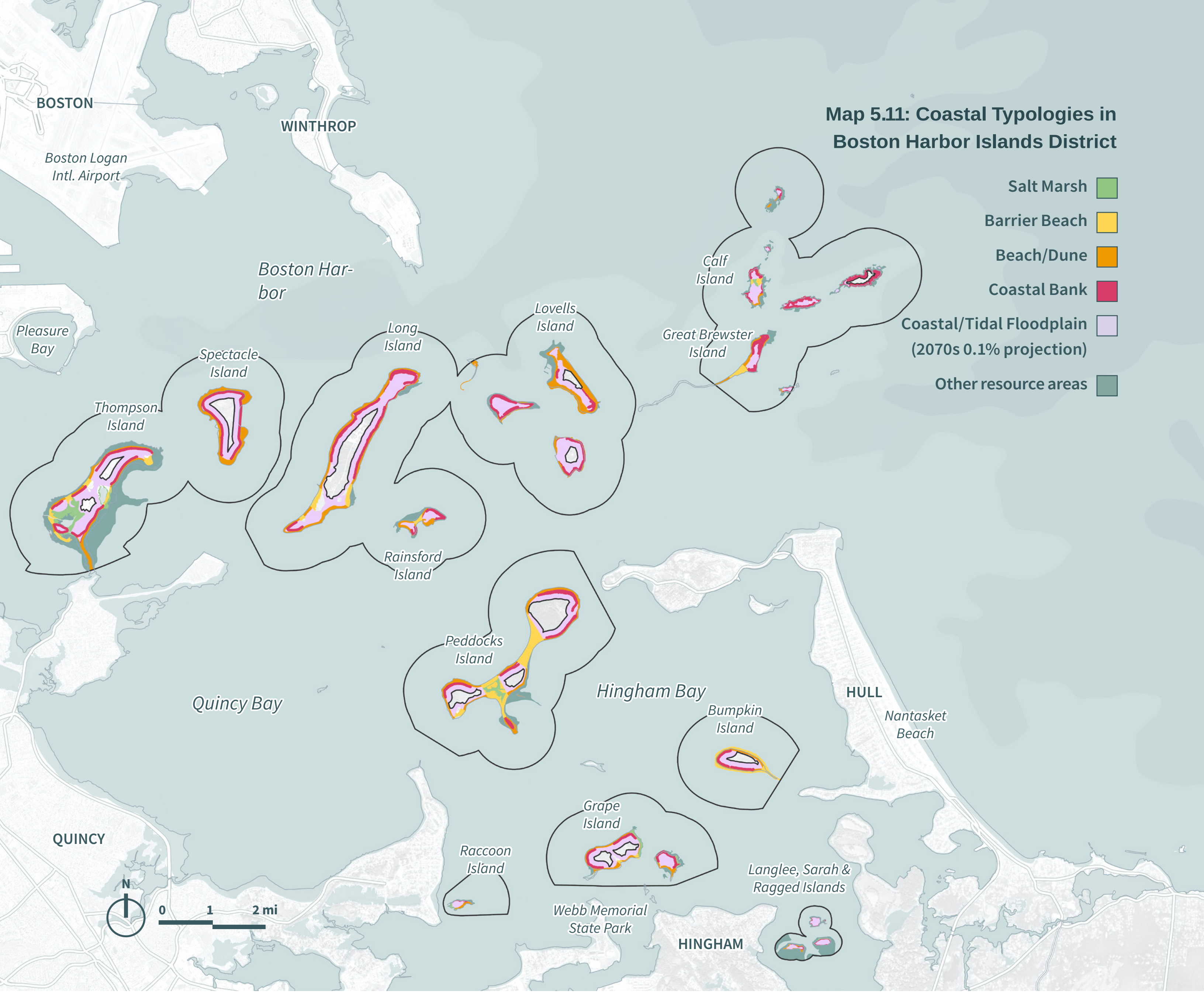
Coastal Environment

Coastal flood exposure is concentrated within and around the Harbor islands' beaches, banks, and dunes. There is a mix of armored and unarmored shorelines. Seawalls and jetties are present on Gallops, Georges, Great Brewster, Little Brewster, Long, Lovells, Moon, Nix's Mate, Ragged, and Rainsford Islands. Armoring is more common on the ocean-facing sides of some islands, which are exposed to high wave energy. Exposure to high wave energy and currents along ocean-facing shores lead to erosion during coastal storms and lowering of beach elevations, especially seaward of coastal armoring structures. Many of the coastal armoring structures on the Harbor islands are historical structures that are deteriorated from exposure to coastal hazards and lack of maintenance. The district's barrier beaches are generally unarmored, undeveloped, and protected, providing potential for natural landward migration over time in response to sea level rise and storms.

The islands perform a valuable hazard mitigation service for landward districts in Boston Harbor, sheltering them from wave action and coastal flooding. Rising seas and stronger storms driven by climate change will exacerbate the erosion of unconsolidated coastal banks along the islands, which provides sediment to nearby harbor beaches. This district also has several smaller but ecologically important marshes. The Harbor Islands are part of the Boston Harbor Islands National Recreation Area and includes two federally designated CBRS units as well as a state park.

Population and Development

The islands do not have a significant year-round population. There are a few remaining summer cottages on the islands and one year-round resident. Development is generally limited to docking infrastructure, paved roads, and educational, recreational, and cultural facilities. Long Island also has health services facilities that are not currently in operation. Most of the islands are currently listed on the National Register of Historic Places.

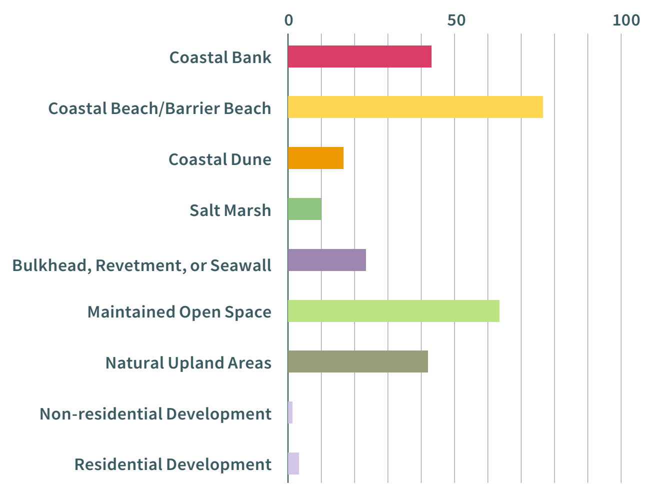


0.5 sq mi	**64 structures**	Exposed to near-term (2030s) 1% AEP flooding
0.7 sq mi	**148 structures**	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

Boston Harbor Islands National and State Park is managed cooperatively by federal, state, city, and nonprofit agencies. While structures exist on several islands, these glacial drumlins are managed as open space to preserve recreational, ecological, and historical/cultural resources.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 07

Neponset-Weir Watersheds

The Neponset-Weir Watersheds district extends from Commercial Point in Boston, through the Neponset and Fore River communities of Milton, Quincy, Braintree, and Weymouth, and the Weir River communities of Hingham, Hull, and Cohasset, ending at Black Rock Beach in Cohasset.

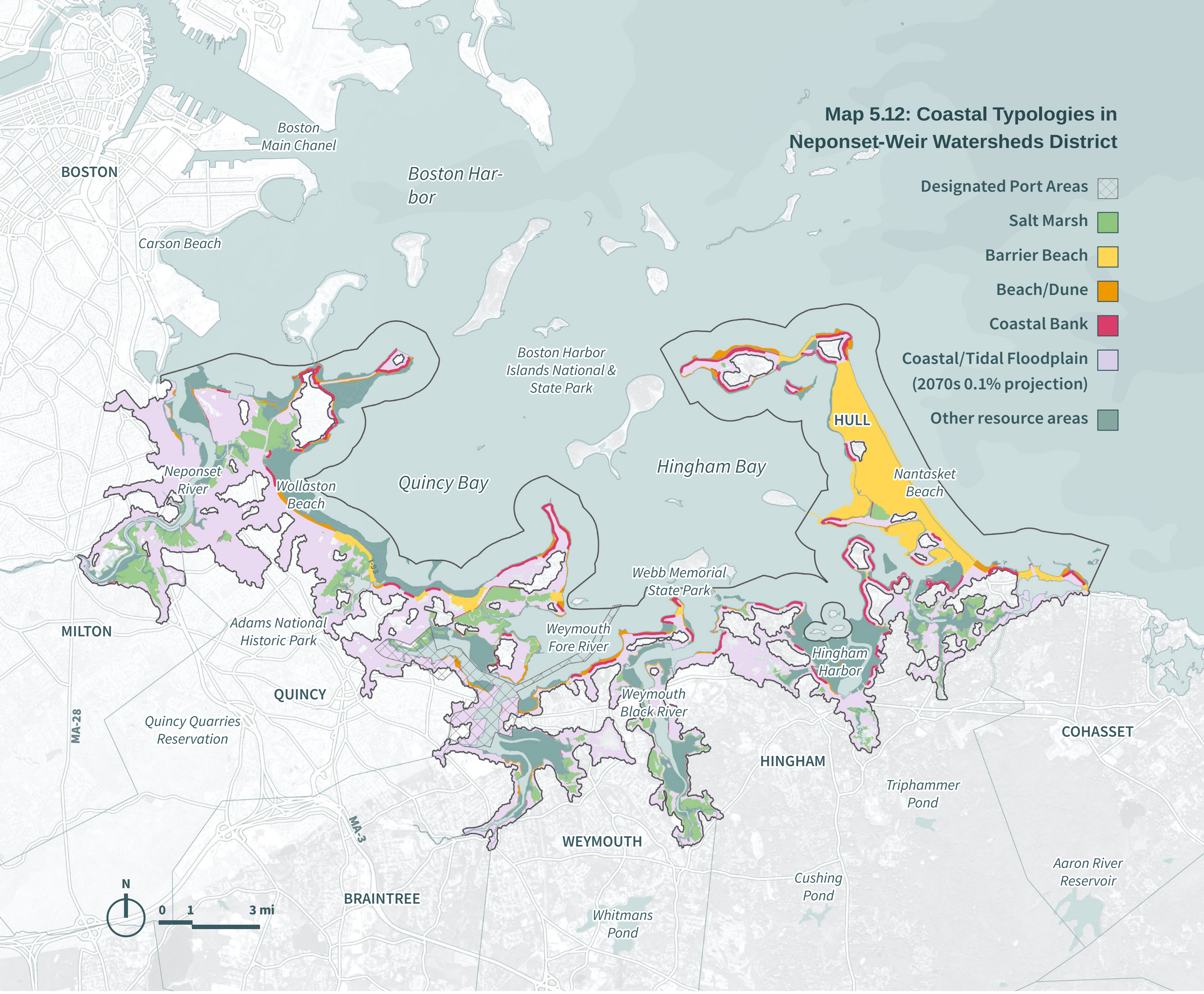
Coastal Environment

Coastal flood exposure is widespread within and around previously filled Tidelands and other historically filled wetlands, including low-lying working waterfronts and densely populated areas. Flood pathways, or narrow, low-lying areas through which entering floodwaters affect a large floodplain, are evident in many of these areas. Coastal flood exposure is also widespread within and around the district's large and mostly armored shorelines, salt marshes, and tidal rivers. Wave overtopping of coastal armoring structures, coastal dunes, and coastal banks exacerbates flooding and damage to property and infrastructure.

The district's beaches are sediment starved, and its barrier beaches have relatively small coastal dunes, most of which are highly developed with buildings or roadways. These factors, combined with high wave energy along ocean-facing shores, leads to erosion during coastal storms and lowering of beach elevations, especially seaward of coastal armoring structures. Narrow beach areas that are dry at high tide today are susceptible to further narrowing due to long-term sea-level rise if the landforms behind the beaches are unable to shift landward. Models suggest that changes will occur within the salt marsh as sea level rises, such as more regular inundation of the marsh, and some conversion of existing regularly flooded areas to open water. Marsh migration potential exists in limited areas of the undeveloped upland/marsh border. This district contains the state-designated Neponset River Estuary, Weymouth Back River, and Weir River ACECs, as well as two federally designated CBRS units, and state reservation land.

Population and Development

This district is the third most populous with just over 86,000 people (4,202 people per square mile) living in affected Census Blocks and just over 40,000 housing units. Extensive areas of the district are within mapped EJ Block Groups including parts of Boston, Quincy, and Braintree and smaller areas in Weymouth. Communities in the district are predominately developing (like Cohasset) or maturing suburbs (like Weymouth and Braintree) with low- to moderate-density residential housing that is primarily owner-occupied single family. There are also inner core communities and urban regional centers (including small portions of South Boston and significant portions of Quincy), which have higher-density multi-family residential, mixed, and commercial land uses. In general, shorelines in these communities are armored and development is minimally setback from the shoreline. Dense residential or commercial/industrial areas in each community in the district are exposed, except Cohasset. This includes the Weymouth Fore River DPA and other smaller working waterfronts. The value of structures at risk in the district is estimated at $7.6 billion (80% residential, 12% commercial/industrial).



6 sq mi	**8.8K** structures	Exposed to near-term (2030s) 1% AEP flooding
9 sq mi	**17K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

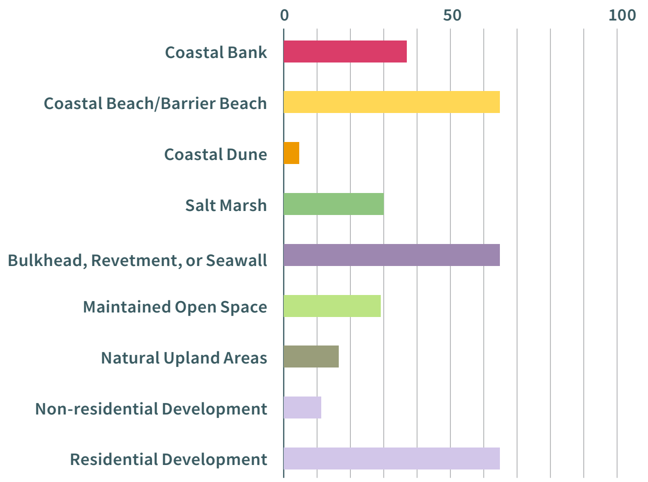
12% **of the district is open space**

92% permanently protected

7% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 08

Mid-South Shore

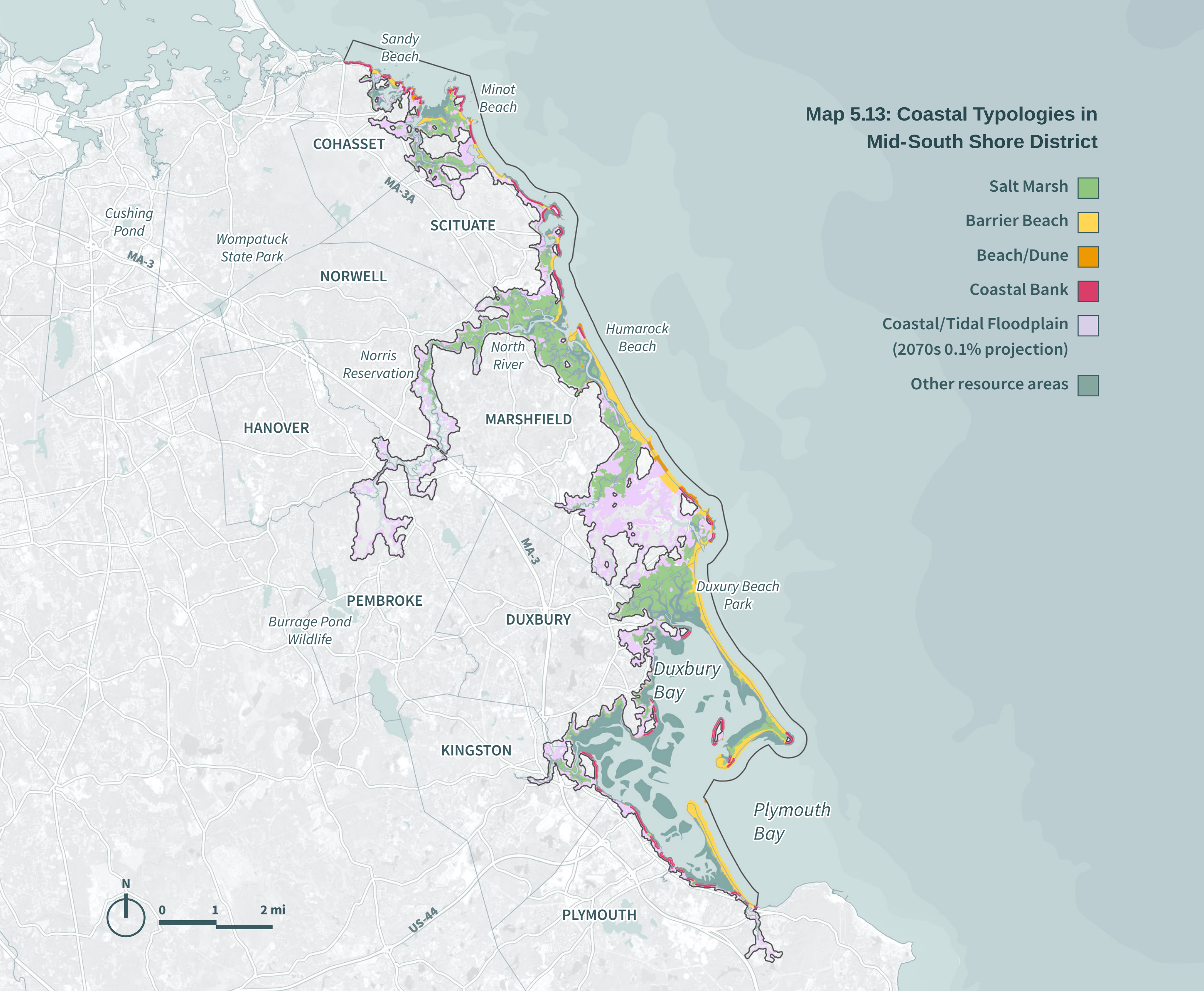
The Mid-South Shore district extends from Black Rock Beach in Cohasset, through the North River communities of Scituate, Norwell, Hanover, Pembroke, and Marshfield, and on through Duxbury, Kingston, and Long Beach in Plymouth.

Coastal Environment

Coastal flood exposure is concentrated within and around the fringes of the district's large and mostly armored shorelines (abutting beaches, salt marshes, and tidal rivers). Wave overtopping of coastal armoring structures exacerbates flooding and damage to property and infrastructure. The district's beaches are sediment starved due to armoring of the sediment sources, and its barrier beaches have relatively small coastal dunes, most of which are developed with buildings or roadways. These factors, combined with exposure to high wave energy along ocean-facing shores, lead to coastal erosion during coastal storms and lowering of beach elevations, especially seaward of coastal armoring structures. Narrow beach areas that are dry at high tide today are susceptible to further narrowing due to long-term sea-level rise if the landforms behind the beaches are unable to shift landward. Models suggest that changes will occur within the salt marsh as sea level rises, including more regular inundation of the marsh, and some conversion of existing regularly flooded areas to open water. Salt marsh and undeveloped beaches have the potential to migrate landward in some areas, especially within protected conservation land and areas where development is setback from the shoreline. This district contains several federally designated CBRS units and state reservation land.

Population and Development

This district has nearly 45,000 people (818 people per square mile) living within affected Census Blocks and about 21,000 housing units. The district includes mapped EJ Block Groups in Hanover and Plymouth. Communities within the district are predominately developing (like Cohasset) or maturing suburbs (like Kingston and Hanover) ranging from low- to moderate-density with large amounts of developable land (like Norwell) to more established low density suburbs approaching buildout (like Marshfield). Population and housing density is generally low in exposed areas. However, there are higher density residential or commercial/industrial areas, including smaller working waterfronts, in Cohasset, Scituate, Marshfield, Duxbury, Kingston, and Plymouth. The value of structures at risk in the district is estimated at $2.8 billion (86% residential, 6% commercial/industrial). In general, many shorelines in these areas are armored and development is minimally setback from the shoreline causing a significant amount of storm damage to be clustered along the shoreline.



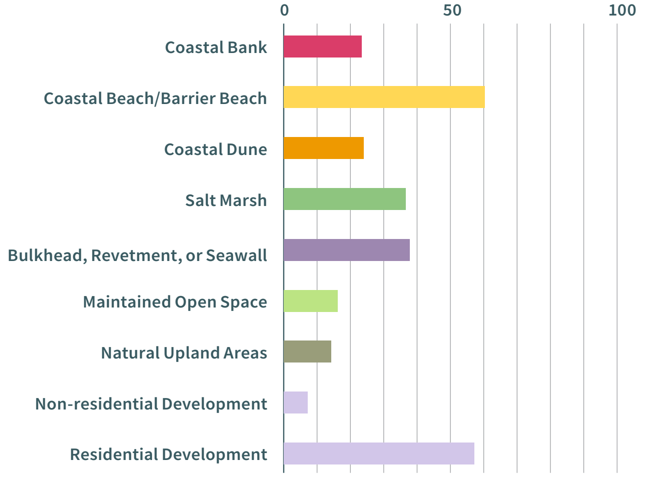
14 sq mi	**6.3K** structures	Exposed to near-term (2030s) 1% AEP flooding
20 sq mi	**11.4K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

16% of the district is open space

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 09

Manomet-Sagamore

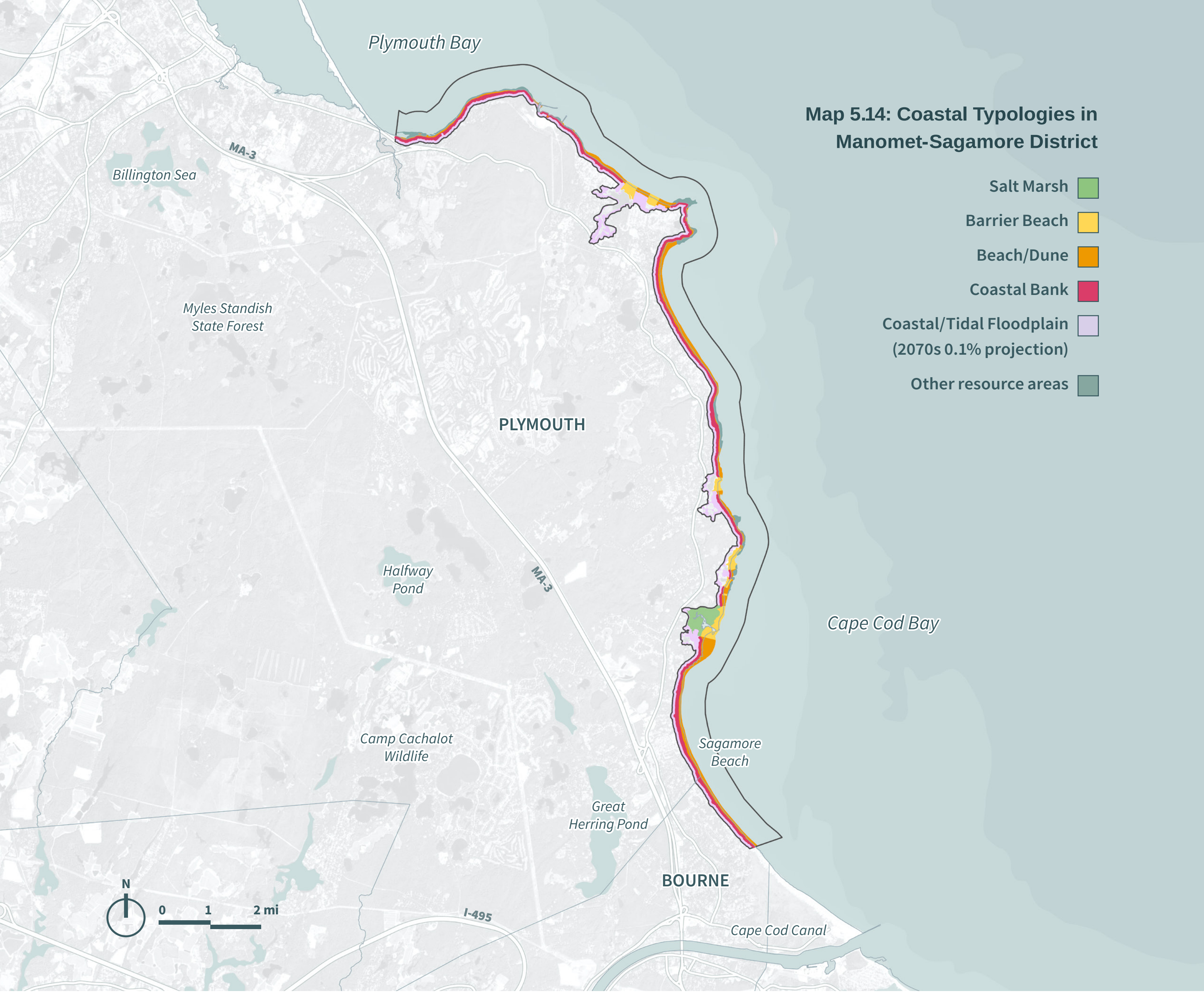
The Manomet-Sagamore district includes Plymouth, south of Long Beach, and the northern portion of Sagamore Beach in Bourne.

Coastal Environment

Coastal flood exposure is concentrated within and around the fringes of the district's ocean-facing coastal beaches, barrier beaches, banks and bluffs, where high-energy waves runup and overtop the shoreline. Due to its sandy geology and exposure to high wave energy, coastal bank erosion is the predominant coastal hazard impacting this district. Coastal bank erosion caused by wave action exacerbated by storms and sea level rise causes the shoreline to move inland, sometimes by dozens of feet, threatening development that sits high atop the coastal banks but adjacent to the eroding edge of the landform. Much of the shoreline is armored with revetments that reduce bank erosion but increase seaward and downdrift beach erosion as well as groins and jetties that slow sediment eroded from beaches and coastal banks from migrating along the shore, starving downdrift areas of sediment and increasing erosion. Several smaller marshes fringe inlets and harbors of this region, including Ellisville Harbor. Models suggest that changes will occur within these salt marshes as sea level rises, including more regular inundation of the marsh, and some conversion of existing regularly flooded areas to open water. There is limited marsh migration potential in areas of the undeveloped upland/marsh border adjacent to existing marsh. This district contains the state-designated Ellisville Harbor ACEC, lands of the Herring Pond Wampanoag Tribe, as well as several federally designated CBRS units.

Population and Development

This district includes portions of two communities: Plymouth and Bourne. It has just over 6,000 people (1,048 people per square mile) living within affected Census Blocks and about 3,700 housing units. The district has a relatively small amount of commercial/industrial land use (1%) and does not overlap with any mapped EJ Block Groups. A significant vulnerability of this district is the presence of single-family homes constructed on or immediately adjacent to eroding coastal banks. While population and housing density is generally low in exposed areas, there is higher density residential development around White Horse Beach and Manomet Bluffs in Plymouth that is exposed to coastal erosion. The value of structures at risk in the district is estimated at $433 million (55% residential, 2% commercial/industrial).



0.3 sq mi	**111K structures**	Exposed to near-term (2030s) 1% AEP flooding
0.8 sq mi	**1.8K structures**	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

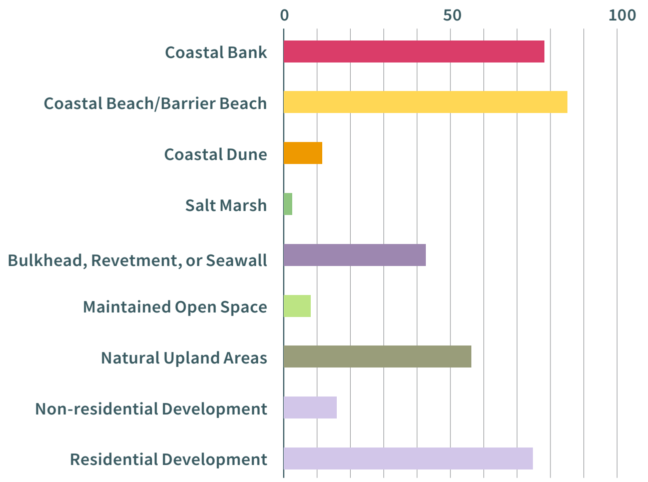
15% of the district is open space

81% permanently protected

15% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 10

North Cape Cod

The North Cape Cod district extends from Sagamore Beach near the Bourne-Sandwich town line, then east and north along Cape Cod Bay, through Sandwich, Barnstable, Yarmouth, Dennis, Brewster, Orleans, Eastham, Wellfleet, Truro, and ending in Provincetown.

Coastal Environment

Coastal flood exposure is concentrated within and around the low-lying areas adjacent to the district's beaches, coastal banks, salt marshes, and tidal rivers. The district has a mix of armored and unarmored shorelines and several developed barrier beaches with buildings, roadways, or beach access parking. Groins and jetties slow sediment eroded from beaches and coastal banks from migrating along the shore, starving downdrift areas of sediment. These factors, combined with exposure to high wave energy leads to coastal erosion and lowering of beach elevations during storms, especially seaward and downdrift of coastal armoring structures. Eroded sediments build up in the high number of navigational channels and harbors, requiring frequent dredging.

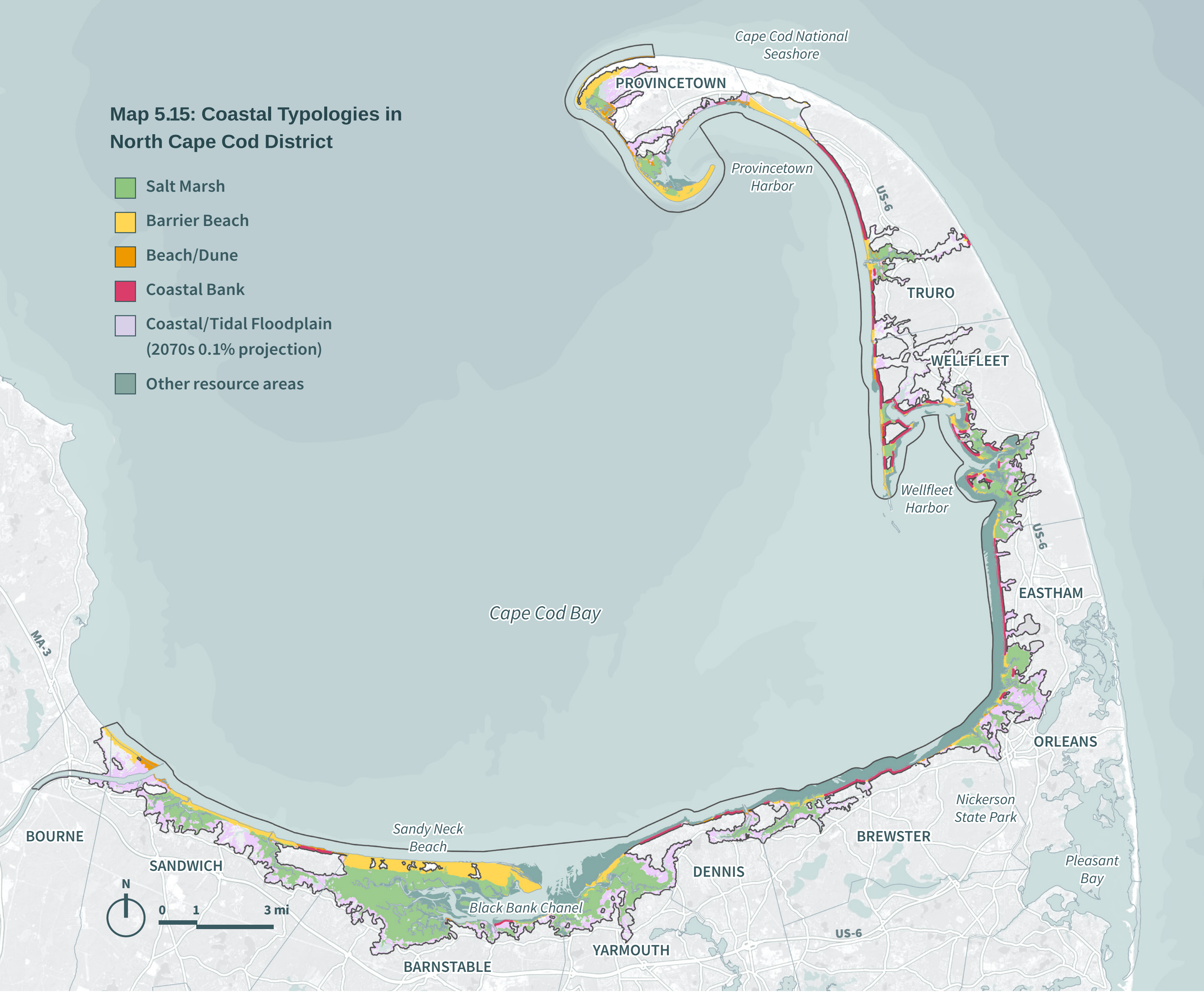
Narrow beach areas that are dry at high tide today are susceptible to further narrowing due to long-term sea-level rise if the landforms behind the beaches are unable to shift landward. Salt marshes range from the large marsh system of Barnstable Great Marsh, which is similar to the Great Marsh of the North Shore, to the more exposed and dynamic marshes of the lower Cape. Models suggest that changes will occur within the salt marsh as sea level rises, including more regular inundation of the marsh, and some conversion of existing regularly flooded areas to open water.

Good marsh migration potential exists in the undeveloped upland/marsh border and into other wetlands, especially protected conservation land and areas where development is setback from the shoreline. This district contains the Sandy Neck Barrier Beach System, Inner Cape Cod Bay, Wellfleet Harbor ACECs, almost a dozen federally designated CBRS units, lands of the Herring Pond Wampanoag Tribe, state reservation, and wildlife management areas. The district also includes portions of the Cape Cod National Seashore National Park.

Population and Development

This district has just over 20,000 people (258 people per square mile) living within affected Census Blocks and about 22,000 housing units. It is the second largest mainland district by land area after Buzzards Bay. Notably, this population estimate is based on year-round residents. Given this district's prominent tourism industry, there are likely many more visitors and seasonal residents in this district than is reflected in the population count.

This district includes mapped EJ Block Groups in Brewster, Eastham, Orleans, Truro, and Provincetown. Population and housing density is generally low in exposed areas. However, there are higher density residential or commercial/industrial areas, including smaller working waterfronts, in many communities. Communities within the district range from more rural towns (like Truro) to denser, regional urban centers (like Provincetown). The majority of communities are established, lower-density suburbs approaching full buildout (like Orleans and Wellfleet). The district has a relatively small amount of commercial/industrial land use (about 1%). The value of structures at risk in the district is estimated at $3.2 billion (85% residential, 9% commercial/industrial).



15 sq mi	**3.7K** structures	Exposed to near-term (2030s) 1% AEP flooding
24 sq mi	**10.1K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

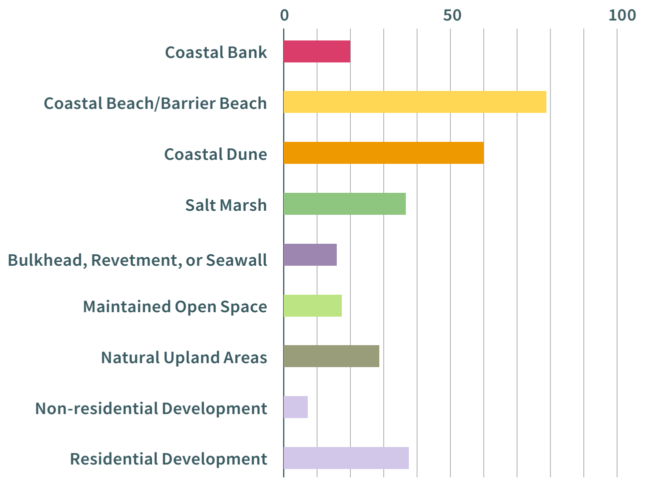
31% of the district is open space

97% permanently protected

2% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 11

Outer Cape Cod

The Outer Cape Cod district extends along the Atlantic Ocean-facing shore of Cape Cod, from east of the Provincetown Municipal Airport, south through Truro, Wellfleet, Eastham, and Orleans, and around the southeast coast of Chatham, ending between Forest Beach and Red River Beach.

Coastal Environment

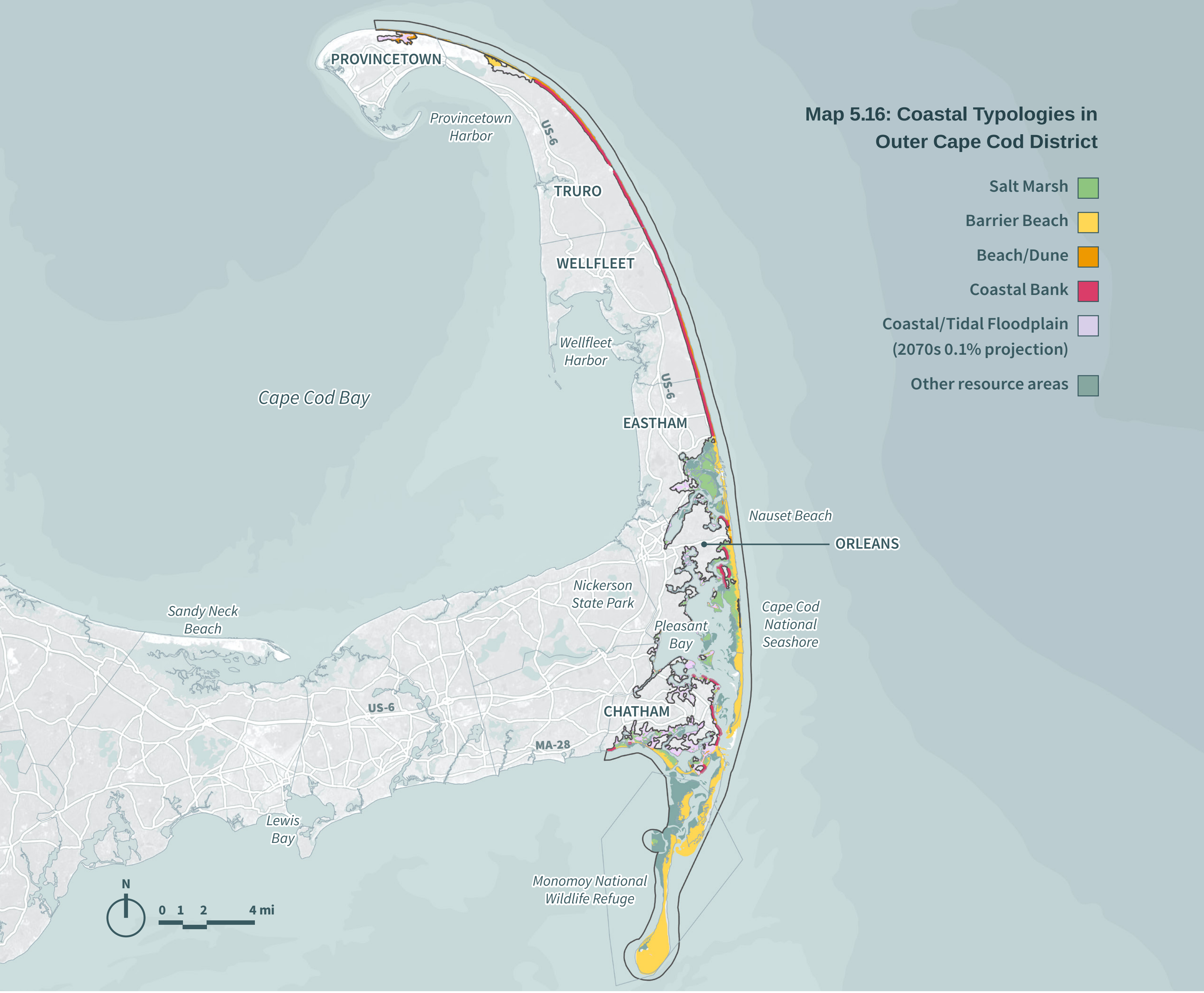
Coastal flood exposure is concentrated within and around the low-lying areas adjacent to coastal ponds, bay, and harbors. Flood exposure is also concentrated around the district's ocean-facing beaches, barrier beaches, and coastal banks. Due to its sandy geology and exposure to high wave energy, coastal bank and beach erosion is the predominant coastal hazard impacting this district, with among the highest erosion rates across Massachusetts. However, because the shorelines of this district are mostly unarmored, natural erosion serves an important function as a sediment source and helps maintain beach width. Eroded sediments that build up in navigational channels and harbors require maintenance dredging.

Barrier beaches are generally extensive, relatively undeveloped, and protected, providing important protection from coastal storm surge and flooding and have the potential for natural landward migration over time in response to sea level rise and storms. Due to the narrower tidal range to which salt marsh habitats in this district are adapted, models predict that long-term sea-level rise will result in a larger area of salt marsh inundation, resulting in the transition to tidal flat or open water in multiple locations.

Salt marsh has the potential to migrate landward in some areas, especially protected conservation land and areas where development is setback from the shoreline. This district contains the state-designated Pleasant Bay ACEC, as well as several federally designated CBRS units. The majority of the district is located within the Cape Cod National Seashore or the Monomoy National Wildlife Refuge, which are federally managed conservation areas.

Population and Development

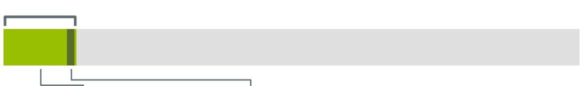
This district has about 7,500 people (172 people per square mile) living within affected Census Blocks and just under 9,000 housing units. Notably, this population estimate is based on year-round residents, not seasonal residents. Given this district's prominent tourism industry, there are likely many more visitors and seasonal residents than reflected in the population count. Communities within the district range from more rural towns (like Truro) to denser, regional urban centers (like Provincetown). The majority of communities are established, lower-density suburbs approaching full buildout. This district includes mapped EJ Block Groups in Truro, Eastham and Chatham. Population and housing density is generally low in exposed areas. However, there are higher density residential or commercial/industrial areas, including smaller working waterfronts, in Eastham, Orleans, and Chatham. Commercial and industrial uses are a relatively small portion of the district at less than one percent. The value of structures at risk in the district is estimated at $1.6 billion (92% residential, 5% commercial/industrial).



6 sq mi	**1.3K structures**	Exposed to near-term (2030s) 1% AEP flooding
9 sq mi	**3K structures**	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

19% **of the district is open space**

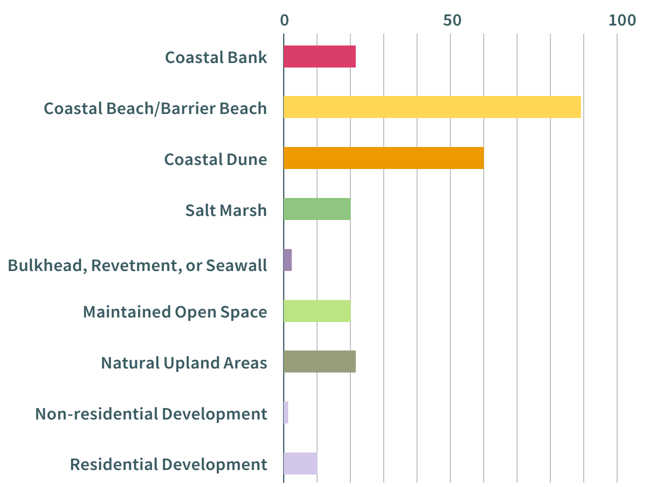


91% permanently protected

8% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 12

South Cape Cod

The South Cape Cod district extends along the south-facing shore of Cape Cod, from between Forest Beach and Red River Beach in Chatham, west through Harwich, Dennis, Yarmouth, Barnstable, and Mashpee, and ending at Surf Drive and Oyster Pond in Falmouth.

Coastal Environment

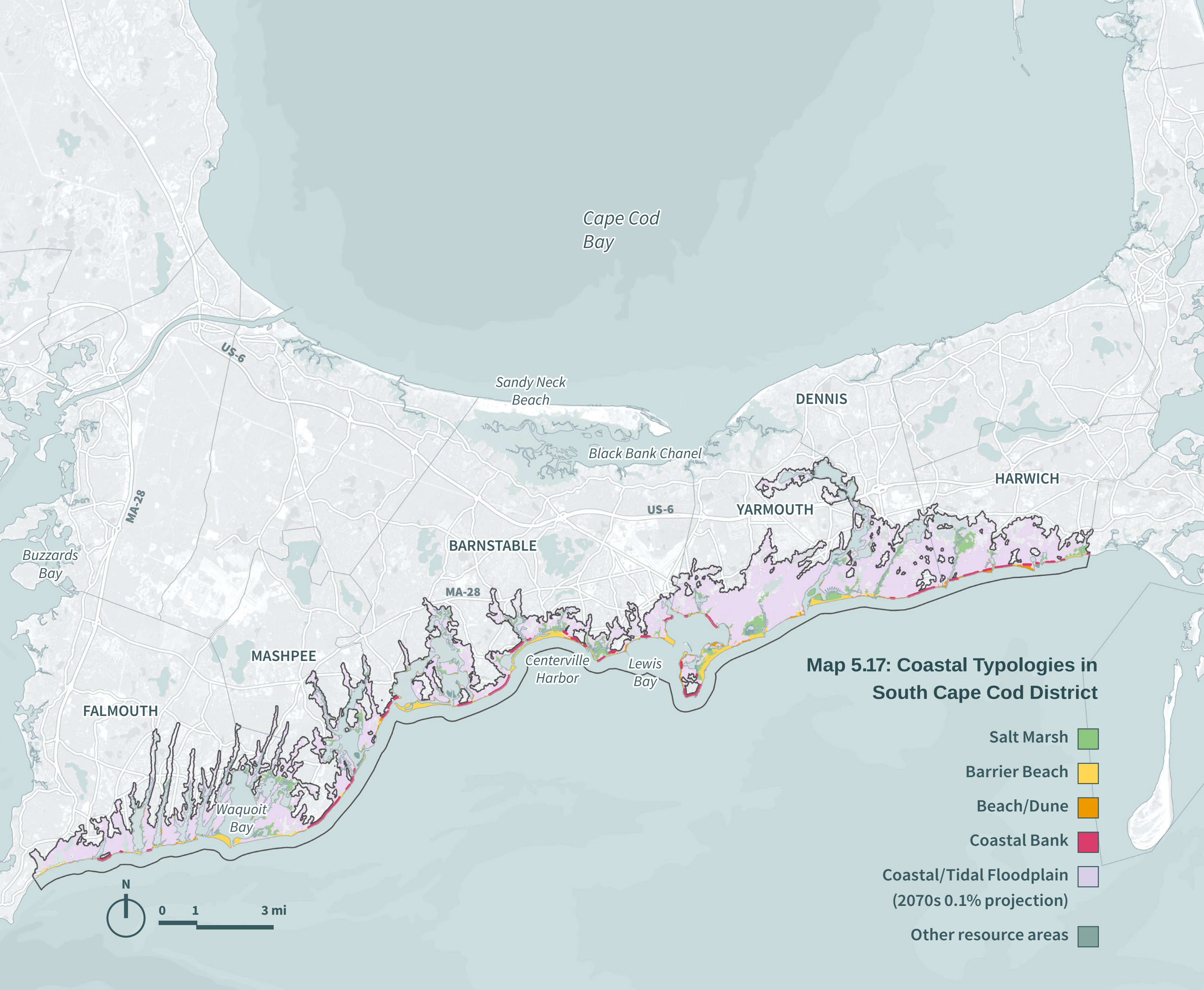
Coastal flood exposure in this district is concentrated within and around the low-lying areas adjacent to coastal ponds, bays, and harbors, as well as ocean-facing beaches, barrier beaches, and coastal banks. The district's south facing orientation makes it particularly susceptible to impacts from tropical storms and hurricanes. Due to its sandy geology and exposure to high wave energy, coastal storms cause coastal bank and beach erosion, especially seaward of coastal armoring structures. There is a mix of armored and unarmored shorelines. Groins and jetties are common and slow sediment eroded from beaches and coastal banks from migrating along the shore, starving downdrift areas of sediment. Eroded sediments build up in navigational channels and harbors requiring maintenance dredging.

Many of the district's barrier beaches are developed with buildings, roadways, or beach access parking, which limit the ability of the barrier beaches to naturally migrate landward over time in response to sea level rise and storms. Due to the narrower tidal range to which salt marsh habitats in this district are adapted, models predict that long-term sea-level rise will cause a larger area of salt marsh to be regularly inundated, and the transition to tidal flat or open water in multiple locations.

Salt marsh has the potential to migrate landward in some areas, especially protected conservation land and areas where development is setback from the shoreline. This district contains the state-designated Waquoit Bay ACEC, as well as nearly a dozen federally designated CBRS units, lands of the Mashpee Wampanoag Tribe, the Waquoit Bay National Estuarine Research Reserve, state wildlife management areas and reservations, and federal wildlife refuges.

Population and Development

This district has just over 52,000 people (786 people per square mile) living within affected Census Blocks and about 48,000 housing units. Notably, this population estimate is based on year-round residents, not seasonal residents. Given this district's prominent tourism industry, there are likely many more visitors and seasonal residents in this district than reflected in the population count. The district includes Mashpee Wampanoag Tribe lands in Mashpee and mapped EJ Block Groups in Chatham, Harwich, Dennis, Yarmouth, Barnstable, and Falmouth. Many of the communities in this district are split with the North Cape Cod CRD. The majority of communities are lower-density suburbs approaching full buildout. There is a mix of armored and unarmored shorelines and development is minimally setback from the shoreline. Population and housing density is mixed in exposed areas with higher density residential areas exposed in Falmouth, Mashpee, Yarmouth, and Chatham. There are also higher density commercial/industrial areas, including smaller working waterfronts, exposed in each community. The value of structures at risk in the district is estimated at $6.8 billion (90% residential, 6% commercial/industrial).



Map 5.17: Coastal Typologies in South Cape Cod District

16 sq mi	11.7K structures	Exposed to near-term (2030s) 1% AEP flooding
34 sq mi	33.2K structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

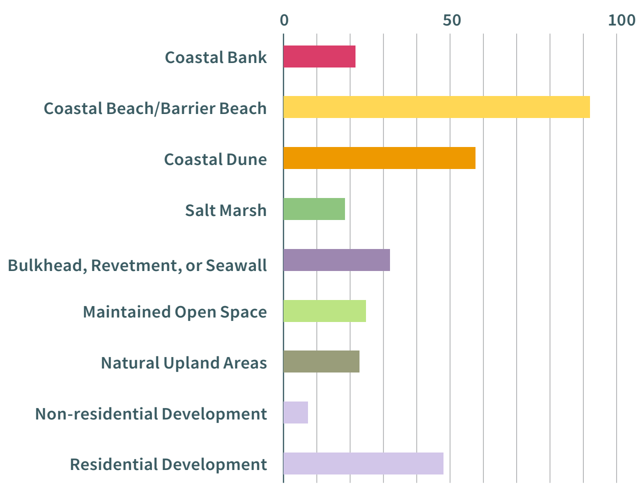
14% of the district is open space

85% permanently protected

6% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 13

Islands

The district includes the island communities of Nantucket, Gosnold, and Edgartown, Oak Bluffs, Tisbury, West Tisbury, Chilmark, Aquinnah on Martha's Vineyard.

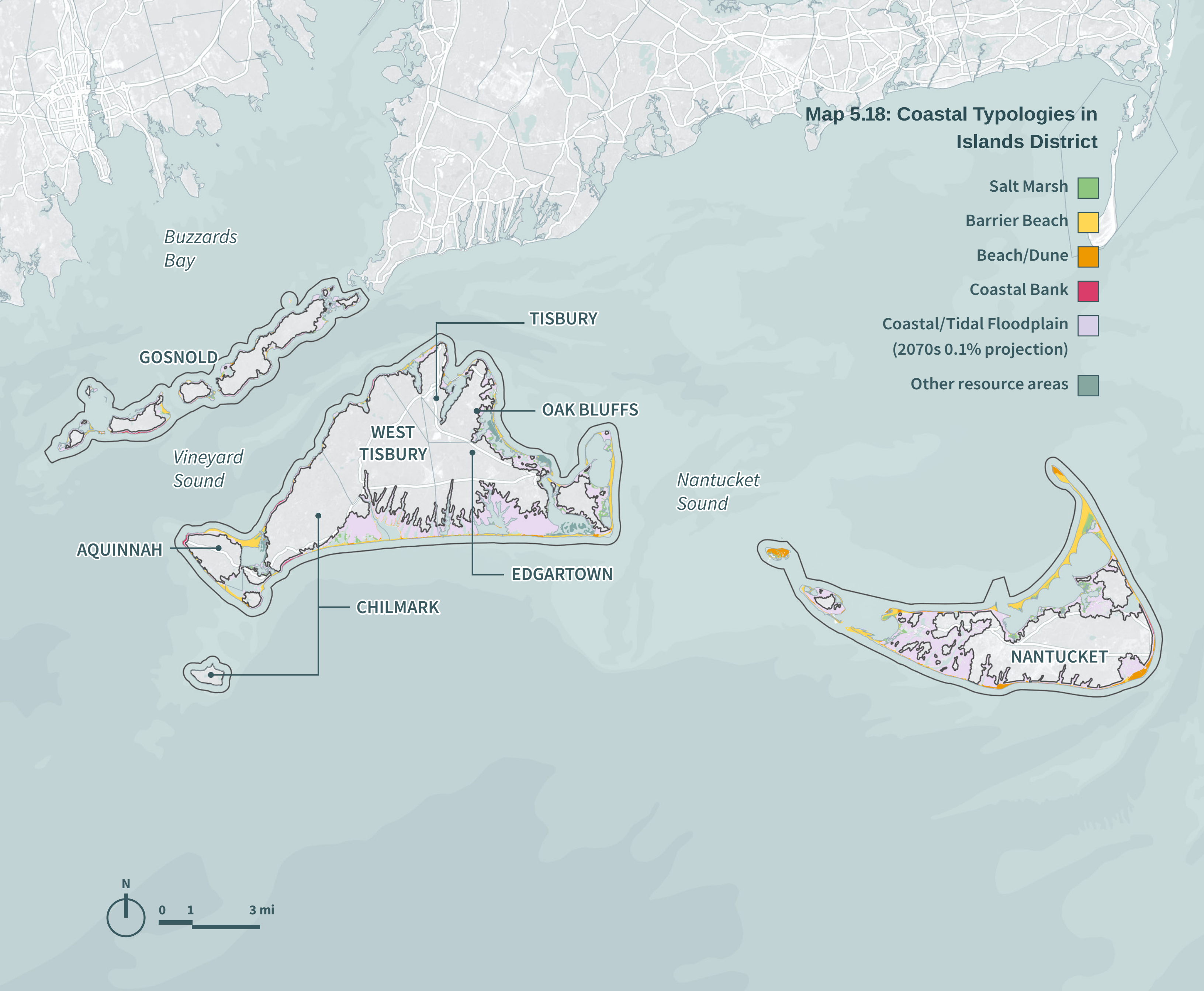
Coastal Environment

Coastal flood exposure is concentrated within and around the low-lying areas adjacent to coastal ponds, bays, and harbors, and the district's ocean-facing beaches, barrier beaches, dunes, and coastal banks. Shorelines are generally unarmored, except in more developed areas. South-facing shores are particularly susceptible to impacts from tropical storms and hurricanes. Due to its sandy geology and exposure to high wave energy, coastal bank and beach erosion are significant coastal hazards impacting this district, with south-facing shores having among the highest erosion rates across Massachusetts. Beach lowering also occurs seaward of coastal armoring. Eroded sediments build up in navigational channels and harbors requiring maintenance dredging. Barrier beaches are generally extensive, undeveloped, and protected, providing potential for natural landward migration over time in response to sea level rise and storms. However, some barrier beaches are developed with buildings or roadways, particularly between Tisbury, Oak Bluffs, and Edgartown, limiting their ability to migrate. Due to the narrower tidal range, models predict that long-term sea-level rise will result in a larger area of salt marsh to be regularly inundated, and the transition to tidal flat or open water in multiple locations. Salt marsh has significant potential to migrate landward in some areas, especially protected conservation land and areas where development is setback from the shoreline. This district contains over a dozen federally designated CBRS units, and lands of the Wampanoag Tribe of Gay Head (Aquinnah).

Population and Development

This district has just over 12,000 people (121 people per square mile) living within affected Census Blocks and about 15,000 housing units. However, population and development density vary significantly between Martha's Vineyard, Nantucket, and Gosnold. Notably, this population estimate is based on year-round residents, not seasonal residents. Given this district's prominent tourism industry, there are likely many more visitors and seasonal residents than is reflected in the population count. This district includes Wampanoag Tribe of Gay Head (Aquinnah) lands in Aquinnah and mapped EJ Block Groups in Aquinnah, Tisbury, Oak Bluffs, and Nantucket.

Communities within this district range from very low-density rural towns (like Aquinnah and Gosnold) to developing suburbs with mixed-use town centers and mixed densities (like Nantucket and Tisbury). The population and development character of the Elizabeth Islands (Gosnold) is relatively unique in this district as it is sparsely populated on all but two islands – Cuttyhunk and Penikese. Shorelines are generally armored and development is minimally setback. Population and housing density is generally low in exposed areas. However, higher density residential or commercial/industrial areas in Tisbury, Oak Bluffs, Edgartown, and Nantucket are exposed. The value of structures at risk in the district is estimated at $9 billion (88% residential, 6% commercial/industrial). Smaller working waterfronts in all the communities, except West Tisbury, are also exposed. Populations in this district face unique challenges as they can become isolated during coastal storms and rely on port infrastructure and boats to access and receive goods from the mainland. Therefore, even areas not within the CRD boundary are likely to be affected indirectly by coastal hazards.



29 sq mi	**3.8K** structures	Exposed to near-term (2030s) 1% AEP flooding
46 sq mi	**9.7K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

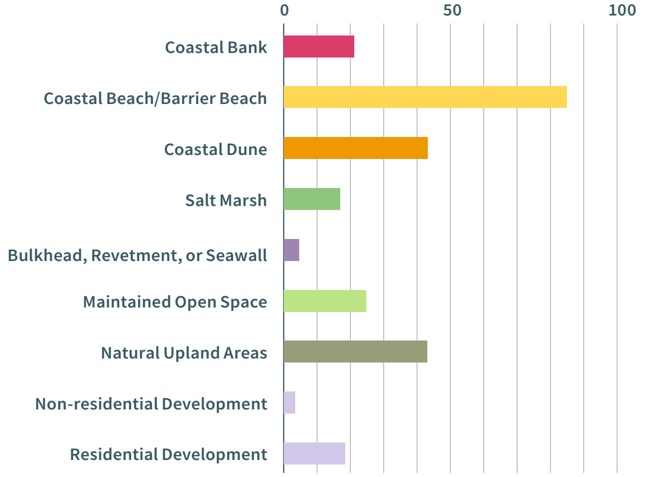
14% of the district is open space

96% permanently protected

2% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

DISTRICT 14

Buzzards Bay

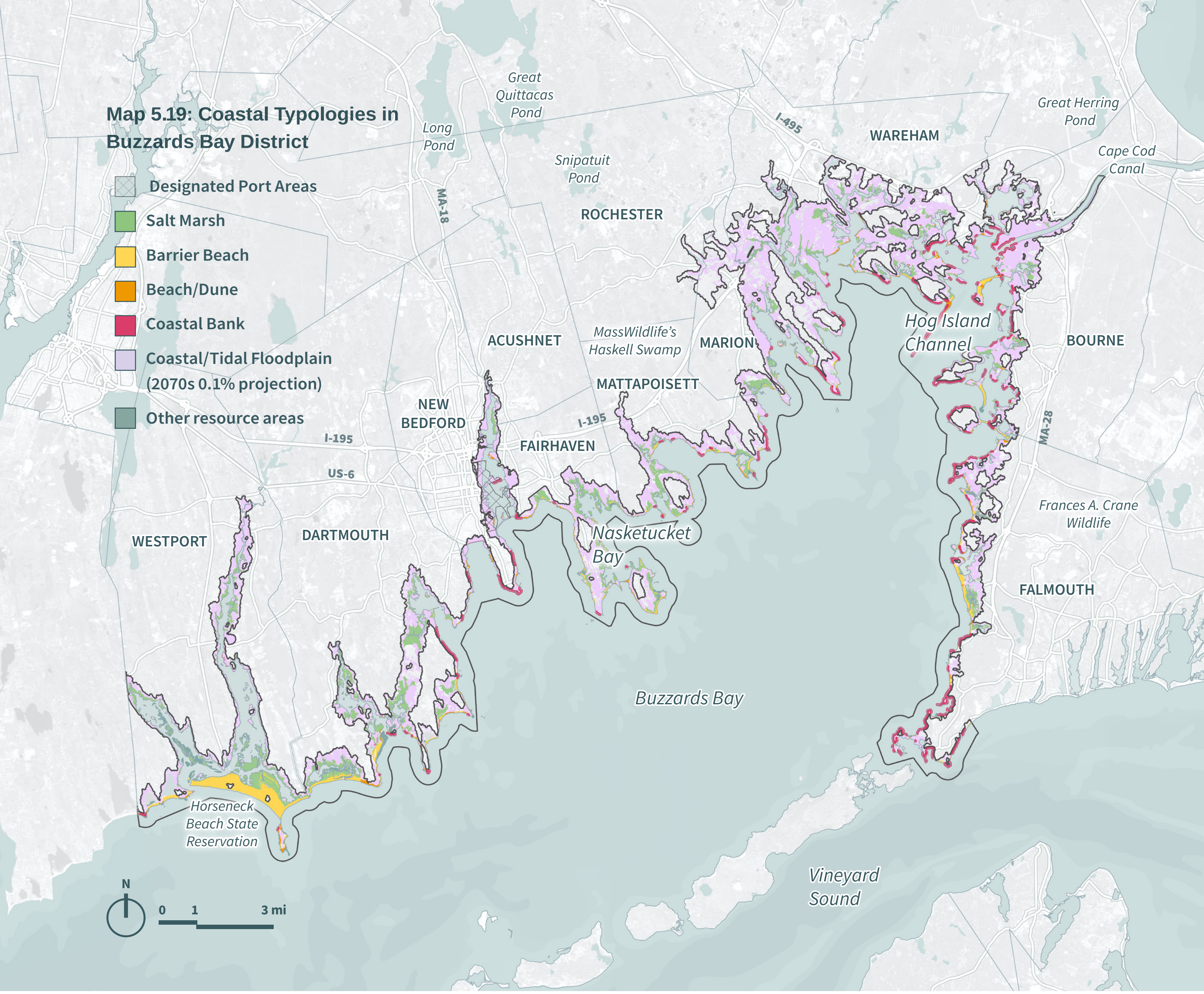
The Buzzards Bay district extends from Woods Hole Village in Falmouth, along the south coast of Bourne, across the Cape Cod Canal to the southern tip of Plymouth, down through Wareham, Marion, Rochester, Mattapoisett, Fairhaven, Acushnet, New Bedford, Dartmouth, and ending in Westport at the Massachusetts state line.

Coastal Environment

Coastal flood exposure is concentrated within and around the low-lying areas adjacent to the district's coastal beaches, barrier beaches, salt marshes, and tidal rivers, and widespread in low-lying areas at the head of Buzzards Bay. Due to its south facing orientation, this district is particularly susceptible to impacts from tropical storms and hurricanes. In these storms, the head of the bay can be exposed to higher levels of storm surge as winds from the south push water into a narrow area with no outlets except the Cape Cod Canal. Tropical storms and hurricanes are historically infrequent in Massachusetts, and the district is less exposed to impacts from nor'easters due to the protective functions of Cape Cod and the Islands. As a result, this district has historically experienced longer periods of time between major coastal flooding and erosion events than other districts, however, the district has recently experienced strong winter storms with a southeasterly wind which have caused significant street flooding and erosion along beaches and dunes.

There is a mix of armored and unarmored shorelines, with armoring more prevalent in densely developed areas like New Bedford and Fall River. Because of the prevalence of heavier glacial materials, sand beaches are found mostly in small pockets; though there are extensive barrier beach systems in Westport where Horseneck Beach State Park is located. The district's beaches tend to be sediment starved and its many, mostly small and undeveloped, barrier beaches have relatively small coastal dunes. These factors, combined with exposure to high wave energy along ocean-facing shores, lead to coastal erosion during less frequent but highly impactful coastal storms and lowering of beach elevations, especially seaward of coastal armoring structures. Narrow beach areas that are dry at high tide today are susceptible to further narrowing due to long-term sea-level rise if the landforms behind the beaches can't shift landward. There are also some barrier beaches that are developed with buildings, roadways, or beach access parking, limiting the ability of these barrier beaches to naturally migrate landward over time in response to sea level rise and storms.

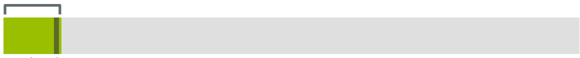
Due to the narrower tidal range to which salt marsh habitats in this district are adapted, models predict that long-term sea-level rise will result in a larger area of salt marsh to be regularly inundated, and the transition to tidal flat or open water will occur in multiple locations. Salt marsh has the potential to migrate landward in some areas, especially protected conservation land, agricultural land, and areas where development is setback from the shoreline. This district contains the state-designated Bourne Back River and Pocasset River ACECs, as well as more than two dozen federally designated CBRS units.



32 sq mi	14K structures	Exposed to near-term (2030s) 1% AEP flooding
46 sq mi	26K structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

15% of the district is open space

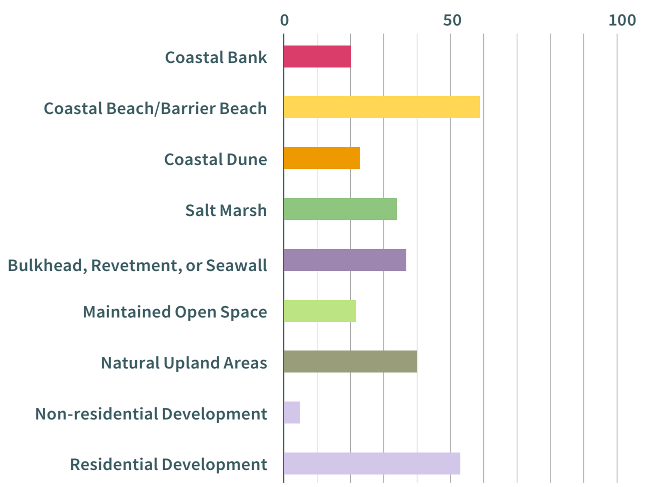


90% permanently protected

4% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

Shoreline Characterization



Note: Data represents the immediate, exposed ocean-facing shoreline. Shoreline types may be overlapping and therefore do not add to 100%.

Population and Development

This district has nearly 68,000 people (596 people per square mile) living within affected Census Blocks and just under 40,000 housing units. It is the largest mainland district by land area and the fourth most populous. This district includes mapped EJ Block Groups in Bourne, Wareham, Marion, Acushnet, Fairhaven, New Bedford, and Dartmouth. Communities within the district are predominately developing suburbs with mixed-use town centers and low-density outlying areas (like Westport and Fairhaven) and maturing, moderate-density suburbs (like Falmouth) with the exception of New Bedford, which is a major regional urban center with higher density land uses.

While population and housing density is generally low in exposed areas, there are several high density residential or commercial/industrial areas that face exposure, including the New Bedford-Fairhaven DPA and other smaller working waterfronts. However, higher density residential or commercial/industrial areas in each community in the district are exposed, including the New Bedford-Fairhaven DPA and other smaller working waterfronts. The Port of New Bedford is the highest-grossing commercial fishing port in the U.S.[69]

Flooding by land area is minimal in Acushnet and Rochester as compared to other communities in the district. In general, shorelines in these areas are armored and development is minimally setback from the shoreline. The value of structures at risk in the district is estimated at $5 billion (79% residential, 8% commercial/industrial). Land use in this district is somewhat unique in that it includes large agricultural areas, including farms and cranberry bogs. These agricultural areas may provide opportunities for salt marsh migration when decommissioned or retired.

Aerial view of IRIS sailboat rafted to Armstrong at WHOI dock with Atlantis, Woods Hole, 2021 (Credit: WHOI)

DISTRICT 15

Taunton Watershed

The Taunton Watershed district extends from the Massachusetts state line in Fall River, Swansea, and Seekonk, upstream through communities on the Taunton, Palmer, and Runnis Rivers, including Somerset, Freetown, Dighton, Berkley, Taunton, Raynham, and Rehoboth.

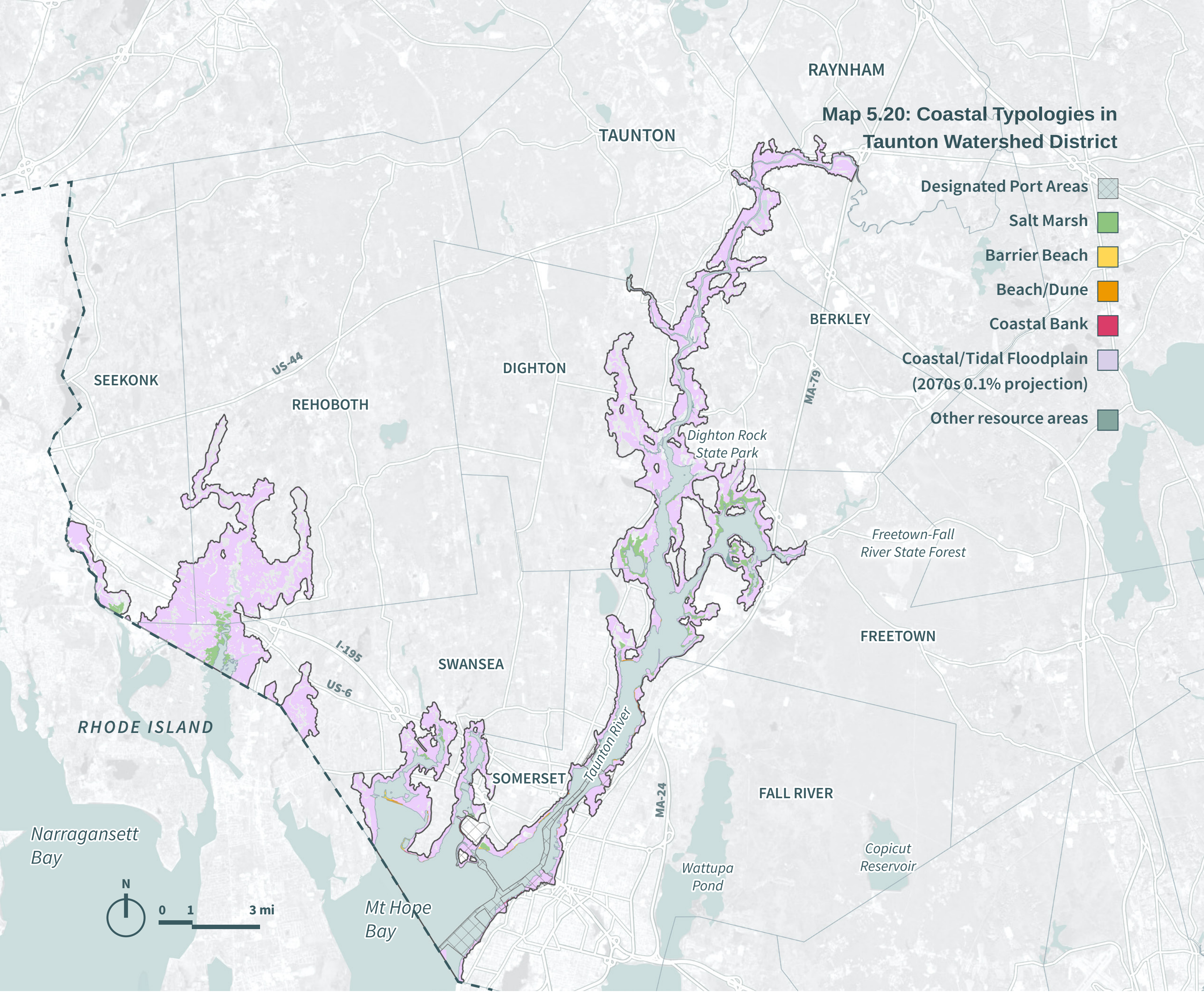
Coastal Environment

Coastal flood exposure is concentrated within and around the banks and wetlands of the Taunton River and other rivers. These areas face increasing exposure to coastal flooding and erosion of wetlands including low-lying areas adjacent to the riverbanks. This district is expected to be impacted by increased tidal influence from sea level rise and communities are likely to face compound risks of coastal flooding and stormwater flooding. While stormwater flooding was not incorporated in the current analysis, it should be a consideration for communities within the district and could make flood exposure more pronounced.

Due to its south facing orientation, this district is particularly susceptible to impacts from tropical storms and hurricanes. Due to the narrower tidal range to which salt marsh habitats in this district are adapted, models predict that long-term sea level rise will result in a larger area of salt marsh inundation, and the transition to tidal flat or open water in multiple locations. Salt marsh has the potential to migrate landward in some areas, especially protected conservation land, agricultural land, and areas where development is setback from the shoreline. This district contains the state designated Three Mile River Watershed ACEC, lands of the Mashpee Wampanoag Tribe, as well as one federally designated CBRS unit.

Population and Development

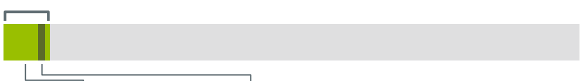
This district has nearly 38,000 people (808 people per square mile) living within affected Census Blocks and just under 16,000 housing units. This district includes mapped EJ Block Groups in Fall River and Taunton. Communities within this district are predominately developing suburbs ranging from very low-density suburbs (like Rehoboth and Dighton) to mixed density suburbs with low-density outlying areas (like Swansea). Taunton, Somerset, and Fall River, which are regional urban centers with higher density land uses, are the exception in this district. Population and housing density is generally low in exposed areas. However, higher density residential or commercial/industrial areas in each community, except Seekonk, Rehoboth, and Raynham, are exposed. This includes the Mount Hope Bay DPA in Somerset and Fall River and other smaller working waterfronts in Somerset, Swansea, and Dighton. The district has a significant amount of both residential (21%) and commercial/industrial (11%) land uses as compared to other districts. In general, shorelines in these areas are armored and development is minimally setback from the shoreline. The value of structures at risk in the district is estimated at $1 billion (72% residential, 21% commercial/industrial).



9 sq mi	**2.6K** structures	Exposed to near-term (2030s) 1% AEP flooding
18 sq mi	**6.1K** structures	Exposed to long-term (2070s) 0.1% AEP flooding

Note: AEP = Annual Excedence Probability

12% **of the district is open space**



73% permanently protected

13% protected in limited way

Note: Open space data includes conservation and outdoor recreational facilities owned by federal, state, county, municipal, and nonprofit enterprises.

What characterizes the shoreline of the Taunton Watershed district?
The shoreline has a mix of high- and medium-density residential housing and commercial and industrial land with swaths of forest, tidal and nontidal swamps, and adjacent ponds at the upper reaches. The river corridor broadens south of Taunton to include even larger swaths of forest, tidal freshwater marsh, and brackish marsh. Shoreline development densifies and armoring increases as the river runs south into Mount Hope Bay.

Investing in Coastal Resilience

Over the past two decades, Massachusetts has invested $194 million in coastal resilience efforts across the 98 communities encompassed by CRDs.

Ongoing State Investment in Coastal Resilience

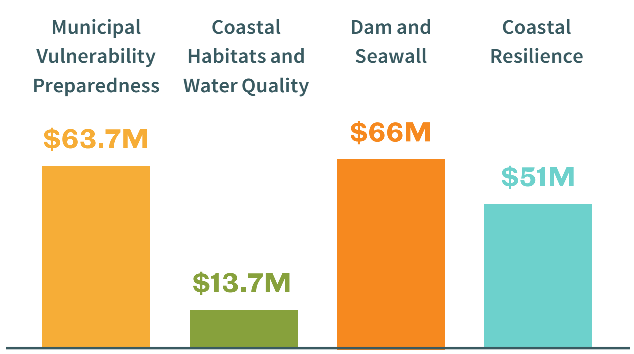
Massachusetts supports coastal communities in their resilience efforts through numerous grant programs including Executive Office of Energy and Environmental Affairs (EEA) Dam and Seawall Repair and Removal Program and Municipal Vulnerability Preparedness (MVP) Program, and CZM's Coastal Resilience Grant Program and Coastal Habitat and Water Quality Program (formerly the Coastal Pollutant Remediation Program). The state has invested a total of $194 million in coastal resilience through these programs across the 98 communities encompassed by CRDs since 2000.

- **Dam and Seawall Repair and Removal Program:** Since 2013, this grant program has offered financial resources to municipalities and nonprofits for design and permitting and construction to support the repair and removal of dams and coastal infrastructure. The program focuses on enhancing the safety and functionality of essential infrastructure. Although this is a statewide program, the numbers included here reflect only investments made within delineated CRDs.[70]

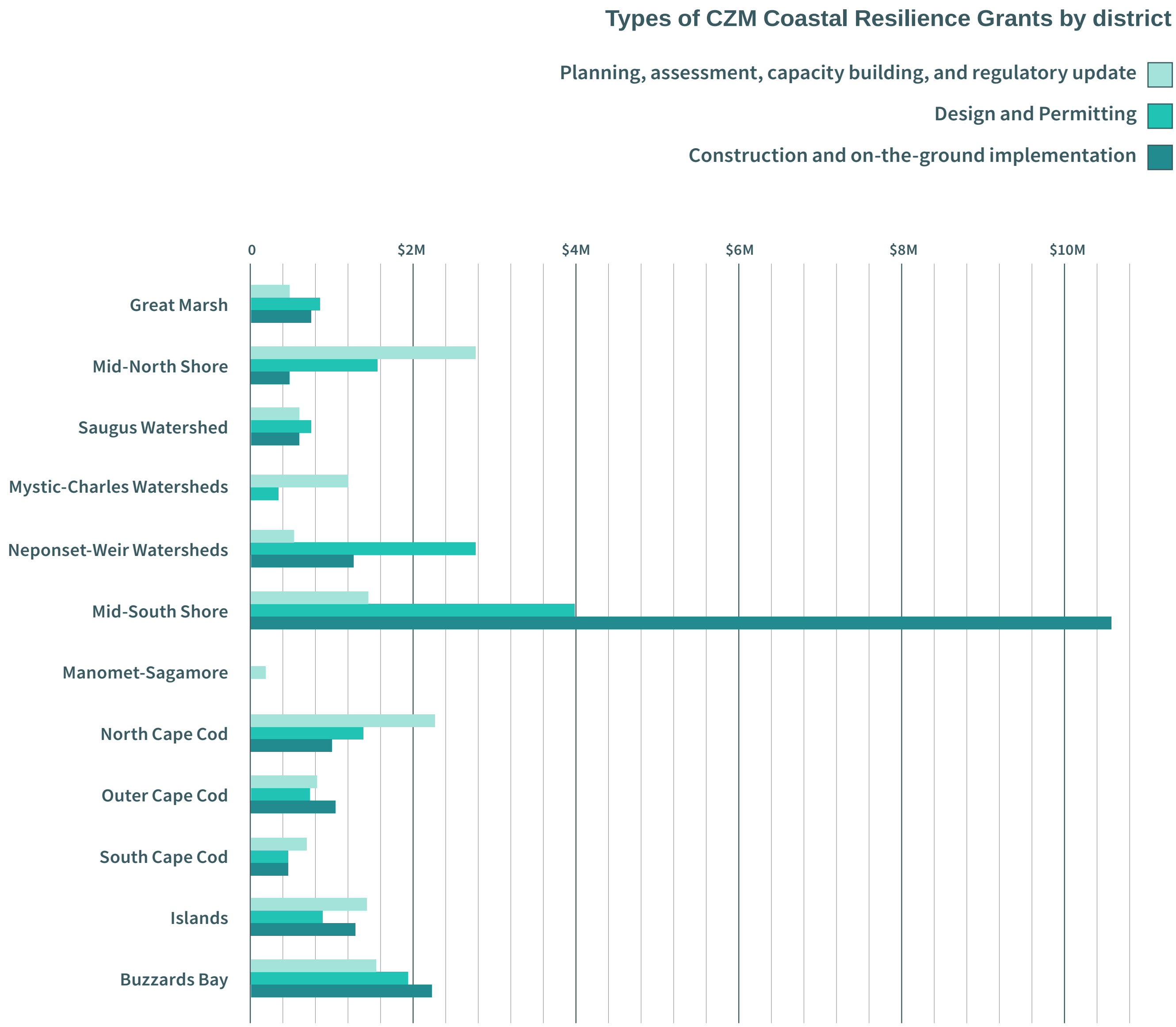
- **Municipal Vulnerability Preparedness Program:** Launched in 2017, this grant program offers funding to municipalities to assess their vulnerability and prepare for climate change impacts and build resilience. Although this is a statewide program and funds projects beyond coastal resilience, the number included here reflects only investments made in coastal resilience projects within delineated CRDs.[71]

- **Coastal Resilience Grant Program:** Launched in 2014, this grant program provides funding and technical assistance to municipalities, nonprofits, and tribes to advance innovative local and regional efforts to address coastal flooding, erosion, and sea level rise impacts through communication and public outreach initiatives, vulnerability assessments, planning activities, engineering projects, and natural storm damage protection.[72]

- **Coastal Habitat and Water Quality Program (formerly Coastal Pollutant Remediation Program):** Since 1996, this program has provided financial resources for projects that assess and treat stormwater impacts and more recently has supported comprehensive habitat restoration planning. The program currently funds municipalities and their partners, including nonprofits and tribes, to undertake these projects. The summary numbers below represent funded projects from 2000 to 2025.[73]



State's coastal resilience spending



CZM Coastal Resilience Grants by Coastal Resilience District (CRD)

Among the programs funding coastal resilience is CZM's Coastal Resilience Grant Program. This program uniquely targets and invests in coastal resilience projects across a range of eligible grantees including local governments, nonprofit organizations, and tribes. Since its inception in 2014, CZM's Coastal Resilience Grant Program has awarded over $47 million across 59 communities to support coastal resilience efforts, including 24 regional projects. This includes over $14 million in planning, assessment, capacity building, and regulatory updates; over $15 million in design and permitting, and over $21 million in on-the-ground construction and implementation. Eligible coastal resilience projects funded under this grant program include detailed vulnerability and risk assessments; public outreach to increase understanding of coastal storm and climate impacts; proactive planning including developing and amending local ordinances and standards; retrofitting and relocating critical public infrastructure and facilities; and shoreline restoration projects.

Future Opportunities for Investment

Massachusetts has made significant and critical investments in resilience coastwide. However, the ongoing cost of adapting to coastal hazards is expected to far outstrip existing resources and spending. New sources of revenue from a variety of stakeholders including local, state and federal governments and private property owners are needed to meet the full scale of the challenge.

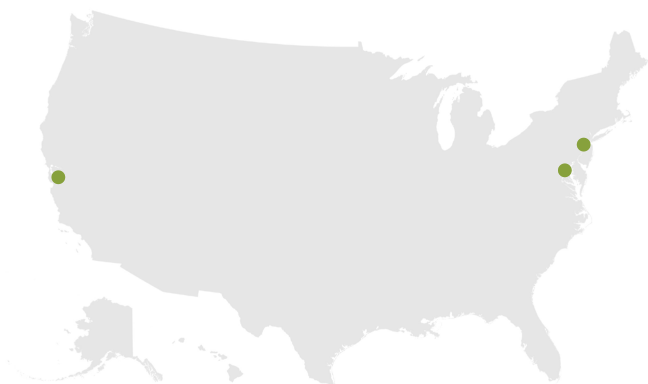
Several parallel ongoing state initiatives aim to identify new sources of funding and financing and will be integrated into future phases of ResilientCoasts. For example, through the ResilientMass Funding and Finance Initiatives, EEA, Office of Climate Innovation and Resilience (OCIR), Executive Office for Administration and Finance (A&F), and the Massachusetts Department of Transportation (DOT), are studying resilience finance mechanisms to help meet the scale of investment needed to implement statewide and coastwide resilience projects.[74] Chapter 8 also includes state-led strategies that could help enable or better facilitate district-scale funding for coastal resilience.

The ResilientCoasts Initiative will work with communities across the 15 CRDs to prioritize and build a pipeline for district-scale interventions and other regionally significant projects. This will include identifying and addressing barriers to district-scale collaboration, governance, and financing and piloting solutions at the CRD level to accelerate coastal resilience at scale. CRDs typically consist of both large and small communities, each with varying capacities. The CRD framework may help with efficiencies in prioritizing, financing, and implementing large-scale coastal resilience projects and help distribute the administrative, financial, and technical burdens of these efforts over a greater number and type of communities. Future phases of ResilientCoasts will also consider whether CRDs can or should be used for the purposes of establishing district-scale funding and financing mechanisms and governance structures for planning and/or managing district-scale projects.

Additionally, there are currently two US Army Corps of Engineers (USACE) projects taking place on the Massachusetts coast to assess coastal risks, identify opportunities for resilience projects, and position the state for federal funding. The first project, a federal partnership between the City of Boston and the USACE, will build on the city's local climate resilience initiatives by identifying and assessing different management approaches for flood risk and recommending solutions that would be eligible for federal funding.[75] The second project, a federal partnership between EEA, CZM, and the USACE, will conduct a regional assessment of coastal flood risk to populations, ecosystems, property, and infrastructure in the Boston Harbor region (extending from Winthrop to Hull), and identify potential projects to manage risk.[76]

These efforts collectively aim to strengthen the state's resilience to climate change, ensuring the protection of its communities, infrastructure, and ecosystems today and into the future.

Other states have explored similar concepts to facilitate greater regional collaboration on resilience and could serve as a model for Massachusetts:



California

In 2023, California passed legislation addressing the need for coordinated and standardized adaptation to sea level rise by requiring local governments along the San Francisco Bay shoreline to develop Subregional Shoreline Adaptation Plans. These plans are required to meet guidelines established by the San Francisco Bay Conservation and Development Commission (BCDC) ensuring effective and collaborative regional responses. Projects and strategies contained within approved plans will be prioritized for State funding. While subregional plans are not required to be developed at the regional scale and can be developed for a single city or town, BCDC strongly encourages multi-jurisdictional teams and coordination with stakeholders like public and private property owners, noting that multi-jurisdictional plans may wish to establish formal agreements like Memorandums of Understanding or Joint Powers Authority to codify decision-making protocols and generate buy-in.[77]

New Jersey

The Resilient NJ program provides funding for four multi-municipal regions to develop and implement Regional Resilience and Adaptation Action Plans. Projects bring together teams of municipalities, counties, and community-based organizations supported by a grant from the U.S. Department of Housing and Urban Development. Resilient Northeastern NJ – one of the four regions – brings together the municipalities of Jersey City, Newark, Bayonne, and Hoboken to identify and implement long-term climate resilience measures across the region, including a proposal to pilot a Regional Infrastructure Coordination Council to oversee the implementation of regional scale projects. Similar to the ResilientCoasts Initiative, the Resilient Northeastern NJ project divides its region into project areas based in part on hydrologic areas or sewersheds, land use, and infrastructure.[78]

Maryland

In 2020 the state of Maryland passed a bill authorizing local governments to establish “resilience authorities” to facilitate funding for, and management of, large-scale infrastructure projects to address climate impacts. The authorities can be created by a single local government, or more than one county, to allow for infrastructure investments to facilitate climate adaptation on a regional scale. The Resilience Authority of Annapolis and Anne Arundel County is the first multi-jurisdictional authority established under the legislation to finance and support climate resilience infrastructure. It is governed by a board of directors and led by an executive director, working in partnership with the City and County to identify, secure, and allocate funding to projects.[79]

Chapter 6

Near-Term Adaptation Areas

Purpose and Methodology

Near-Term Adaptation Areas have high concentrations of people and housing, built infrastructure, and/or economic resources exposed to coastal flooding by the 2030s.

The purpose of mapping Near-Term Adaptation Areas is to inform coastwide and district-level priorities for coastal resilience. The results of this analysis are also useful for communities and other stakeholders to understand how their vulnerability compares to others in their Coastal Resilience District as well as coastwide.

Across the Massachusetts coast, near-term vulnerability to coastal flooding from sea level rise and storm surge is expected to be extensive and severe.[80] Near-term, the 1% annual chance floodplain will grow to include tens of thousands of homes and businesses, municipal, healthcare, and utility facilities, impacting hundreds of thousands of residents and workers. The 1% annual chance floodplain will grow to encompass nearly 900 total miles of roadways – which constitutes about 3.6% of the 24,000 total road miles in Massachusetts coastal counties. Of these, about 135 miles are in high-tide flood zones as verified by the National Oceanic and Atmospheric Administration (NOAA).[81] High tide flooding of roadways, which can occur on sunny days without any storms, will result in over 4 million vehicle delay hours annually. These and other direct impacts threaten public health and safety and may send ripple effects through society and the economy at large.

The economic case for investing resources in mitigating future flood risks is strong. For every dollar spent, it is estimated that the public saves $13 dollars in economic, flood damage, and recovery costs.[82] Investing in coastal resilience not only prevents catastrophic losses of life and property, but also strengthens households, businesses, and public finances, and enhances the quality of life in our communities. However, available public and private resources to help mitigate these risks are and will likely continue to be limited. It is therefore in the public interest to prioritize and target resources to where they can have the greatest benefit for the most people, balancing for equity and fairness.

While ResilientCoasts does not propose a specific formula for future state funding or technical assistance, it applies the best available coastwide data to help all stakeholders recognize the spectrum of vulnerabilities that exist across our coast and identify areas that have the highest concentrations of vulnerability to sea level rise and storm surge in the near-term. Many of the data used in this analysis was also used in the 2022 Massachusetts Climate Change Assessment and the 2023 ResilientMass Plan. The Near-Term Adaptation Areas identified in this chapter will inform, not dictate, prioritization of limited resources to implement suitable coastal resilience measures where they are most urgently needed. This focus on near-term implementation will be in concert with, and not at the expense of, recommended long-term coastwide planning and policies described elsewhere in this report.

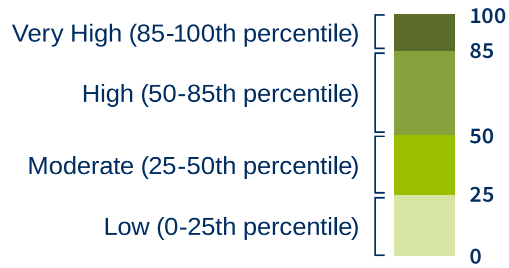
Near-Term Adaptation Areas do not currently account for the vulnerability of natural areas like beaches, banks, and marshes because of data limitations. Existing data on the vulnerability of beach and salt marsh systems are discussed at the end of this chapter but were not mapped according to the Near-Term Adaptation Area methodology. A future phase of ResilientCoasts will address natural resource vulnerability and prioritization in more detail and address existing gaps in data and information.

Finally, this analysis serves as a starting point but is not exhaustive. Numerous data constraints limited consideration of the full range of population, economic, and infrastructure assets – both built and social – that should be evaluated. Only datasets that were available consistently coastwide and at an appropriate scale were used in the analysis. Therefore, these results should not be used in place of local vulnerability assessments and plans but rather to provide a broader, coastwide perspective to those efforts. Impacts on vulnerable and priority populations, and the role of social infrastructure – a subset of infrastructure that includes organizations, places, and spaces that enable communities to create social connections – should also be evaluated locally in more detail as well as in future phases of ResilientCoasts.

Methodology Overview

Near-Term Adaptation Areas are mapped for three sectors: People and Housing, Built Infrastructure, and Economy. For each sector, four to six indicators were developed using available coastwide datasets. Exposure and risk were assessed for each indicator using geospatial analysis and other methods. The analysis focused primarily on the 2030 1% annual chance flood extent within 893 U.S. Census Block Groups (CBGs) on the coast that have some area in this flood extent, within the limits of available data.[83] Exposure and estimated damage results were summed for each indicator for the flood extent areas within each CBG. The CBGs were then ranked for each indicator. Composite scores were then calculated for each sector for each CBG, using equal indicator weighting.

Near-Term Adaptation Areas were identified for each sector by mapping composite vulnerability scores across all CBGs in the 2030 1% annual chance flood extent. These areas were then categorized into Low, Moderate, High, and Very High Concentrations of vulnerability based on the ranking of each CBG coastwide.



In addition, a cross-sector analysis was performed to identify CBGs that were classified as Very High Concentration in 1, 2, or 3 sectors. These CBGs represent the Near-Term Adaptation Areas with the highest concentration of vulnerability across sectors coastwide. A summary of the methods and results for each sector and the cross-sector analysis are provided in the sections that follow.

Maps of Near-Term Adaptation Areas are shown using the full CBG boundary for visibility. However, in many cases, only a portion of the CBG is within the 2030 1% annual chance flood extent. More detailed maps in **Appendix III: Near-Term Adaptation Areas by District** show the results of the analysis on a Coastal Resilience District scale and depict only the area of the CBG that is within the 2030 1% annual chance flood extent. Additional detail and links to data sources used in the analysis can be found in **Appendix II: Near-Term Adaptation Areas Technical Documentation**.

People & Housing

People need safe and secure places to live. When flooding damages homes, it affects people's finances, health, and quality of life. If neighboring homes are also damaged, these impacts can be multiplied and harder to cope with and recover from. If multiple homes in the same neighborhood are affected, the flood was likely large and widespread, which can put significant pressure on public services and infrastructure such as roads, utilities, and emergency response. This can make recovery even more difficult, as resources available to help everyone may be stretched thin. The broader the impact, the more challenging it becomes for both individuals and the community to recover.

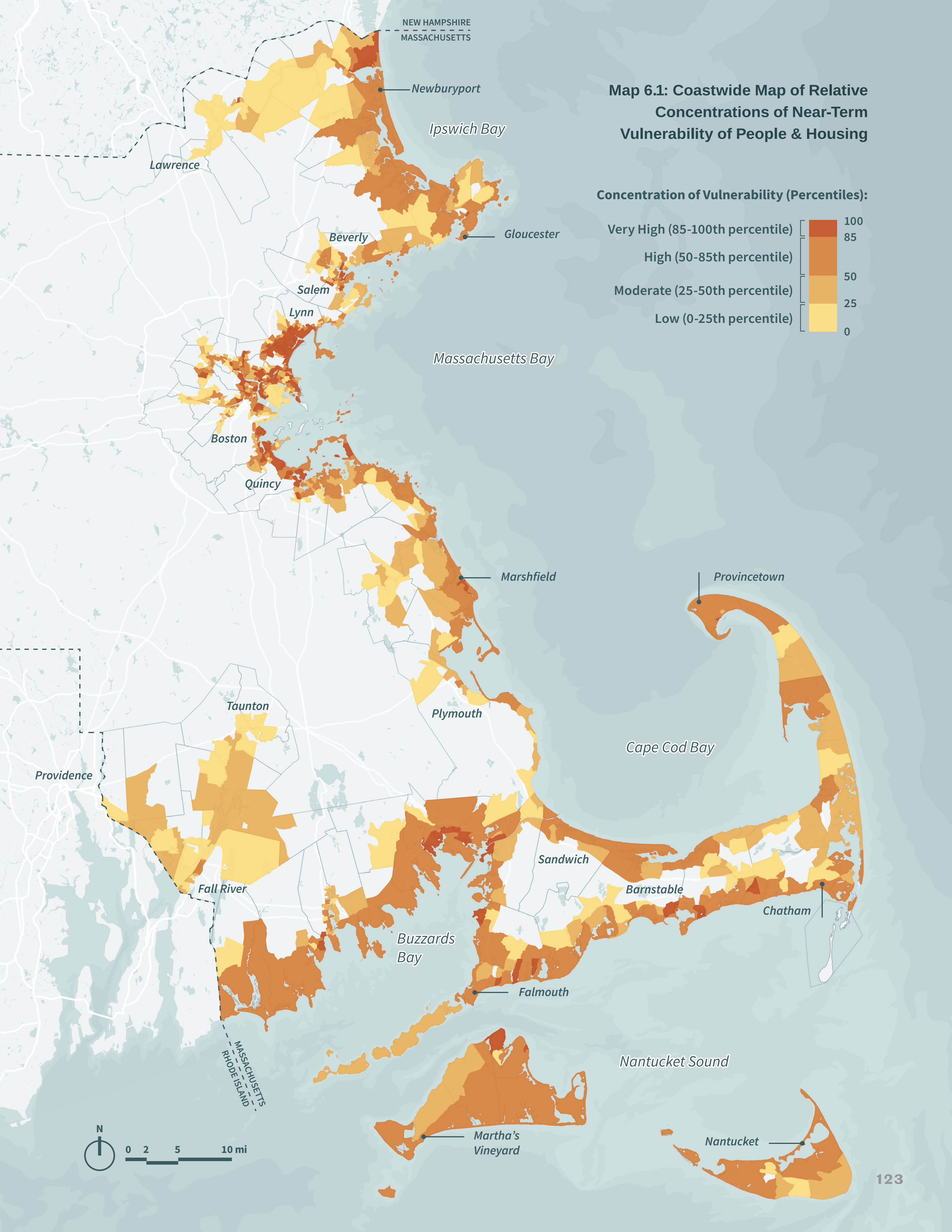
Further, if property values go down as a result of flood impacts or risks, municipal property tax revenue may be impacted. In the near-term, some coastal residents and neighborhoods will face increased risks of property damage, displacement, injury, or even loss of life from coastal flooding. Due to underlying inequities, these risks are heightened for certain vulnerable and priority populations.

The 2022 Massachusetts Climate Change Assessment characterized the consequences of damage to residential buildings from increased coastal flooding as extreme. The total value of residential buildings in the 2008 1% annual chance flood extent was about $40 billion, and these properties are estimated to experience on average over $160 million in damages per year under the sea level rise and storm conditions of that period.[84] By the 2030s, annual damages are projected to increase by more than 75%. In addition, the assessment identified reduction in the availability of affordably priced housing from direct damage (e.g., flooding) and the scarcity caused by increased demand as one of the most urgent climate change impacts facing Massachusetts.

To identify Near-Term Adaptation Areas for the **People and Housing sector,** four indicators were developed and assessed for all CBGs in the 2030 1% annual chance flood extent.

- **Residential population exposed** was used as an indicator of the health and safety impacts to coastal residents.
- **Projected residential structure damage** was used as an indicator of the direct financial impacts on residents.[85]
- **Environmental Justice (EJ) population exposed** in EJ CBGs was used as an indicator of the disproportionate impacts of coastal flooding on these populations.
- **Deed-restricted affordable housing units exposed** was used as an indicator of limited secure and stable housing options for lower-income residents.

Using CBG rankings for these indicators, composite scores were developed, and areas were ranked based on concentration of vulnerability, including CBGs with a Very High Concentration of people and housing vulnerability. The maps on the following page show the composite score rankings coastwide according to these concentrations.



Map 6.1: Coastwide Map of Relative Concentrations of Near-Term Vulnerability of People & Housing
Concentration of Vulnerability (Percentiles):
Very High (85-100th percentile)
High (50-85th percentile)
Moderate (25-50th percentile)
Low (0-25th percentile)
100
85
50
25
0
NEW HAMPSHIRE
MASSACHUSETTS
Newburyport
Ipswich Bay
Lawrence
Gloucester
Beverly
Salem
Lynn
Massachusetts Bay
Boston
Quincy
Marshfield
Provincetown
Plymouth
Taunton
Cape Cod Bay
Providence
Sandwich
Barnstable
Chatham
Fall River
Buzzards Bay
Falmouth
Nantucket Sound
MASSACHUSETTS
RHODE ISLAND
Martha's Vineyard
Nantucket
N
0 2 5 10 mi

Built Infrastructure

The state's extensive coastline encompasses a broad range of important public infrastructure, including local government and health facilities, ports, transit systems, roads, and utilities that are essential for providing energy, clean water, public health and safety, public services, and transportation. However, these infrastructure systems are increasingly vulnerable to the impacts of coastal flooding, which are exacerbated by rising sea levels and more frequent storm surges. Impacts to public infrastructure from coastal flooding can cascade to other sectors.

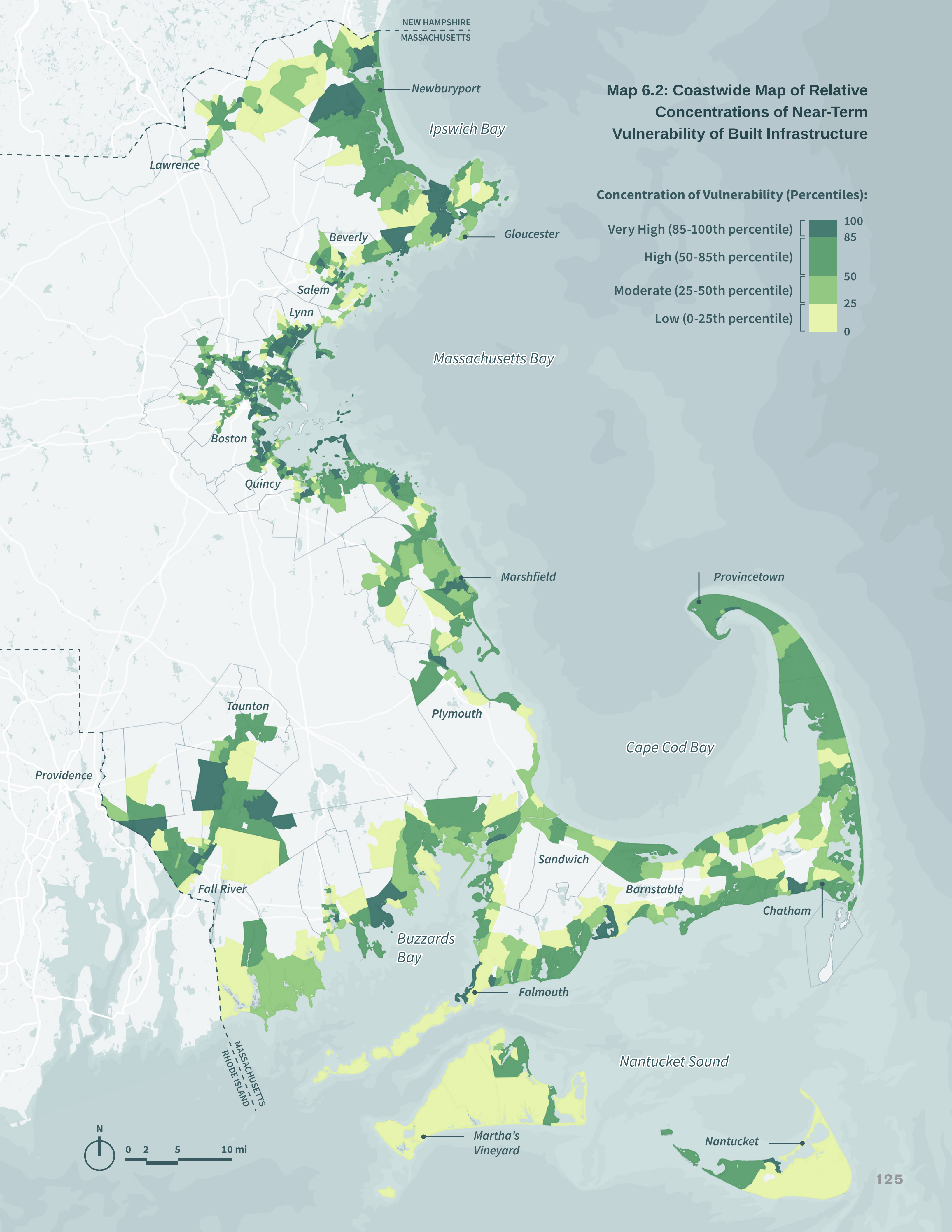
The 2022 Massachusetts Climate Change Assessment identified major and urgent coastal flooding impacts in the infrastructure sector due to the vulnerability of roadways, utilities, passenger rails, and state and municipal buildings. For example, a total of 4 million vehicle delay hours per year are expected to be caused by daily high tide flooding by the 2030s. Impacts to rails and loss of rail/transit service were among the most urgent impacts identified, in part due to the vulnerability of infrastructure to sea level rise and coastal flooding and also because of the disproportionate impact to vulnerable and priority populations who rely more heavily on public transit services.[86]

To identify Near-Term Adaptation Areas for the **Built Infrastructure sector**, five indicators were developed and assessed for all CBGs in the 2030 1% annual chance flood extent.

- Two indicators, costs associated with **high-tide flood vehicle delays** and, for coastal storm flooding, 1% annual chance **flood vulnerability** based on the total average daily traffic volume for exposed roadway segments, were used as indicators of roadway vulnerability.
- Two indicators, the length of **passenger rail track exposure** and critical Massachusetts Bay Transportation Authority (MBTA) **maintenance facilities** within the 1% annual chance flood extent, were used as an indicator of public transit infrastructure vulnerability.
- **Utility exposure**, which estimates the number of wastewater treatment plants, fuel terminals, major electrical substations (including those serving public transportation infrastructure), and large power generation and hazardous waste generating facilities in the 1% annual chance flood extent, was used as an indicator of impacts on critical utility infrastructure.
- **Public services and health infrastructure**, which estimates the number of public services and facilities including police, fire, schools, libraries, city and town halls, and childcare, as well as hospitals, health centers, and long-term care residences in the 1% annual chance flood extent, were used as an indicator of impacts on important social, safety, and health infrastructure.

Using CBG rankings for these indicators, composite scores were developed, and areas were ranked based on concentration of vulnerability, including CBGs with a Very High Concentration of built infrastructure vulnerability. The maps on the following page show the composite score rankings coastwide according to these concentrations.

Map 6.2: Coastwide Map of Relative Concentrations of Near-Term Vulnerability of Built Infrastructure



Economy

The Massachusetts coastal economy is critical to the state's vitality, drawing in major employers and supporting local businesses and workers across a broad range of industries. Coastal flooding affects the economy directly by damaging buildings and inventory and indirectly by causing business downtime, restricting access to customers and suppliers, and disrupting people's ability to get to work. In the near-term, downtowns, main streets, and waterfront businesses will face increased risks from these impacts.

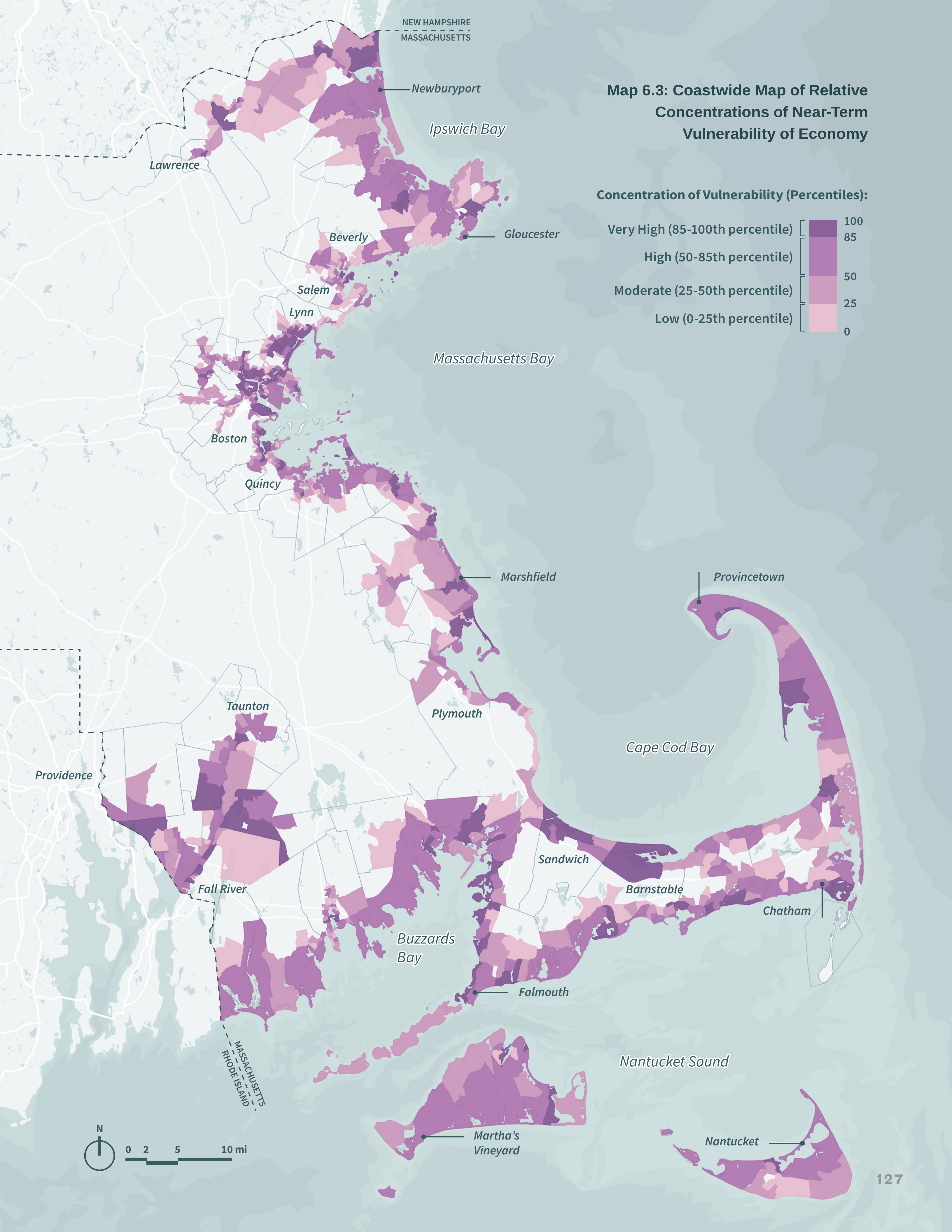
The 2022 Massachusetts Climate Change Assessment estimated the total value of industrial and commercial buildings in the 2008 1% annual chance flood extent was about $14.5 billion, and these properties are estimated to experience on average over $22 million in damages per year.[87] By the 2030s, annual damages to these structures are projected to increase by more than 150%. In addition, indirect losses from business downtimes, while more difficult to estimate, could be six to seven times larger than direct damages.[88]

The Building Resilience in Massachusetts Designated Port Areas pilot study demonstrated significant current and future flood risks to the Gloucester Inner Harbor, with 50% and 91% of all water-dependent industrial use buildings exposed to the historic monthly high tide[89] and the present (2008 baseline) MC-FRM 1% annual chance flood, respectively.[90] Relative to 2008 conditions, the number of buildings exposed to monthly high tides is expected to increase 50% by the 2030s.

To identify Near-Term Adaptation Areas for the **Economy sector**, five indicators were developed and assessed for all CBGs in the 2030 1% annual chance flood extent.

- **Projected commercial and industrial structure damage** was used as an indicator of the direct financial impacts of coastal flooding on businesses, understanding that indirect impacts such as business interruption are likely multiple times higher than damage impacts.
- **Jobs exposure** used as an indicator of the health, safety, and economic security impacts to workers, using U.S. Census data on employment within CBGs and the location of structures supporting commercial and industrial employment within the 2030 1% annual chance flood extent.
- **Designated Port Area and working waterfront exposure** was used as an indicator of impacts to water-dependent sectors in both large ports and small harbors, which range from commercial fishing, recreational boating, and shipping to tourism and research.
- **Freight line exposure**, which estimates the total length of active freight rail track within the 2030 1% annual chance flood extent, was used as an indicator of supply chain and business interruption vulnerability.
- **High-tide flood vehicle delays**, also featured in the Built Infrastructure sector, was used as an indicator of impacts to roadways, commuter wages and business productivity, customer volume, supply chains, and potentially coastal tourism.

Using CBG rankings for these indicators, composite scores were developed, and areas were ranked based on concentration of vulnerability, including CBGs with a Very High Concentration of economic vulnerability. The maps on the following page show the composite score rankings coastwide according to these concentrations.



Map 6.3: Coastwide Map of Relative Concentrations of Near-Term Vulnerability of Economy
Concentration of Vulnerability (Percentiles):
Very High (85-100th percentile)
High (50-85th percentile)
Moderate (25-50th percentile)
Low (0-25th percentile)
100
85
50
25
0
NEW HAMPSHIRE
MASSACHUSETTS
Newburyport
Ipswich Bay
Lawrence
Beverly
Gloucester
Salem
Lynn
Massachusetts Bay
Boston
Quincy
Marshfield
Provincetown
Taunton
Plymouth
Cape Cod Bay
Providence
Sandwich
Barnstable
Chatham
Fall River
Buzzards Bay
Falmouth
Nantucket Sound
MASSACHUSETTS
RHODE ISLAND
Martha's Vineyard
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Cross-Sector Vulnerability

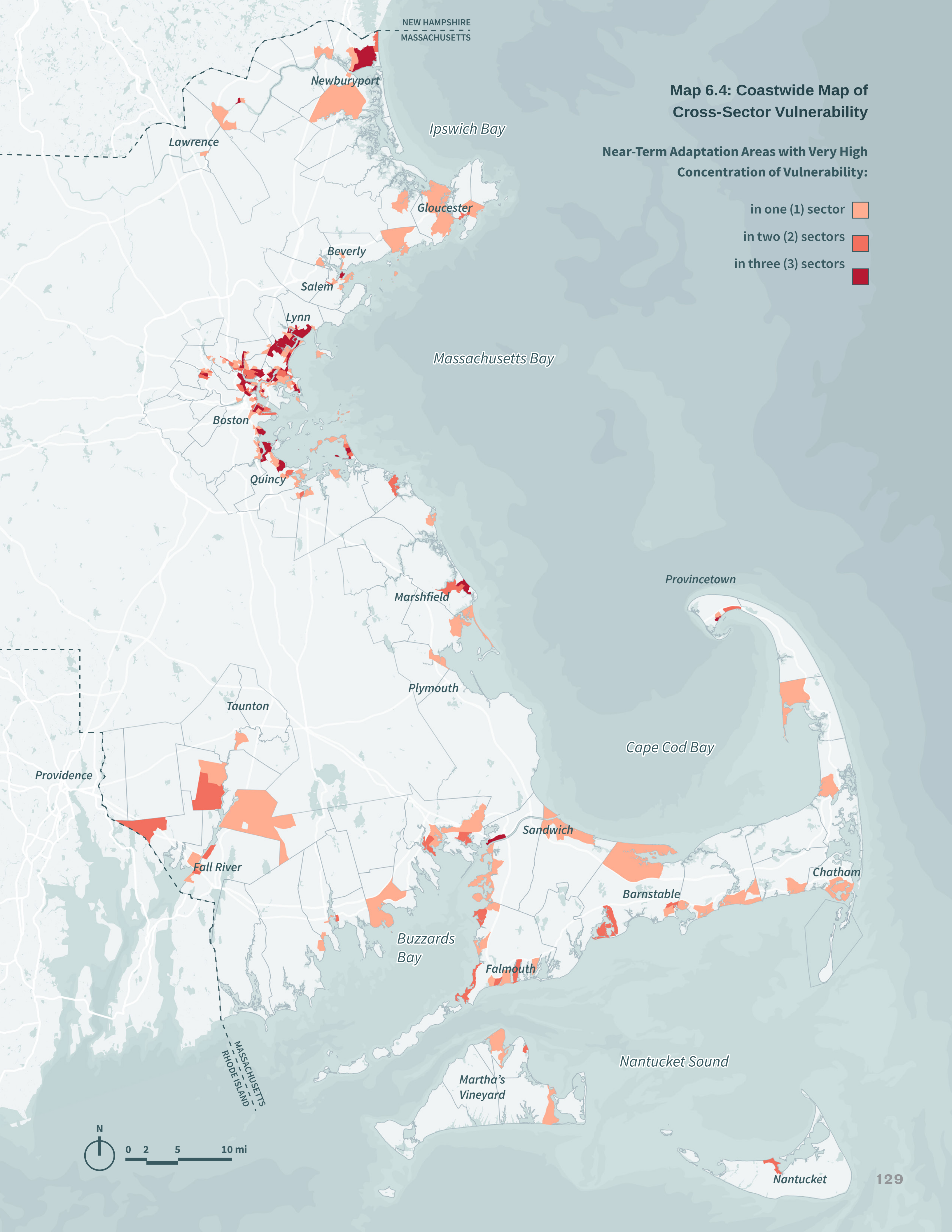
Some areas of the coast have Very High Concentrations of vulnerability across one or more sectors. Understanding where this cross-sector vulnerability exists can further help inform state and local prioritization of resources and action.

Areas ranked in the Very High Concentration category for any one of the People and Housing, Built Infrastructure, or Economy sectors show a higher level of vulnerability than most other CBGs for that sector. As shown in the preceding sections of this chapter, different sets of CBGs are ranked in the higher vulnerability categories for each sector, but there is also some overlap. CBGs exhibiting Very High Concentrations of vulnerability across multiple sectors suggest a higher level of overall vulnerability, compared with those with Very High Concentrations of vulnerability in a single sector.

Cross-sector vulnerability matters in two ways. First, an area identified as having Very High Concentration of vulnerability in more than one sector simply has more assets in harm's way, because it ranks highly for more of the 15 vulnerability indicators used in the overall analysis. Second, while the sectors represent aggregation of discrete measures of vulnerability and risk, there are many instances where Very High Concentrations of vulnerability in one sector amplifies vulnerability measured in another sector. For example, Built Infrastructure vulnerability in the roads indicators also affects the accessibility of People and Housing during floods, including accessibility of emergency vehicles, which in turn can affect the health and safety of residents. Delayed emergency response times have been shown to elevate mortality from heart attacks and strokes. Power sector disruptions in Built Infrastructure also affect health. In the 2022 Massachusetts Climate Change Assessment, power outages were shown to have a measurable impact on injuries and carbon monoxide poisonings, increasing only about 4% by the 2030s (from a historical era of 1980-2005) but by between 25 and 30% by the 2050s.[91]

Another example of this "threat multiplier" effect involves threats to employment centers or the structures that comprise commercial, employment activity, or health-care provision in the Economy sector. Impacts on health services provision have immediate impacts on the health of the local population. Hurricane Sandy has been shown to have disrupted dialysis service provision, led to respiratory disease hospitalizations, contributed to pregnancy complications, and increased mortality for a month after the event, attributed to a combination of direct impacts and indirect effects through damage to hospitals and electric power provision.[92] Impacts on places of commerce or employment could hamper the restoration of residences damaged by floods or even increase damages if deployment of equipment such as pumps is slowed.

The approach to generating an overall composite cross-sectoral ranking across the three sectors is based on the sectoral composite scores. First, CBGs in the top 15 percent of sectoral ranking (the 85- 100th percentile, constituting the 134 highest ranked CBGs) were identified. Then, the cross-sectoral CBGs with 85- 100th percentile rankings in one, two, or three sectors were identified as having the highest cross-sectoral rank.



Map 6.4: Coastwide Map of Cross-Sector Vulnerability
Near-Term Adaptation Areas with Very High Concentration of Vulnerability:
in one (1) sector
in two (2) sectors
in three (3) sectors
NEW HAMPSHIRE
MASSACHUSETTS
Newburyport
Lawrence
Ipswich Bay
Gloucester
Beverly
Salem
Lynn
Massachusetts Bay
Boston
Quincy
Marshfield
Provincetown
Plymouth
Taunton
Cape Cod Bay
Providence
Sandwich
Fall River
Chatham
Barnstable
Buzzards Bay
Falmouth
Nantucket Sound
Martha's Vineyard
MASSACHUSETTS
RHODE ISLAND
Nantucket
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0 2 5 10 mi

Vulnerable & Priority Populations

The impacts of coastal hazards are not equal. Some populations and communities will be disproportionately affected by coastal hazards and have less capacity to adapt to changing conditions. An equitable approach to coastal resilience requires the integration of information and strategies that address this reality.

Unequal Coastal Vulnerability

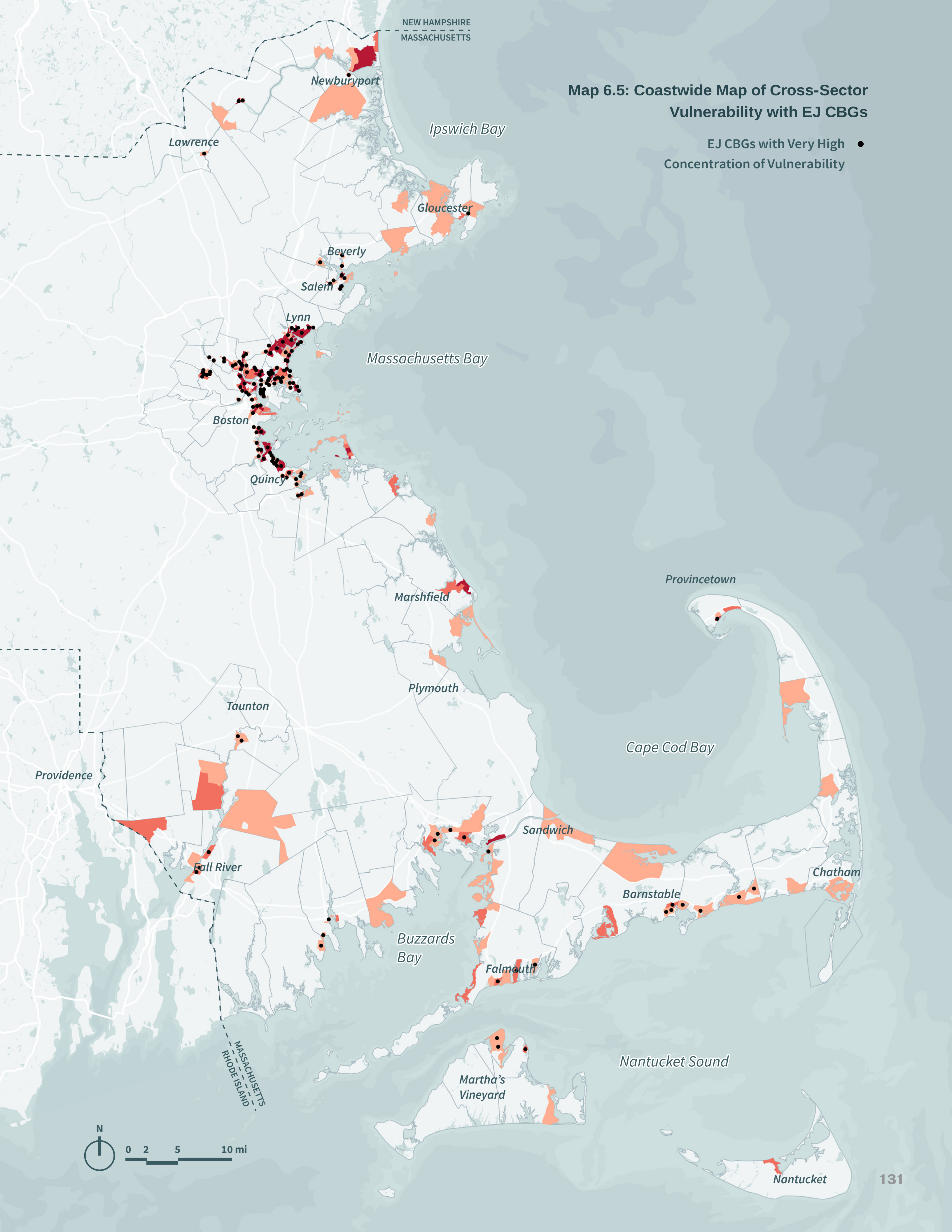
Vulnerable and priority populations are disproportionately affected by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors like income and language isolation, other factors like physical ability, access to transportation, housing insecurity, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This is driven by underlying contributors such as economic disparities or accessibility barriers that create vulnerability. The term “priority populations” acknowledges that the needs of people with these experiences must take precedence when developing resilience solutions to reduce vulnerability. This demonstrates that vulnerable populations often live in areas where the greatest near-term risk is projected.

To ensure that coastal resilience measures are equitable and inclusive, it is critical for state and local governments, along with other coastal partners, to center the voices of vulnerable and priority populations, including tribes. This centering involves developing and prioritizing resilience measures that directly benefit these communities, engaging with residents in planning and decision making, incorporating their voices in policy creation, and addressing systemic inequities in coastal resilience plans and projects.

Coastwide, there are approximately 894 CBGs identified as Near-Term Adaptation Areas because they have some level of near-term vulnerability to coastal flooding. Of those, nearly half (45%) are also state-designated EJ CBGs. Of the 255 CBGs that have Very High Concentrations of vulnerability in one or more sectors, 64% are state-designated EJ CBGs. This demonstrates that EJ Populations often live in areas where the greatest near-term risk is projected.

While the analysis of Near-Term Adaptation Areas takes into consideration the location of mapped EJ Census Block Groups (CBGs) to identify areas with high concentrations of vulnerability, it does not fully capture the effects of coastal hazards on these and other priority populations. The analysis uses data methods for calculating and attribution a portion of the population to the area exposed to coastal flooding. The analysis also considers the location of deed-restricted affordable housing units vulnerable to flooding, as these units are critical for providing secure and stable housing options for lower-income residents. However, the analysis does not account for the full scale of direct and indirect impacts faced by vulnerable and priority populations, including the potential combination of risks that can have cascading impacts – both direct and indirect – on communities.

Map 6.5: Coastwide Map of Cross-Sector Vulnerability with EJ CBGs



Natural Resources

In addition to assessing the vulnerability of people and the built environment, it is important to understand how the state's critical coastal ecosystems will be impacted by climate change and identify methods to conserve and enhance them in the face of increased coastal hazards.

What We Know

Our coastal ecosystems provide numerous services including enhanced water quality and habitat, flood absorption and carbon storage, buffering from wave action and erosion, recreation, and more. However, more frequent flooding and storm events and increased erosion, threaten these ecosystems and the benefits they provide.

Better understanding the vulnerability of these ecosystems to coastal hazards can help prioritize interventions to protect, conserve, and enhance their function.

The analysis of Near-Term Adaptation Areas does not take into consideration the state's critical coastal ecosystems. This omission was due to the type and scale of data currently available on natural resource vulnerability and the additional time needed to conduct a more robust stakeholder engagement process around prioritization of resources for conservation and restoration. However, there are several publicly available datasets that shed light on the relative vulnerability of certain coastal ecosystems across the 15 Coastal Resilience Districts (CRDs), namely salt marshes and beaches. Beaches and salt marshes were selected due to the proximity to critical infrastructure and vulnerability to coastal hazards.

It is important to note that an assessment of vulnerability based on these datasets does not account for other important factors that should be considered when developing a prioritization methodology for state intervention and resources. This analysis also focuses specifically on salt marshes and beaches and does not consider other critically important coastal ecosystems. A more comprehensive analysis to inform prioritization will be undertaken in future phases.

Salt Marsh along Neponset River, Boston, MA (Credit: CZM)

Salt Marsh Vulnerability

Increases in sea level, precipitation, and air and water temperature, pose a serious threat to salt marshes. Increased sea levels will result in salt marsh change and loss, particularly for locations where the opportunity to migrate inland or into other wetlands is limited. The Massachusetts Sea Level Affecting Marshes Model (SLAMM) can be used to examine salt marsh vulnerability based on potential losses of present-day marsh in response to sea level rise and potential gains of salt marsh through marsh migration.[93] This initial analysis looks at the impacts from the SLAMM sea level rise scenario of 4.5 feet from 2011 to 2100 in Boston. This scenario closely resembles the 2070 sea level rise scenario used in the Massachusetts Coast Flood Risk Model (MC-FRM), which forms the basis of the CRDs and other analyses in this plan. While this analysis does not represent a comprehensive assessment of salt marsh vulnerability, it evaluates potential outcomes in response to sea level rise, a main stressor to salt marshes, and provides a basis for further study.

Salt marshes are assessed using a longer-term sea level rise scenario than the Near-Term Adaptation Areas because impacts of sea level rise on salt marshes result in cascading changes that are not as immediate compared to, for example, direct inundation of infrastructure. Therefore, predicted changes and loss are more appropriately quantified on a longer time scale. A description of the methodology used to perform the salt marsh loss and marsh migration analyses can be found in **Appendix IV: Salt Marsh Loss and Migration Technical Documentation**.

Salt Marsh Loss

The state could lose nearly 35% of present-day salt marsh under 4.5 feet of sea level rise, according to data derived from SLAMM. Massachusetts currently has over 48,000 acres of salt marsh and the potential loss under a sea level rise scenario of 4.5 feet is more than 16,000 acres. This estimate does not include any offsets from salt marsh gains through processes such as marsh migration, whereby upland areas and freshwater wetlands convert to salt marsh.

A stark contrast exists in the amount of salt marsh loss between CRDs in microtidal (tidal ranges of less than 6.6 feet) and mesotidal (tidal ranges of 6.6 to 13.1 feet) environments. Of the six CRDs that stand to lose more than 50% of present-day salt marsh, four are microtidal (South Cape Cod, Buzzards Bay, Islands, and Taunton Watershed) and one (Outer Cape Cod) straddles microtidal and mesotidal environments. In combination, these losses represent 25% of present-day salt marsh area in the state. Marshes in these districts tend to be lower in elevation, which when combined with a small tidal range generally make them more vulnerable to rapid sea level rise. In terms of acreage, the greatest losses by far could come from Buzzards Bay, with nearly 4,500 acres, or 93% of present-day salt marsh, predicted to be lost.

The Great Marsh CRD contains the largest marsh area of all CRDs and includes 35% of the total acres of salt marsh in Massachusetts. The North Cape Cod CRD, home to the Barnstable Great Marsh, has the second largest relative salt marsh area by CRD and contains 20% of all Massachusetts salt marsh. Together, these 2 CRDs make up over 50% of all present-day salt marsh in the state.

The Great Marsh CRD is projected to lose 13% of existing salt marsh and the North Cape Cod CRD is projected to lose 25% of existing salt marsh. These two districts have mesotidal environments with marshes that are typically higher in elevation with significant depth of peat, so they may be relatively less vulnerable to immediate losses with rapid sea level in comparison with microtidal CRDs. It is worth noting that although areal losses are predicted to be less for these two CRDs than others, rising sea level can impact and change the biological community of salt marshes long before losses are observed.

Salt Marsh Migration

The term “marsh migration” often refers to a process where tidal marshes move into formerly dry land (upland) in response to rapid sea level rise. This analysis also considers marsh migration to include the movement of salt marshes into freshwater wetlands, such as inland emergent marshes, tidal and nontidal swamps.

Two datasets on marsh migration derived and processed from SLAMM are useful in assessing marsh vulnerability to sea level rise. The first dataset predicts the extent and distribution of marsh migration areas assuming that currently developed lands will be allowed to become marsh. In this dataset, developed upland areas (e.g., residential neighborhoods, parks, etc.) are included as marsh migration areas if relative elevation and other conditions are met. The second dataset predicts the extent and distribution of marsh migration areas with currently developed lands excluded under the assumption that infrastructure on these lands will be protected from future tidal flooding and/or conversion to salt marsh. Including both scenarios allows coastal managers to identify potential opportunities for restoration with marsh migration in mind.

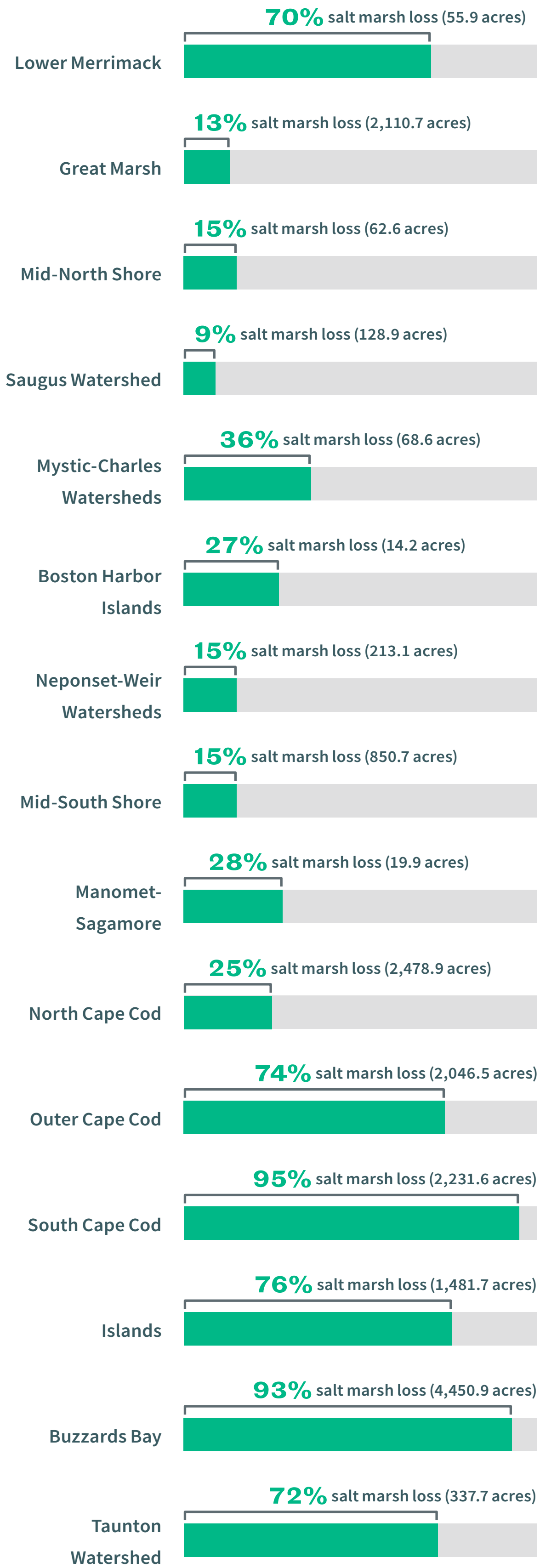
Both datasets are likely an overestimation of marsh migration area given the uncertainty of how future conditions will shape adaptation responses for any given area (e.g., future dam capacity, tide gate management, shoreline armoring, managed retreat, etc.), and the unknowns and uncertainties in ecological processes leading to marsh migration. The 15 CRDs vary considerably in size, development density, and tidal range and elevation, all of which impact migration potential. Several CRDs have more limited migration potential when developed lands are excluded, including three CRDs (Mystic-Charles Watersheds, Saugus Watershed, and Neponset-Weir Watersheds) where the marsh migration potential is reduced by more than 50%.

For instance, the Mystic-Charles Watersheds CRD is predicted to have over 1,400 acres of marsh migration area when developed lands are included, but less than 200 acres when they are excluded. This difference is not surprising given this CRD’s highly urbanized landscape with significant impervious surface area. Most of the 200 acres, much of which is currently open space or parkland, is upriver of the Charles River Dam. Management of the dam under future conditions will impact marsh migration in these areas.

In contrast, the Buzzards Bay CRD, which is the largest of the 15 districts, has the greatest potential marsh migration. Nearly 2,000 acres of upland marsh migration is possible, even with developed lands excluded.

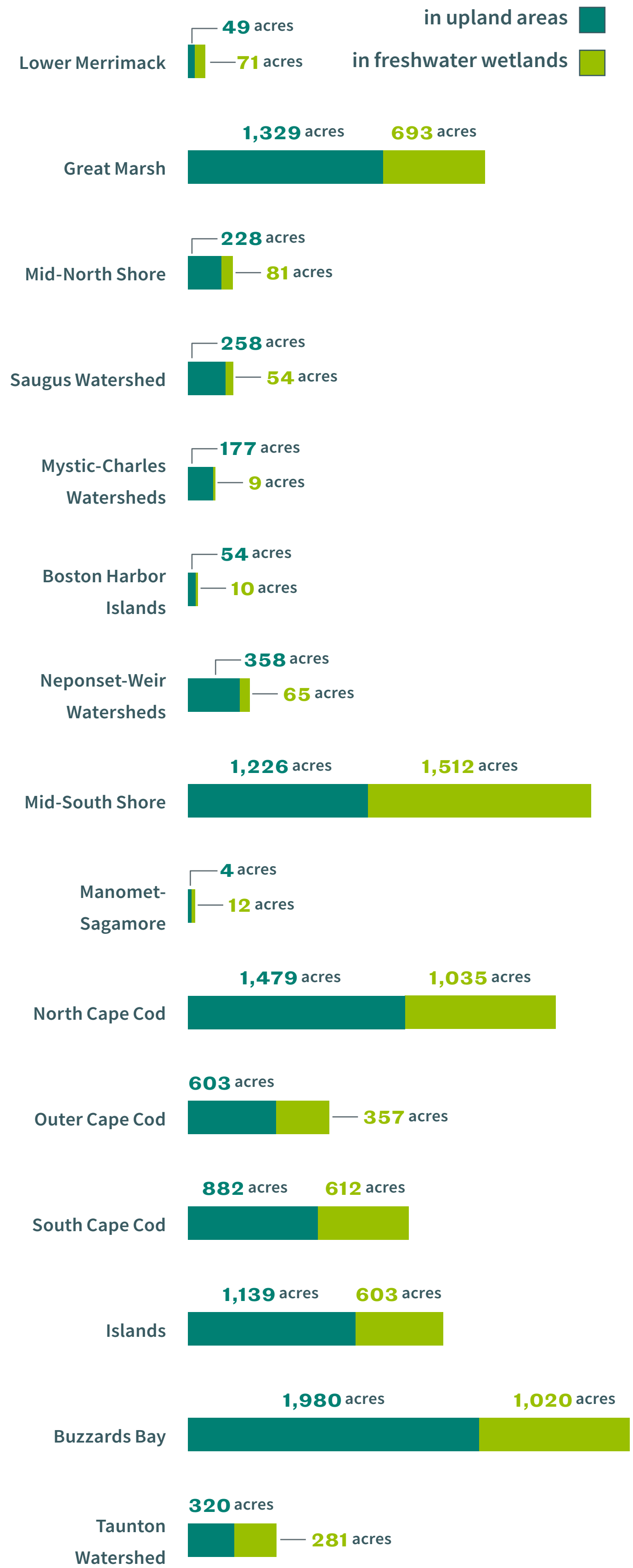
There are five CRDs that have the potential for over 1,000 acres of upland marsh migration (Buzzards Bay, North Cape Cod, Great Marsh, Mid-South Shore, and Islands), all of which (except Islands CRD) also have the potential for over 1,000 acres of migration into freshwater wetlands.

% salt marsh loss per district



Note: Data represents potential salt marsh loss under 4.5 feet of sea level rise.

salt marsh migration potential per district



Note: Data represents potential marsh migration area with 4.5 feet of sea level rise and exclusion of developed lands.

Publicly Accessible Beach Vulnerability

The Massachusetts coast is largely composed of sandy and gravelly beaches interspersed with rocky headlands, developed shoreline, and salt marsh. Beaches make up a large portion of coastline exposed to waves and coastal storms and provide significant economic and ecological value, including tourism revenue, coastal flood defense, and biodiversity. Like many natural features, beaches are subject to numerous threats including rising sea levels, erosion, and human interference.

Human alteration of the shoreline in the form of shoreline stabilization structures (revetments, groins, seawalls, bulkheads, etc.) is designed to block or alter the natural movement of sand and other sediment across and along the coast (longshore drift). Updrift accretion occurs when sand gets trapped on the side of a shore-perpendicular structure that faces prevailing currents, building up the beach. Concurrently, downdrift erosion occurs on the opposite side of the structure with the shortage of sediment leading to beach loss. Seawalls and other vertical shore-parallel structures reflect wave energy back toward the shore, which can concentrate wave force and accelerate erosion in front of the structure.

More research is needed to better understand the relative long-term vulnerability of Massachusetts beaches to climate change and other forces; however, some publicly available data can help identify areas at more or less risk. To narrow the focus on the beaches that currently provide the greatest public benefits, this analysis is limited to publicly accessible beaches (both publicly and privately-owned) on, mostly, the ocean-facing shoreline. The analysis focuses on stretches of publicly accessible beaches along the coast that are most at risk for erosion and potential disappearance.

A description of the methodology used to perform the beach vulnerability analysis can be found in **Appendix V: Publicly Accessible Beach Vulnerability Technical Documentation**.

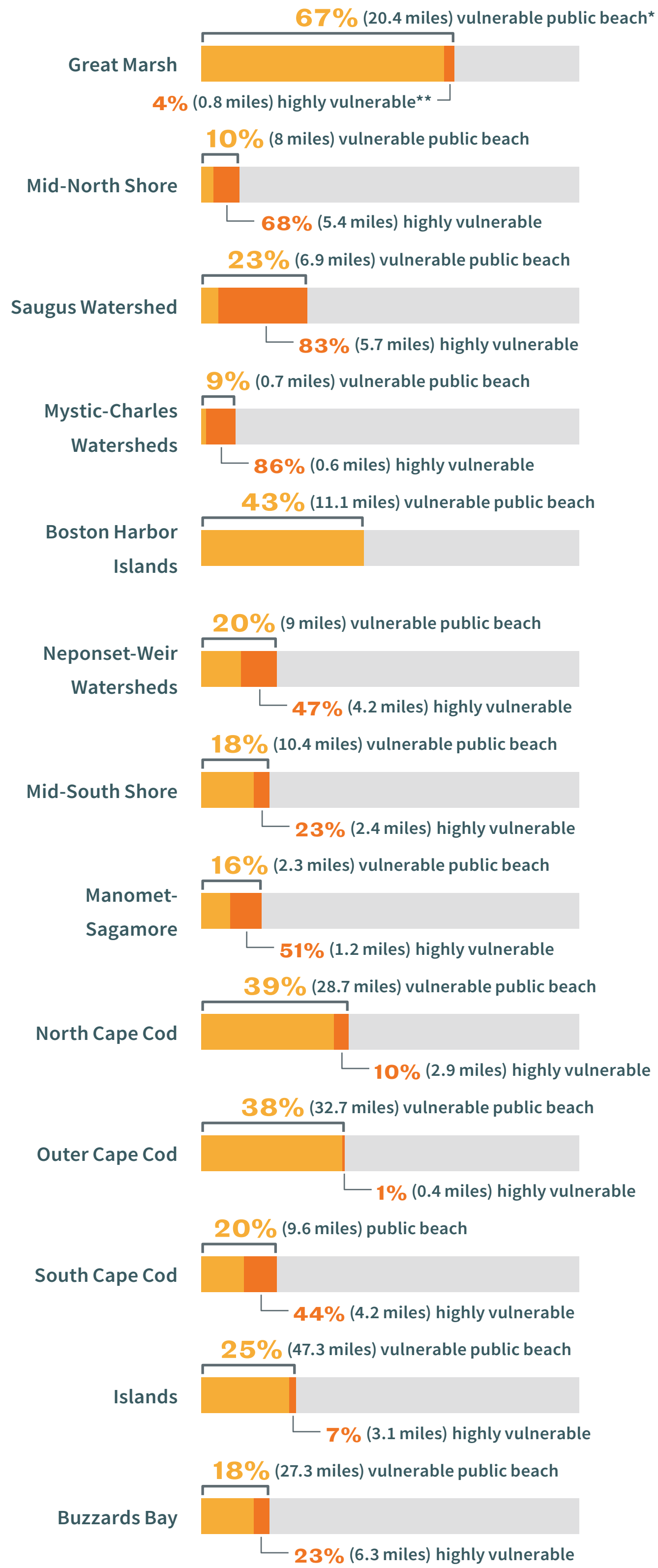
To assess which stretches of publicly accessible beach along the coast are vulnerable to erosion (both horizontal and vertical) and even potential disappearance with sea level rise, this analysis first identified beaches that have eroded or remained relatively static over the past approximately 50 years. Beaches that have accreted sand (accumulated sand, rather than lost it) were excluded. The analysis assumes that beaches with human alteration – that is beaches with shoreline stabilization structures (armoring) that are also backed by developed lands (commercial, residential, or other development including roads and other impervious surface) – have the highest potential vulnerability.

The analysis relies on the following existing public datasets: Massachusetts Shoreline Change Transects, MassDEP Wetlands, Shoreline Stabilization Structures, Massachusetts Land Cover/Land Use, and Massachusetts Protected and Recreational Open Space. Publicly accessible beaches that are not accreting (or vulnerable) were identified where they have been developed and armored. The reasoning for the combination of these criteria is that while developed shorelines are vulnerable to erosion because of the impact they have on natural dynamic processes of beaches, developed shorelines that also have been armored are even more vulnerable because they interrupt sediment transport and often reflect wave energy, intensifying scouring at the base and along adjacent unprotected areas.

Vulnerable publicly accessible beaches that were identified as developed and armored are considered highly vulnerable.

In many districts, publicly accessible beaches are a limited and important community resource. Where publicly accessible beaches are limited and highly vulnerable to erosion due to development and armoring, they will likely continue to narrow or disappear over time resulting in a loss of critical public resources. Urban floodplains exemplify this scenario. For example, the Mystic-Charles Watersheds and Saugus Watershed CRDs have limited miles of publicly accessible beach and they are also relatively highly vulnerable. Overall, there are approximately 37 miles of highly vulnerable publicly accessible beaches in Massachusetts.

publicly accessible beach vulnerability per district

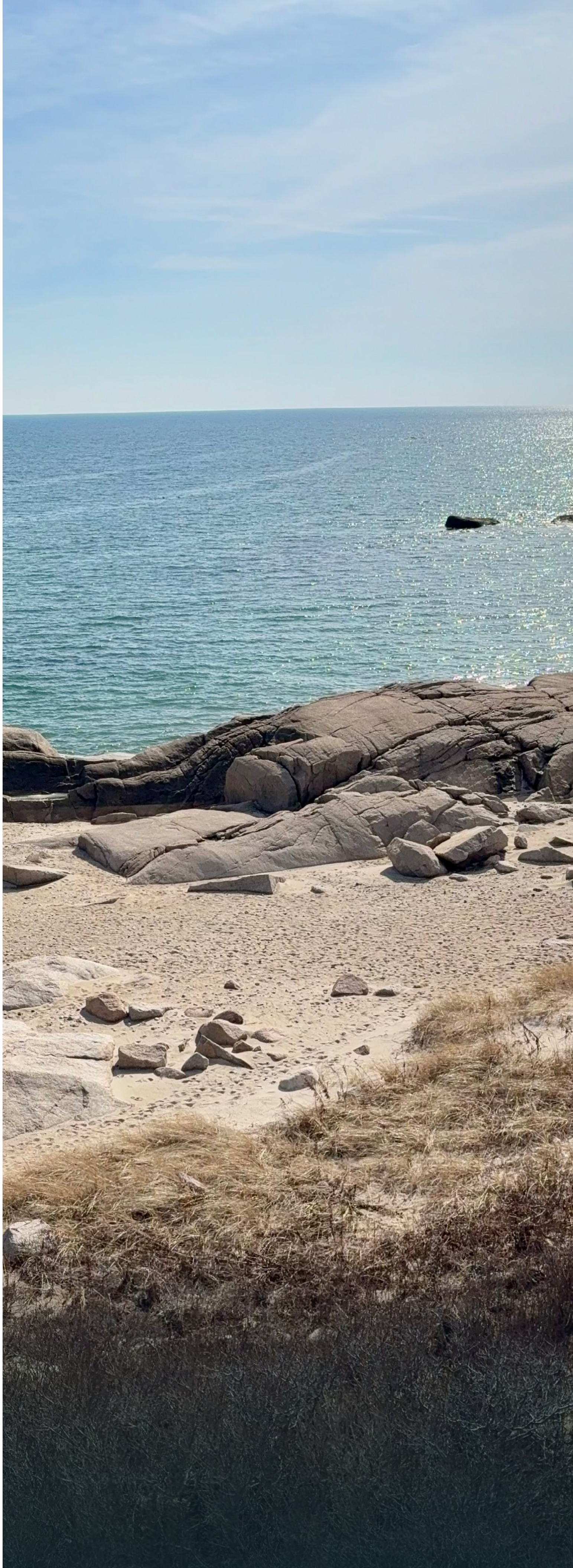


*represents non-accreting publicly accessible beach.
**meets Vulnerable Public Beach criteria and is backed by development and shoreline stabilization structures (including, groins, bulkheads, and seawalls).
Note: Lower Merrimack and Taunton Watershed districts are excluded due to a lack of ocean-facing shoreline.

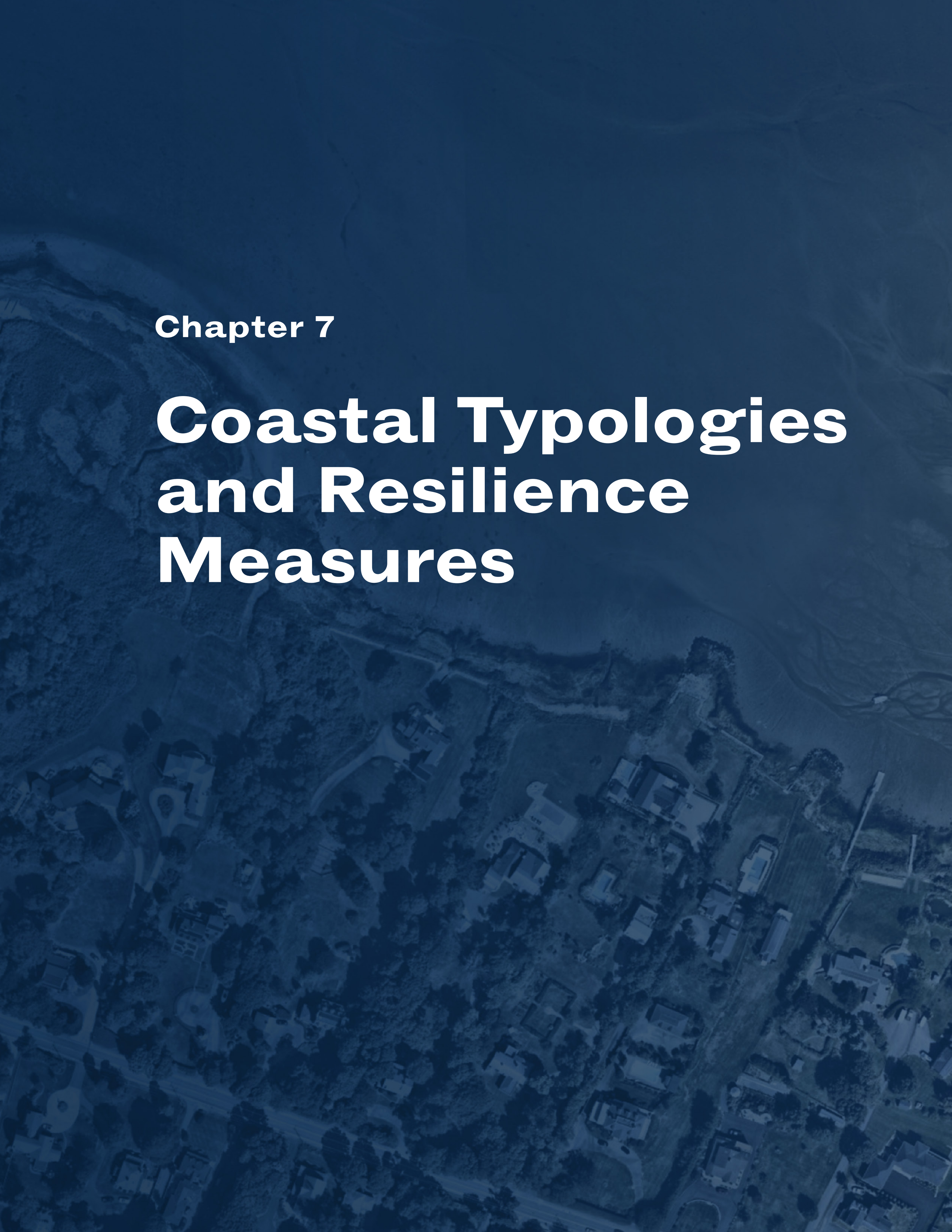
What’s Next

Future phases of ResilientCoasts will undertake a more detailed examination of the vulnerability of critical coastal resource systems, and develop a method for prioritizing state resources and intervention. This effort will necessitate a robust stakeholder engagement process, including coordination with other ongoing state initiatives like biodiversity.

It is important to note that the data above depicts publicly available information that can be used to interpret the vulnerability of these resource areas. However, numerous other factors need to be considered in determining the resilience of these areas and the prioritization of state investments in protection, restoration, and enhancement. This more complex prioritization methodology should take into consideration factors such as socio-economic value, cultural resources, resilience benefits, rare species habitat, likelihood of restoration success, current ecosystem function, ecological processes (sediment supply, hydrology, etc.), existing stressors (water quality, development, etc.), presence of nursery and/or breeding grounds for sensitive species, and public benefit.



Knubble Beach, Westport, MA, 2025 (Credit: WHG)



Chapter 7

Coastal Typologies and Resilience Measures

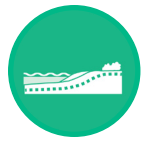
Coastal Typologies

Spanning more than 1,500 miles, the Massachusetts coastline is diverse and highly vulnerable to coastal hazards. These vulnerabilities differ based on the underlying coastal environment, land use, and development character of each area. Because each of these areas, or “coastal typologies,” face unique types and levels of risk, they often require different approaches to coastal resilience.

The coastal typologies listed to the right (in no particular order) represent different types of coastal landforms and environments, natural and man-made, that exist and repeat across the Massachusetts coastline. These coastal typologies are not an exhaustive list of coastal environments but represent a common and relevant subset, primarily along the immediate shoreline and within the floodplain where the highest risks for coastal hazards coincide with vulnerable development. Identifying these typologies, their associated characteristics, and unique risks and management challenges provides a framework for evaluating the effectiveness of different approaches to coastal resilience. While some coastal typologies may be more or less prevalent in an individual Coastal Resilience District, many repeat across the 15 districts, offering an opportunity for coast-wide peer learning and knowledge sharing on best practices.

While other critical habitats in the intertidal to subtidal zone have resilience benefits and vulnerabilities such as mudflats, eelgrass, kelp, and shellfish beds, and hard and complex habitat, these are beyond the scope of this plan. These habitats will be more closely examined in future phases and through parallel state initiatives.

SALT MARSHES



COASTAL BEACHES / DUNES

BARRIER BEACHES

COASTAL BANKS

TIDAL RIVER FLOODPLAINS

COASTAL FLOODPLAINS

PORTS & WORKING WATERFRONTS

Saugus and Pines Rivers, Revere and Lynn, MA, 2022 (Credit: WHG)

SALT MARSHES

Salt marshes are coastal wetlands that extend landward up to the highest high tide line, that is, the highest spring tide of the year. They are characterized by salt tolerant plants and may contain tidal creeks, ditches, and pools. Salt marshes range from broad meadows where the topography is relatively flat to narrow patchy fringes along the shoreline. Brackish wetlands are generally found in areas influenced both by marine tidal waters and fresh waters, like at the upper reaches of estuaries and tidal rivers or along the coastal shoreline in areas with significant fresh groundwater seeps or stormwater runoff. In addition, restrictions to tidal flow, such as berms or roadway culverts, can restrict the extent of the tide and lead to the formation of a brackish wetland that would otherwise be salt marsh.

Salt marshes are among the most productive ecosystems on earth and serve as vital habitat for various life stages of fish, shellfish, and other wildlife. A buffer between land and sea, they provide an important water quality function by intercepting and retaining nutrient pollution, protecting habitat quality for seagrasses and associated wildlife. The platform of grasses and soil within salt marshes also decrease wave energy, capture and store carbon, provide flood storage, and protect life and property from coastal hazards.

Sea level rise threatens to upset the delicate balance that allows salt marshes to occupy the space between land and sea. Long term studies have observed losses and other ecological changes within salt marshes as a result of sea level rise. As sea level increases, a greater proportion of the marsh may receive more frequent tidal flow (inundation) and for longer periods of time, including areas that are typically flooded only at the highest tides.

Not all salt marshes in Massachusetts will be affected in the same way, or in the same timeframe. The distribution of many species that live within and on the marsh depend on the level and frequency of fresh and tidal water reaching the marsh platform, including plants key to the salt marsh ecosystem. In turn, salt marsh plants produce organic material and trap sediments brought in from the tides to build and maintain elevation of the marsh relative to sea level.

Salt marsh plants that are less tolerant to tidal inundation may shift landward towards the upland, while salt marsh plants that tolerate higher levels and longer periods of inundation may expand farther from the seaward edge of the marsh into the marsh platform. Areas that are more regularly flooded close to tidal creeks and the marsh-sea edge may begin to die back if water levels are greater than vegetation can handle. Salt marsh plants may also die back in areas where water does not effectively drain from the marsh surface, including where natural hydrology has been altered by ditches, berms, fill, and tidal flow restrictions. If sea level rises beyond the capacity of the salt marsh to maintain elevation, and tidal water on the platform is at a level and duration beyond what the plants have adapted to tolerate, the marsh will begin to break down and change to mudflat or open water. These conditions are expected to continue to deteriorate with increased sea level rise and inundation.

If suitable conditions exist, salt tolerant plants may begin to encroach landward into the upland and into other wetlands in a process called marsh


Salt Marsh in Wellfleet, MA, 2023 (Credit: CZM)


Salt Marsh in Quincy, MA, 2022 (Credit: CZM)

migration. However, in many coastal areas the presence of development such as roads, homes, hardened shorelines, and other structures, along with steep topography, create a barrier preventing the ability of marshes to adapt to rising sea levels in this way. Restrictions of tidal flow from undersized infrastructure crossings (culverts, bridges, etc.), dams, and tide gates further limit the future extent of marsh migration upstream.

Coastal storms, while contributing to erosion of the seaward edge of salt marshes, may also help the marsh build vertical elevation by bringing sediment from marine sources and the marsh edge to the marsh platform. For example, during Winter Storm Grayson in 2018, ice rafted sediment was transported by storm tides to several locations within the Great Marsh and other salt marshes.[94] Strong winds and storm surge may also kick off the process of marsh migration in adjacent forested upland by contributing to tree falls, creating light and space required for marsh plants to begin to migrate upland.

The type of development adjacent to salt marshes is an important consideration for management and coastal resilience. Areas adjacent to salt marshes should be considered when analyzing and selecting appropriate resilience measures. In undeveloped regions, where the marsh platform and surrounding watershed is largely contiguous and not fragmented by infrastructure and development, the focus should be maintaining and protecting ecosystem services, including acquisition of adjacent lands and marsh migration corridors, and restoring function where needed through application of appropriate techniques. These locations are ideal for studying baseline conditions of the marsh and establishing long-term monitoring sites.

When adjacent development is high density, marsh systems and the surrounding watershed are often fragmented, separated by roads, infrastructure, impervious surfaces and development. Because opportunities for marsh migration in these areas are more limited, any suitable areas should be prioritized for acquisition to help facilitate migration. Increased investment in stormwater and wastewater infrastructure is likely needed to address nutrient pollution and other contaminants. Shoreline protection structures and tidal restrictions may negatively influence sediment availability to the marsh platform, increasing its vulnerability. The focus in these areas should be supporting existing and future ecological function of the marsh, including connectivity of the system within the watershed, through methods like removing flow restrictions, protecting the buffer, finding opportunities to restore and create new salt marsh habitat through repurposed areas of former development, and applying restoration techniques to support ecological function and enhance resiliency where appropriate.

In contrast, low density development areas typically have more limited disruption in connectivity from road and transportation crossings. However, restoring ecological function where appropriate is still critical for these areas. Crossings should be assessed and prioritized for retrofit or replacement as necessary to support full tidal flow, and for resilience of the structures over the design life. Acquisition of adjacent lands and marsh migration corridors should also be a priority for these areas and may be more available or cost effective than in high density areas. Improved stormwater and wastewater management may still be needed to reduce nutrient pollution.

Salt Marsh along Main Street, Essex, MA, 2016 (Credit: CZM)

COASTAL BEACHES / DUNES

Coastal beaches are unconsolidated sediments subject to wave, tidal, and coastal storm action which form the gently sloping shore of a body of salt water and includes tidal flats. Coastal beaches extend from the mean low water line landward to the dune line, coastal bank line, or the seaward edge of existing man-made structures, whichever is closest to the ocean. The size of unconsolidated sediments that make up coastal beaches in Massachusetts range from silt to sand, to gravel, pebbles, cobbles, and boulders. Coastal dunes are any natural hill, mound, or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash or artificial fill that help slow down floodwater (like sacrificial dunes and developed dunes).

Coastal beaches and dunes are dynamic landforms that change seasonally and in response to storm energy. They tend to build up and become wider during the summer months and/or after storm events, when sediments are deposited by relatively low-energy waves, and erode during winter and/or storm events, when sediments are moved into nearshore sand bars by higher-energy waves. Nearshore sand bars serve a critical role in dissipating wave energy before it reaches the shoreline. Coastal beaches and dunes provide storm damage protection and flood control by moving, shifting, and changing form to dissipate energy.

More intense storms and higher sea levels caused by climate change are causing the effects of wind, waves, and flooding to be felt further inland. In areas of reduced sediment supply, these impacts can reduce the width of beaches and dunes, lower beach elevations, and alter sediment transport patterns. Communities in Massachusetts with northeast-facing shorelines are more susceptible to significant damage on a frequent basis from Nor'easter storms, which are coastal storms with strong winds that blow from the northeast, causing coastal flooding and typically occur from October through April.

Where engineered structures, like seawalls, are used to stabilize shorelines, waves can be reflected onto fronting and adjacent beaches, increasing erosion of the beaches and nearshore. This results in loss of beach and increased overtopping of the coastal engineering structure over time. Loss of dry beach width and elevation can result in wave energy being transmitted farther shoreward before the wave is tripped. This increases wave battery and overtopping of the structure, flooding of the backshore area, and exacerbates wave reflection scour of the beach immediately seaward of the structure, which can lead to destabilization of the structure and eventually failure. Engineered structures can reduce erosion of coastal bluffs or banks but also reduce the amount of natural sediment supply available for coastal beaches, dunes, tidal flats and salt marshes to maintain width and elevation. When sediment supply is reduced, it diminishes the ability of beaches, dunes, and salt marshes to provide protection from storm damage and flooding to landward areas.

While no shoreline stabilization option will permanently stop all erosion or storm damage, beach and dune nourishment can provide shoreline protection by adding compatible sediment to increase the ability of the landforms to provide protection to landward areas. Artificial and nourished dunes not only increase the direct level of protection to inland areas by acting as a physical buffer but also support

Dune Erosion along Dr Botero Road, Dennis, MA, 2017 (Credit: CZM)

the protective capacity of the entire beach system. Sand eroded from the dune during a storm is not lost or wasted but added to the surrounding beach and nearshore area where it dissipates wave energy, reducing the strength of incoming storm waves. To maintain the dune as an effective physical buffer, sediment must be added regularly to keep the dune's height, width, and volume at appropriate levels. Planting the restored/nourished dunes with native, salt-tolerant, erosion-control vegetation with extensive root systems is also highly recommended to help hold the sediments in place where it doesn't adversely affect threatened or endangered shorebird habitat.

Cobble berms, which use compatible rounded gravel or cobble-sized rocks to mimic a natural cobble dune for the purpose of reducing wave energy and reducing coastal erosion, may be an effective strategy in areas with natural gravel and cobble in the system. Unlike seawalls and revetments, cobble berms are designed to allow wave action to shift and rearrange the stones into an equilibrium profile, disrupting wave action and dissipating wave energy as the cobbles move. Seawalls can protect the area behind them, but wave reflection increases beach scouring, lowering the beach elevation and volume over time, resulting in more wave overtopping of the walls resulting in wave battery of structures and flooding of backshore areas.

BARRIER BEACHES

Barrier beaches are relatively narrow, low-lying strips of land generally consisting of coastal beaches and dunes and extending roughly parallel to the coastline. They are separated from the mainland by a narrow body of fresh, brackish or saline water or marsh system and serve as fragile buffers that protect landward areas from coastal storm damage, flooding, and erosion by absorbing wave energy. The Massachusetts barrier beach inventory estimates there are approximately 681 barrier beaches coastwide, and they are composed of sand, gravel, and/or cobble. In addition to their flood and storm protection benefits, barrier beaches provide coastal habitat, recreational opportunities, and economic benefits.

Barrier beaches are highly dynamic coastal environments, undergoing natural landward migration caused by the movement of sediment by wind, storm wave overwash, and sea level rise. Overwash is the process by which beach sediment is carried landward across the barrier by elevated water levels and waves. It is a natural land-building process that is essential for barriers to maintain elevation and width as sea levels rise. It is also important for dissipating storm wave energy.

This movement also occurs when sand is swept through tidal inlets into the bays and rivers behind barrier beaches, as well as over the barrier beach. The continuation of these dynamic processes maintains the volume of the landform, which is necessary to carry out important storm and flood buffer functions. This sediment is also essential for salt marshes on the landward side of the barrier beach to maintain and build elevation relative to sea level. Barrier beaches and dunes protect back barrier marshes from storm surge and wave action at the exposed shoreline.

Developed barrier beach systems are uniquely susceptible to sea level rise and coastal storm impacts. Massachusetts recognized this in 1980 when Executive Order No. 181 was issued to direct state agencies to strengthen the protection of barrier beaches.[95] Barrier beach flooding occurs from the seaward and landward sides, depending on wind direction, storm surge and precipitation. In some cases, flooding occurs on both sides during the same event. During other events, like very high tides, the flooding may only be on the back side of the barrier. Barrier beaches can also flood from below due to the freshwater lens lying above the seawater that rises in tandem with sea level rise.

Over time, as sediment (e.g., sand, gravel and cobble) erodes in some places and accumulates elsewhere due to storms, winds, tides, and currents, the location, shape, and size of beaches and dunes can change dramatically. Human uses and alterations, including development and coastal engineering structures, decrease the ability of the landform to provide storm damage prevention and flood control to areas landward, including salt marshes. If the landward flux of naturally occurring overwash is insufficient, or if it is interrupted by human use (e.g., removed from roadways or private property) as is often the case for developed barrier beaches, the barrier beaches may narrow over time and potentially drown.

There are limited effective long-term measures for increasing the resilience of developed barrier beaches to coastal hazards. Armoring of barrier beaches does not adequately address risk

Town Neck Beach, Sandwich, MA, 2025 (Credit: WHG)

and can often further exacerbate the problem. For example, shoreline structures reflect wave energy and can increase erosion of the beaches in front and around them, as well as adversely affecting the salt marshes landward of them. They also do not prevent the landform from shifting beneath or around them during coastal storm events, which helps dissipate storm wave energy. Once overtopped, shoreline structures can create a bathtub effect as floodwaters are unable to recede at a normal rate. Rainwater and snowmelt also get trapped behind the walls, exacerbating flooding. Finally, these structures do not protect against freshwater flooding from below.

Beach and dune nourishment can be an effective strategy for barrier beaches, especially in the short-term, but may become more costly and less sustainable long-term.

Similarly, some building-level adaptations like elevation of structures can provide short-term protection but may be insufficient over time as sea levels continue to rise. Strategic relocation of people and assets can be an effective long-term strategy for these areas.

COASTAL BANKS

Coastal banks are the seaward face or side of any elevated landform, other than a coastal dune, which lies at the landward edge of a coastal beach, land subject to tidal action, or other wetland resource area. Regulatory coastal banks may also consist of artificially deposited fill, provided they serve the functions of storm damage prevention and flood control. Coastal banks differ from dunes in that they have not been sorted and reworked by wind, tides, waves, and erosion. They may be composed of various materials, ranging from solid bedrock to sediments consisting of silt, sand, or unconsolidated rocks and soil.

Rocky coastal banks, like those found on the North Shore of Massachusetts, often occur in high-energy environments with strong wave action. The consolidated, rocky nature of the coast provides stability and protection against erosion, resulting in rugged and steep landforms. In contrast, unconsolidated (i.e., a mix of sand, gravel, cobble and boulders) coastal banks are constantly changing in response to storms, waves, winds, tides, sediment supply, sea level rise, and human activities.

Unconsolidated coastal banks are more vulnerable to coastal hazards like erosion and are the primary source of sediment for beaches, dunes, barrier beaches, tidal flats, and salt marshes. Wave action, precipitation, land use and upland landscaping practices cause eroding coastal banks to have natural and variable erosion and landward migration. The slope, shape, composition, and amount of vegetation covering a coastal bank, and width of the beach and dunes fronting the bank, are directly related to the susceptibility of the bank face to erosion.

No shoreline stabilization option will permanently stop all erosion or storm damage on coastal banks. If the toe of a bank is eroding, the upper bank may collapse even if it is well vegetated. Some nature-based solutions including coastal bioengineering projects can be used to reduce erosion and stabilize eroding shorelines. These projects use a combination of deep-rooted plants and erosion control products made of natural, biodegradable materials, such as coir rolls. These techniques may allow some limited erosion from the site while hard structures impede virtually all natural erosion of sediment. However, without this sediment supply, down-current areas of the beach, dunes, barrier beaches and salt marsh systems are subject to increased erosion.

Several areas along the Massachusetts coastline, including areas in Plymouth and Cape Cod National Seashore are characterized as highly eroding coastal banks. In these areas, it is important to limit or avoid new development near the vulnerable tops of banks and avoid landscaping, irrigation, and land use practices that can lead to bank instability. There is a delicate balance of natural erodibility of coastal banks that provide sediment source for coastal beaches, dunes, and other systems downdrift, and the vulnerability of the area landward of the eroding bank. In some circumstances, it may be more appropriate or cost-effective to consider relocation of vulnerable structures rather than pursuing major erosion control efforts, particularly if there is sufficient land area to accommodate such actions.

Coastal Bank erosion in Truro, MA, 2016 (Credit: CZM)


Coastal Bank erosion in Boston Harbor, 2017 (Credit: CZM)

TIDAL RIVER FLOODPLAINS

Tidal river floodplains are low-lying areas that are periodically submerged by the waters of a tidal river. They are more frequently submerged than floodplains along upstream rivers. The water levels in tidal river floodplains fluctuate daily, seasonally, and annually due to tides, flooding, groundwater recharge, and evapotranspiration. Like coastal floodplains, tidal river floodplains provide important flood control functions, including storing stormwater runoff as well as other ecosystem services like fish and wildlife habitat and mitigating source pollution.

Though they are often located farther away from the ocean, tidal river floodplains are influenced by coastal hazards like sea level rise, which can increase the tidal range in rivers and bays, effectively raising the baseline for high tides (reducing the distance between high tide and flood levels). This means that even a normal high tide can reach flood thresholds more easily, increasing the impact of tidal fluctuations and making flooding more frequent by extending the tidal portion of the river further upstream.

Marine, brackish, and riverine wetlands are associated with tidal rivers, including freshwater tidal marsh, a critically imperiled habitat in Massachusetts due to its relative rarity. These freshwater wetlands are often fringing wetlands of small widths along river edges or occasionally larger meadows and are important locations for future salt marsh migration when the tidal portion of the river extends further upstream with sea level rise. Increased tidal influence may result in increased salinity of groundwater, erosion of wetlands and riverbanks, inundation of agricultural land, and backwater effects which can limit the ability of the tidal river to drain, especially during high tide events and periods of heavy river discharge.

Urbanized areas along tidal rivers are particularly vulnerable to increased flooding from backwater effects due to their reduced natural floodplains. These areas can also be susceptible to compound flooding, or flooding associated with rainwater discharge compounded by tidal inundation. In these situations, high water levels from tidal storm surge and sea level rise can prevent rainwater flows from being conveyed downstream cumulatively exacerbating flooding of adjacent low-lying areas.

Road and rail crossings must be carefully designed and managed to effectively balance rainwater drainage, coastal storm surge flooding, and future bi-directional tidal flow over the life of the structure. This includes analysis to size culverts and bridges appropriately, as well as robust operation and maintenance plans for existing tide gates. Some of these tidal floodplains also have existing dam infrastructure (like the Amelia Earhart and Charles River Dams) that support flood control but may be at risk for flanking or overtopping with climate impacts. Failure of these dams could catastrophically increase flood impacts to adjacent communities.


Taunton River, Dighton, MA, 2015 (Credit: CZM)


Tidal River, Revere, MA (Credit: WHG)

COASTAL FLOODPLAINS

Coastal floodplains are areas along coastlines that experience flooding from tides, storm surge, and/or wave effects. They often overlap with other coastal environments like salt marshes and coastal beaches. In some areas of the coast, including the City of Boston, the coastal floodplain includes areas of filled tidelands, which are formerly submerged lands and tidal flats that are no longer subject to tidal action due to the presence of fill.

Historically, coastal floodplains have been mapped based on past flood patterns. However, due to climate impacts like increasing rates of sea level rise, flood risks in existing, mapped coastal floodplains are changing faster, and the extent of coastal floodplains is increasing as well. Low-lying areas including filled tidelands are particularly susceptible to changes because they were historically filled only a foot or two above the high tide line. Sea level rise and continued development puts these low-lying areas increasingly at risk. In Massachusetts, the regulatory coastal floodplain is identified by the Federal Emergency Management Agency (FEMA) based on historical storms. It is regulated as Land Subject to Coastal Storm Flowage (LSCSF) under the Massachusetts Wetlands Protection Act (WPA). Development in coastal floodplains is also subject to standards under the Massachusetts State Building Code.

Within the FEMA-mapped floodplain, there are variations in the level of risk. High hazard portions of coastal floodplains such as FEMA V Zones and Coastal A Zones are areas subject to high-velocity wave action and fast-moving water during storms.[96] In addition, AO Zones are areas of shallow flooding, with depths of 1-3 feet, that often include high velocity overwash with unpredictable flow paths. Areas just landward of FEMA V Zones and Coastal A Zones can also have fast-moving floodwater. These areas often require a different coastal resilience measure than more inland areas of the coastal floodplain.

Because the coastal floodplain in Massachusetts is changing, the state has also mapped the projected coastal flood extent for various sea level rise scenarios using the Massachusetts Coast Flood Risk Model (MC-FRM).[97] MC-FRM is not intended to replace FEMA flood maps; each has a different purpose. Though the projected future floodplain is not currently regulated under the WPA or the Massachusetts State Building Code, the latter includes freeboard requirements above the mapped FEMA Base Flood Elevation to address increasing precipitation and sea level rise. These requirements do not currently extend to the projected future floodplain outside of the mapped FEMA floodplain.

The current and future coastal floodplain plays an important role in flood protection. It provides a buffer from the force of the ocean during storms and tidal surges, absorbing wave energy and slowing down floodwaters, which helps protect inland areas from coastal erosion, flooding, and storm damage. When the coastal floodplain is well-functioning, it also provides important co-benefits such as improved water quality and habitat for fish and wildlife.

The coastal floodplain may be developed or undeveloped and have a range of population and development densities and types of land use. Many of the coastal floodplains in Massachusetts are comprised of medium to high density residential and commercial development. As the floodplain is developed, it loses its ability to dampen and absorb storm energy, allowing storm impacts to be felt further inland. Hard, paved surfaces in the floodplain also prevent


Marshfield, MA, 2011 (Credit: CZM)

water from being absorbed into the ground, allowing floodwaters to travel further inland.

As sea levels rise, and coastal flooding becomes more frequent and severe, development and infrastructure in coastal floodplains will be increasingly subjected to impacts and damage. Many of these areas are altered with dense development or shoreline engineering structures that are vulnerable to coastal hazards as well. Minimizing pavement and impervious surfaces, increasing vegetation and protecting and enhancing the natural functions of coastal landforms to provide storm damage prevention and flood control to landward areas can reduce storm impacts.

Fill in the floodplain has been used to raise buildings and infrastructure above the floodplain elevation. This can be effective in some areas, but it can also redirect floodwater to adjacent areas, increasing flooding and storm damage.

Fill should only be placed in floodplains if it will not increase flooding or storm damage to adjacent buildings, infrastructure, or cause adverse impacts to natural resource areas. Similarly, high hazard areas of the coastal floodplain like V and Coastal A, and AO Zones often require specific measures like elevating structures on open piles due to wave energy and high velocity flows.

PORTS & WORKING WATERFRONTS

Working waterfronts serve an important function in the Massachusetts economy, providing a critical connection between land and water for uses such as fishing, tourism, energy, and transportation. The function of these areas depends on locational factors, including proximity to the waterfront, access to navigable waterways and roads, availability of waterfront infrastructure, and presence of maritime support functions and suppliers. This unique combination of physical characteristics, land uses, systems services, consumers, and suppliers are not easily created, replicated or relocated, and thus these areas are worthy of protection.

There are 10 Designated Port Areas (DPAs) along the Massachusetts coast including Gloucester Inner Harbor, Salem Harbor, Lynn, Mystic River, Chelsea Creek, East Boston, South Boston, Weymouth, Fore River, New Bedford-Fairhaven, and Mount Hope Bay.[98] These areas are particularly well-suited to water-dependent industrial and maritime uses and encompass many, but not all, of Massachusetts' working waterfronts. Additional areas of the coast that have not been formally designated as DPAs operate as working waterfronts as well.

Because these resource areas are defined, in part, by their dependency on proximity to water, they are vulnerable to a range of coastal flood hazards. Sea level rise and storm surge can pose a significant risk to water-dependent uses. They may also have unique risk tolerances to these hazards. For example, while the risk of structural damage from tidal flooding is generally low, frequent tidal flooding on even a monthly basis can be highly disruptive to normal port operations, leading to business interruption, loss of service for critical infrastructure, and increased wear and tear on systems that support business continuity. Working waterfronts also play an important role in resilience and storm response. For example, boat landings may serve as launch points for emergency rescue operations during extreme weather events.

Working waterfronts often overlap with other coastal typologies – most often coastal floodplain – but may require different coastal resilience measures to meet the physical and operational needs of water-dependent uses. For example, elevating roads and buildings may compromise the land-water connection that is critical to port operations. Elevating critical systems like emergency generators and dry or wet flood proofing facilities may be a more cost-effective option in these areas. However, for some port uses, critical equipment or inventory may need to be permanently or temporarily relocated creating logistical challenges and expense.

In some cases, working waterfronts are located within residential and mixed-use communities and face pressures from market-rate development and land use conflicts. Communities should consider and avoid resilience measures that negatively impact the operations of ports, making them less viable. For example, making upgrades or improvements to roadways may be essential both for the surrounding community and to maintain access in and out of the port. However, failing to take into consideration the unique needs of the port in this process could unintentionally restrict truck access, negatively impacting port operations.

Port and working waterfront, Rockport, MA (Credit: CZM)

Coastal Resilience Measures

Numerous potential resilience measures can be implemented to address coastal hazards, ranging from site and building-level measures to community and regional-scale interventions. Each scale of action involves a variety of potential partners including federal, state, and local governments and private property owners.

Achieving coastal resilience is complex and there is no one-size-fits-all approach. However, understanding the coastal context, including existing development and the underlying coastal typologies, can inform the selection of suitable coastal resilience measures. The guidance in this chapter crosswalks a set of coastal resilience measures with the previously identified coastal typologies. This is a subset of potential measures and is not intended to be an exhaustive list. However, they represent some of the most effective and commonly used coastal resilience measures in Massachusetts and around the country.

It is important to note that there is variation within the identified coastal typologies that should be considered when determining appropriate coastal resilience measures. Two of the typologies – coastal banks and salt marshes – require consideration of land and development adjacent to these natural resources areas when selecting an appropriate measure. Coastal resilience measures listed for these typologies may be suitable or allowable for the areas adjacent, but not in the resource area itself. The extent of these "adjacent areas" may vary by site and community, but regulatory buffer areas are typically at least within 100 feet of the natural resource.

There is also variation within coastal floodplains that impact the suitability of some measures. For example, areas mapped as FEMA V and Coastal A Zones are more vulnerable to wave action than other areas of the coastal floodplain and often require a different approach like elevation on open pilings. In all typologies, there may be site-specific conditions or circumstances that factor into the analysis and selection of coastal resilience measures. For example, historic structures may require a more tailored approach to reduce risk of flood damage without destroying significant historic materials, features, or spaces.[99] Similarly, varying levels of density, housing or construction type, shoreline condition and armoring, or unique land uses like agriculture may influence the suitability of certain measures. Erosion and rate of erosion should also be taken into consideration. Certain areas of the Massachusetts coastline experience higher rates of erosion, making them unsuitable for increased development and priority areas for avoidance measures.

Note that many of the coastal typologies described in this chapter, in whole or in part, are resource areas subject to various existing state, federal, and local regulatory requirements including the Massachusetts Wetlands Protection Act and the Massachusetts State Building Code. Some coastal resilience measures may not currently be permittable in certain resource areas under existing regulations due to impacts to the functions and values of a given resource area or impacts to adjacent buildings or infrastructure. The site-specific resource areas, uses, and regulations should be used to decide on the best approach for individual sites.

The guidance below is intended to be a starting point for end users to consider the suitability of different coastal resilience measures. More granular local planning and site-specific analyses, including but not limited to baseline resource area data collection, feasibility, and permitting and regulatory assessment, are required to determine the most effective approach.

TYPES OF COASTAL RESILIENCE MEASURES

There are a variety of tools available to communities in addressing coastal hazards. The coastal resilience measures discussed in this chapter can be grouped into one or more of the following five types:

AVOID	These measures aim to avoid coastal hazard risk by proactively intervening in an area to prevent putting people, homes, critical facilities, and infrastructure at risk. This may include measures like zoning regulations and criteria for siting new infrastructure.
RESTORE	These measures aim to restore and enhance the functioning of natural systems to protect natural resource areas from coastal hazards and leverage them as natural protection for people and property. This may include measures like wetland restoration, bank stabilization, and removal or relocation (undevelopment) from floodplains.
ACCOMMODATE	These measures aim to accommodate coastal hazards like flooding by using adaptive measures designed to allow continued use of flood-prone areas and improving the ability of people, communities, and infrastructure to experience occasional flooding or limit damage from flooding. This may include measures like elevation, floodable open spaces and ground floor uses, and upgrading infrastructure like culverts.
PROTECT	These measures aim to protect people and assets from risk by keeping floodwaters away from homes, communities, critical facilities and infrastructure. This may include measures like repairing and retrofitting seawalls and revetments, deploying flood barriers, and implementing dry floodproofing techniques.
RETREAT	These measures aim to reduce or eliminate exposure to coastal hazards by enabling relocation of people, property, and critical infrastructure, and sites of historic or cultural significance out of areas vulnerable to recurrent hazards. This may include measures like buyout programs, relocation of critical infrastructure, and rolling easements.

In many cases, a single coastal resilience measure may be categorized as more than one of the types above. Understanding the different approaches to coastal resilience and what they aim to achieve, as well as the benefit of combining measures to achieve complementary outcomes, can help maximize impact.

How to Use this Guidance

This guidance can help inform community or district-level planning and analyses and serve as a starting point for identifying suitable coastal resilience measures for different coastal typologies. It can also help communities select a suite of measures that work together in a coastal typology or on a stretch of shoreline where multiple coastal typologies are co-located. In all cases, further site-specific feasibility analysis will be required to scope and implement these coastal resilience measures.

Coastal Resilience Measures

A total of 23 coastal resilience measures are described and ranked based on a qualitative assessment of suitability for different coastal typologies. Information on the types of coastal hazards addressed, advantages and disadvantages, the scale and difficulty of implementation, and information about cost and design life are also provided. For some measures, information about existing regulatory requirements or site-specific considerations are noted.

Suitability Rankings

A “suitability ranking” is provided for each measure within each coastal typology. These rankings are on a qualitative scale from “poor” to “site-dependent” to “high.” A poor suitability ranking indicates a measure is unlikely to be effective (or in some cases prohibited) in a coastal typology. A site-dependent suitability ranking indicates a measure may be effective but is highly site- and circumstance-specific. This is often the case in highly variable coastal typologies like coastal floodplains that include areas subject to wave energy and high velocity moving floodwater. While a measure may not be suitable for those areas of the floodplain, it may be suitable for more inland areas of the floodplain. A high suitability ranking indicates a measure is likely to be effective in a coastal typology and should be considered.

The suitability ranking is not necessarily a reflection of feasibility. A measure may be “suitable” in that it is likely to be effective in minimizing or eliminating coastal hazards but is not necessarily feasible from a technical or cost perspective. For example, beach nourishment may be an effective measure for protecting coastal beaches and dunes from erosion, storm surge and wave action, but the long-term cost of nourishment and/or limited availability of sediment could make this measure infeasible for some sites.

In all cases, site-specific analysis is required to identify the most effective measures. Suitability rankings merely highlight where certain measures are likely to be more or less effective and can serve as a guide for developing a short list of measures for more detailed study. It is important to note that measures often can and should be used in combination with each other for greater effectiveness.

Cost, Difficulty, and Design Life

Some measures may be more or less expensive to implement and maintain. Understanding the range of costs can help inform selection of measures. Each measure includes an estimated cost range for a typical project displayed as dollar signs according to the following key:

$ = less than $2 million
$$ = $2-10 million
$$$ = $10-30 million
$$$$ = more than $30 million

Measures also include information on ongoing maintenance costs based on a qualitative scale of low to high. Difficulty rankings, also on a qualitative scale of low to high, are intended to convey the range of potential obstacles to implementation including complexity, political challenges, permitting, and more. Design life indicates how long a typical project would be expected to serve its intended function and can help in assessing the benefit-cost of different measures.

Natural dune, Crane Beach, Ipswich, MA, 2022 (Credit: CZM)

Coastal Typologies and Resilience Measures Suitability Matrix

List of Coastal Resilience Measures

Zoning and Regulations	Land Use Management	AVOID, RETREAT
	Transfer of Development Rights	AVOID, RETREAT
New Building Standards	Build to Design Flood Elevation	ACCOMMODATE
Building Retrofits	Wet Floodproofing	ACCOMMODATE
	Dry Floodproofing	PROTECT
	Elevate on Piers or Pilings	ACCOMMODATE
Voluntary Acquisition	Relocate People and Housing	RESTORE, RETREAT
Road Infrastructure	Elevate and Right-Size Infrastructure	ACCOMMODATE
	Relocate or Reroute	RESTORE, RETREAT
Critical Public Utilities & Other Infrastructure	Elevate	ACCOMMODATE
	Relocate	RESTORE, RETREAT
	Harden / Floodproof	PROTECT
Land Protection	Protect Natural Resource Areas, Migration Pathways, and Enhance Buffers	RESTORE, RETREAT
Nature-Based Solutions	Waterfront Parks and Open Spaces	ACCOMMODATE, RETREAT
	Beach and Dune Restoration	RESTORE, PROTECT
	Bank Stabilization	RESTORE, PROTECT
	Enhance Fringing Salt Marsh	RESTORE, PROTECT
	Cobble Berms	RESTORE, PROTECT
	Other Restoration and Enhancement	RESTORE, RETREAT
Hybrid Solutions	Floodwalls and Berms	PROTECT
Coastal Engineering Structures	Retrofit and Redesign Seawalls	PROTECT
	Retrofit and Redesign Breakwaters	PROTECT
	Retrofit and Redesign Revetments	PROTECT

SALT MARSHES*	COASTAL BEACHES / DUNES	BARRIER BEACHES	COASTAL BANKS*	TIDAL RIVER FLOODPLAINS	COASTAL FLOODPLAINS	PORTS & WORKING WATERFRONTS
High	High	High	High	High	High	Poor
High	High	High	High	High	High	Poor
Site-Dependent	Site-Dependent	Site-Dependent	Site-Dependent	High	Site-Dependent	Site-Dependent
Poor	Poor	Poor	Poor	High	Site-Dependent	High
Poor	Poor	Poor	Poor	High	Site-Dependent	High
Site-Dependent	Site-Dependent	High	Site-Dependent	High	Site-Dependent	Site-Dependent
High	High	High	High	High	High	Poor
Site-Dependent	Site-Dependent	Site-Dependent	Poor	High	Site-Dependent	Site-Dependent
High	High	Site-Dependent	High	High	High	Site-Dependent
Site-Dependent	Site-Dependent	Site-Dependent	Poor	High	Site-Dependent	High
High	High	Site-Dependent	High	Site-Dependent	Site-Dependent	Site-Dependent
Poor	Poor	Poor	Poor	High	Site-Dependent	High
High	High	High	Site-Dependent	High	Site-Dependent	Poor
Site-Dependent	High	High	High	High	High	Site-Dependent
Site-Dependent	High	High	Site-Dependent	Poor	Poor	Poor
Poor	Poor	Poor	High	High	High	Poor
High	Site-Dependent	Site-Dependent	Poor	Site-Dependent	Site-Dependent	Poor
Poor	High	Site-Dependent	High	Site-Dependent	Site-Dependent	Poor
High	Site-Dependent	Site-Dependent	Site-Dependent	High	High	Poor
Poor	Poor	Poor	Poor	Site-Dependent	High	High
Poor	Site-Dependent	Poor	Site-Dependent	High	High	High
Poor	Site-Dependent	Site-Dependent	Site-Dependent	Poor	Site-Dependent	High
Poor	Poor	Poor	Site-Dependent	Site-Dependent	Site-Dependent	High

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

AVOID RESTORE ACCOMMODATE PROTECT RETREAT

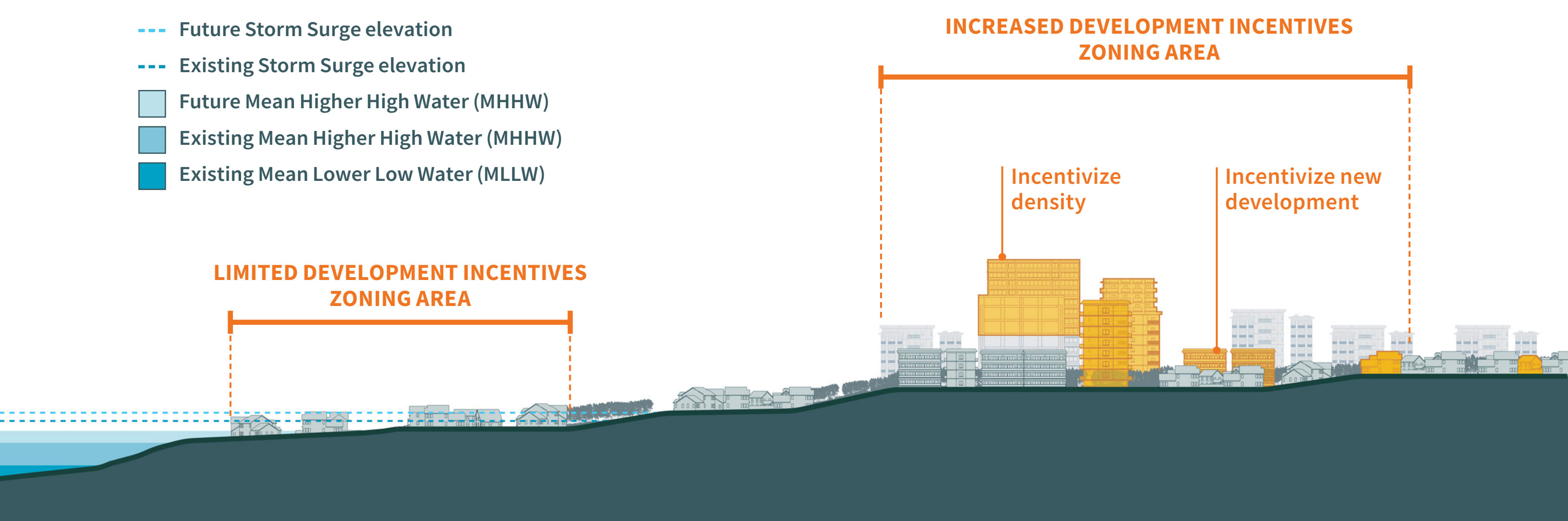
ZONING AND REGULATIONS – Land Use Management

Establish zoning and other local regulations to limit new and redevelopment in areas with high exposure to coastal hazards and encourage growth in safer upland areas.

Cities and towns can use zoning and other local regulations to govern the form and use of buildings to manage risks to development and infrastructure in coastal areas. For example, zoning regulations may include buffer and setback requirements that limit the proximity of new construction to hazardous shorelines and vulnerable natural resource areas. They can impose requirements or restrictions that limit certain uses, like residential, in high-risk areas with wave action and fast-moving water. Communities can also use zoning to prioritize or incentivize denser development in upland areas away from coastal hazards.

Two commonly used mechanisms for local growth and land use management in Massachusetts are zoning bylaws/ordinances and wetland bylaws/ordinances. Communities may use zoning bylaws to update or set requirements broadly or may use more narrowly targeted zoning overlay districts, adopted as part of a zoning bylaw, to superimpose one or more conditions over existing zoning requirements. Similarly, cities and towns in Massachusetts can pass wetlands bylaws/ordinances that superimpose more stringent requirements on coastal resource areas than exist under the state's Wetlands Protection Act.

Communities interested in this measure may consider incorporating climate risks like sea level rise, storm surge, and increased rates of erosion in their local wetlands bylaws and ordinances. Similarly, communities can consider adopting resilient zoning overlay districts with heightened requirements or restrictions for building all or certain uses in flood- or erosion-prone areas. This may be complemented with an overlay district that prioritizes or incentivizes denser development in areas that are less coastal hazard prone.



Section 01: Illustrative section of potential land use management measures. Drawing not to scale.

Municipalities in Massachusetts are limited in what they can require as-of-right under zoning bylaws where certain requirements related to building construction would conflict with the state building code. However, cities and towns may impose more stringent requirements through special permits because they are a form of discretionary, conditional approval. Alternatively, municipalities may use incentives to encourage development in certain areas or more resilient design and construction. For example, offering density bonuses in exchange for elevating first-floor elevations or mechanical equipment.

The use of zoning and wetlands regulations are suitable in most coastal typologies but may be less useful for ports and working waterfronts because there are state-level land use requirements for Designated Port Areas and because working waterfronts are unique in that their proximity to the water is required for specific water-dependent and maritime industrial users.

Advantages:

- Promotes long-term reduction in community's exposure to coastal hazards
- Reduces potential damages to property and health/safety risks to residents and first responders
- Encourages growth in less risky areas of the community while supporting and protecting the function of natural resources

Disadvantages:

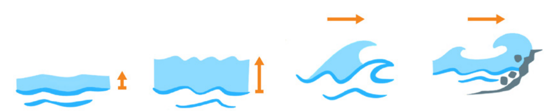
- May reduce opportunities for development and associated property tax revenue in communities with large areas of coastal hazard exposure
- Could lead to gentrification or displacement in upland areas if not taken into account
- Primarily relevant for new and redevelopment and does not address vulnerability of existing development

To support local management of development and land use, the state has developed several resources including a Local Action Guide for flood-smart development. In addition, ResilientCoasts proposes new state-led strategies including training materials for local boards and commissions on climate and development and resources to help cities and towns track repetitive loss properties (those with repeat flood damage claims).

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



SEA LEVEL RISE | STORM SURGE | WAVE ACTION | EROSION

Scale of Implementation	Community-wide
Cost	$$$$
Maintenance	N/A
Difficulty	Medium
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	High
Coastal Beaches / Dunes	High
Barrier Beaches	High
Coastal Banks*	High
Tidal River Floodplains	High
Coastal Floodplains	High
Ports & Working Waterfronts	Poor

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

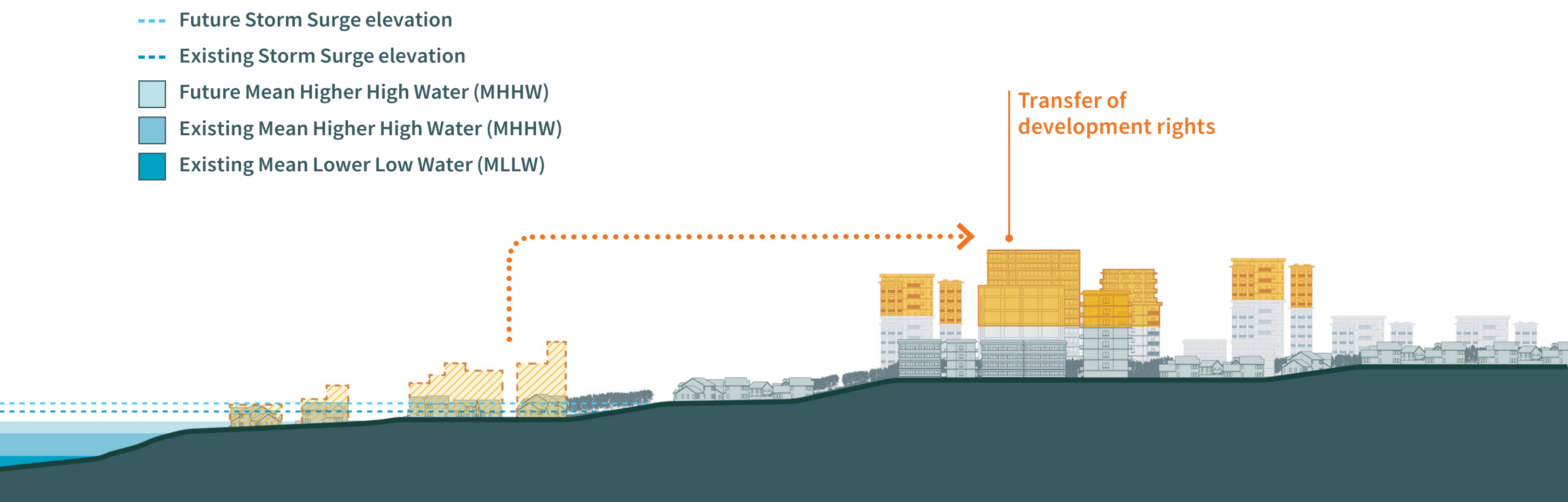
AVOID RESTORE ACCOMMODATE PROTECT RETREAT

ZONING AND REGULATIONS – Transfer of Development Rights

Establish local Transfer of Development Rights bylaws/ordinances to encourage the transfer of development rights between private property owners in areas with high exposure to coastal hazards to lower-risk areas.

Transfer of Development Rights (TDR) is a zoning technique that allows municipalities to facilitate the transfer of development rights within or between zoning districts by special permit. Unlike zoning requirements more generally, TDR is a market-based method that allows municipalities to achieve less development in certain areas by shifting it to locations where development is more desirable. It relies on the voluntary participation of private property owners. In Massachusetts, a municipality with TDR in its zoning code must provide incentives, like density bonuses, to encourage transfers. TDR may be used for many purposes, including preserving open space or agricultural land. While it has not yet been used specifically for coastal resilience purposes in Massachusetts, there is an opportunity to do so.

To utilize TDR, municipalities must pass a local TDR zoning ordinance/bylaw that identifies which parcels or areas of a jurisdiction could transfer rights out (sending areas), and which areas could accept those rights (receiving areas)[100]. In addition to the purchase and transfer of specific rights from one parcel to another, municipalities can allow the purchase of ‘in lieu’ rights as another way of allowing bonus density in designated areas. Under this model, developers can propose developments in receiving areas without acquiring development rights from a sending area. The developer makes a payment to the town for the purchase of development rights. This alternative method of TDR may be used in cases where no one is interested in selling development rights at the time of development. Funds received by the town under this scenario, can be placed in a special account or “TDR bank” and reserved for the acquisition of development rights or fee title to lands in sending areas at a later date. Similarly, municipalities may purchase development rights for the purpose of sale or



Section 02: Illustrative section of Transfer of Development Rights. Drawing not to scale.

use in the receiving districts at a later time, even if there is not a buyer immediately interested.

Municipalities that choose to use TDR for coastal resilience can encourage new construction and increased density in less hazard prone inland areas, away from high-risk coastal zones. This can help manage development patterns and mitigate risk along vulnerable shorelines. It can also help municipalities prioritize lower density development or conservation in critical environmental areas where there may be opportunities for resource migration or enhanced floodplain function to protect against coastal hazards.

Advantages:

- Helps conserve undeveloped or underdeveloped areas to serve as habitat and flood buffers
- Helps prevent new development that is now or likely to become vulnerable to coastal hazards while still allowing sellers to benefit from the development potential of their property
- Allows communities to prioritize new and denser development in more strategic and less hazardous locations

Disadvantages:

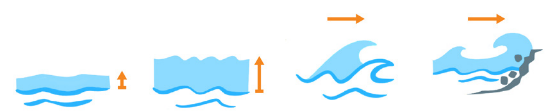
- May be difficult to set up and administer locally, especially in situations where TDR is being used cross-municipally
- Requires identification of receiving areas which can be challenging in communities that are fully built out
- Market-based approach that relies on the participation of willing sellers and buyers
- Could lead to gentrification or displacement in upland areas if not taken into account

To support communities who choose to use TDR, ResilientCoasts proposed promulgation of TDR regulations to set clear processes and criteria for municipalities, making it easier to use. It also proposes a state TDR bank to help facilitate local TDR transactions.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



SEA LEVEL RISE | STORM SURGE | WAVE ACTION | EROSION

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$
Maintenance	N/A
Difficulty	Low
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	●
Coastal Beaches / Dunes	●
Barrier Beaches	●
Coastal Banks*	●
Tidal River Floodplains	●
Coastal Floodplains	●
Ports & Working Waterfronts	○

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

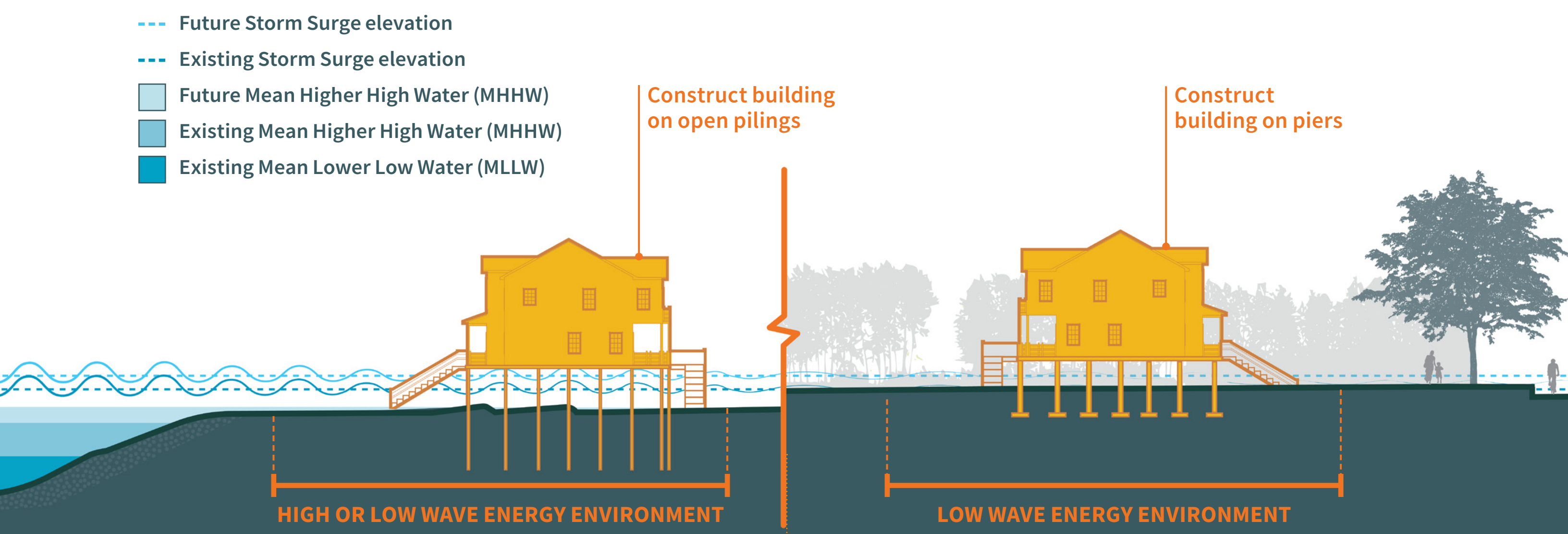
NEW BUILDING STANDARDS – Build to Design Flood Elevation

Require new development and redevelopment to be designed to a flood elevation that takes into consideration sea level rise.

Requiring new structures to be built so that the lowest floor and all plumbing, electrical systems, and ductwork are at or above a "Design Flood Elevation" can help prevent flood damage to the building and its contents. Design Flood Elevation (DFE) refers to the minimum elevation to which a structure must be elevated or floodproofed. A DFE can be identified from dynamic coastal flooding models informed by sea level rise (e.g., MC-FRM) or considering FEMA's base flood elevation (BFE) with freeboard. Freeboard is an added level of protection above BFE that accounts for uncertainties in flood mapping projections and changing conditions like sea level rise. It is typically more cost-effective to account for higher elevation of buildings during construction than to retrofit them later.

Requiring new development and substantial renovations/improvements to be elevated above projected flood levels helps minimize potential flood damages over the life of the structure. The manner of elevation should also be considered. Elevation on piers or pilings with open foundations allows water/waves and sediment to flow through/migrate underneath the structure. This strategy helps maintain sediment supply and continuity of the floodplain and is suitable (and in many cases required) in areas subject to high wave energy and high velocity waters. For more information on elevation on piers and pilings, see building retrofit measure on pg. page 176.

Local zoning for building height restrictions can be modified to allow elevation of new buildings for flood protection without reducing the amount of developable flood area. Uses below the DFE are typically limited to minor storage, parking, and building access. This measure is commonly used for 1-2 family structures but can also be used for low, mid, and high-rise residential and commercial structures as well as industrial.



Section 03: Illustrative section of constructing new buildings to a Design Flood Elevation (DFE). Drawing not to scale.

Site-specific considerations may be warranted for ports and working waterfronts so that building facilities and critical infrastructure to a future DFE does not interfere with current operations and access at the water's edge. Depending on harbor configuration and use/exposure profiles, it may be more feasible to elevate docks and piers (along with landform/access tie-ins) to future tidal or high frequency storm conditions, and consider wet and/or dry floodproofing strategies to meet the DFE for facilities with water dependent uses.

Advantages:

- Helps reduce health/safety risks to building occupants during and after floods and reduces economic damages to buildings and building contents
- May reduce flood insurance premiums and claims
- Can reduce adverse impacts to adjacent buildings and infrastructure from redirection of moving floodwaters and waves

Disadvantages:

- Can add additional up-front construction costs depending on size of structure, underlying soil/sediment, and materials used (e.g., wood or concrete)
- May pose negative impacts on pedestrian realm of streets (e.g., disconnection of streetscape primarily in urban areas and downtown areas of suburbs) if not mitigated through thoughtful street design
- Below and at-grade utilities and vehicles are still exposed to flooding
- Requires sufficient space for access elements like stairs, ramps, and elevators
- May not be suitable for areas that experience regular flood events and can increase risks to first responders facing flood hazards when responding to emergencies at structure

To support this measure, the state recently increased the freeboard requirements in the **Massachusetts State Building Code**. ResilientCoasts proposes the state establish a **Resilience Technical Subcommittee** to help inform future updates to the code including those related to design flood elevation.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE | WAVE ACTION

Scale of Implementation	Building-level
Cost	$$$$ (1 of 4)
Maintenance	N/A
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Site-Dependent
Coastal Beaches / Dunes	Site-Dependent
Barrier Beaches	Site-Dependent
Coastal Banks*	Site-Dependent
Tidal River Floodplains	High
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	Site-Dependent

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

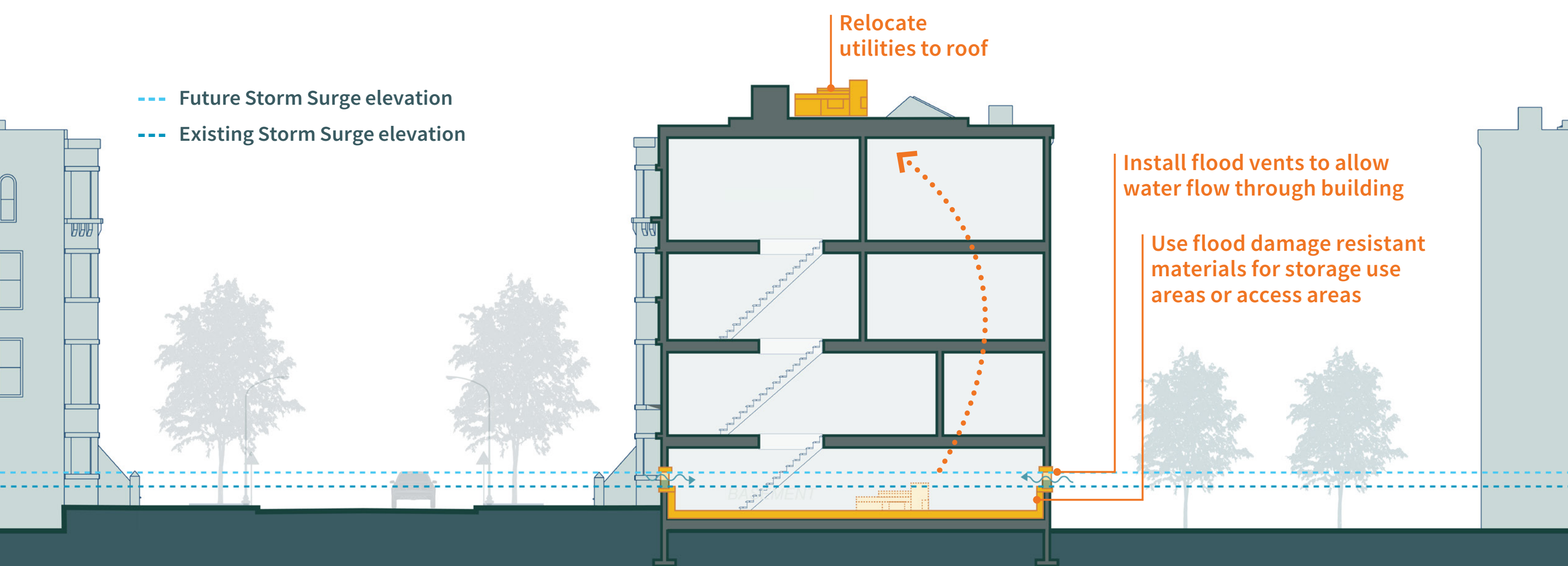
BUILDING RETROFITS – Wet Floodproofing

Retrofit existing buildings to better withstand coastal impacts by wet floodproofing and converting ground floors to floodable uses.

Existing buildings can be retrofitted with wet floodproofing techniques to reduce vulnerability to flood hazards. Wet floodproofing techniques allow a building to accommodate floodwaters by using flood damage-resistant structural and finish materials and construction techniques below the required level of protection to minimize flood damage. Wet floodproofing is required for any enclosure beneath an elevated structure in an A Zone, V Zone, or Coastal A Zone.

Wet floodproofing allows floodwaters to enter and exit the enclosed areas of a structure, equalizing hydrostatic forces on either side of the walls, reducing the loads imposed on the structure during a flood and the likelihood of structural damage. It requires the installation of flood vents throughout the exterior walls to let water enter the building and allow water forces to equalize on either side of the exterior wall. Flood-damage resistant materials are used within the wet floodproofed space to minimize damage. Any utility equipment located below the Design Flood Elevation should also be elevated or otherwise protected. For existing non-residential structures, utility equipment can be dry-proofed in a vault or dry-proofed room. Wet floodproofed spaces have limited uses because the contents may be inundated during a flood event. It is typically used for unfinished crawlspaces below the lowest occupiable floor, but can also be used for minor storage, building access, and parking garages.

Wet floodproofing often has lower upfront costs than dry floodproofing but can become expensive over time because of its exposure to floodwaters which may require extensive cleaning and/or replacement of finishes after a flood event. There may also be exposure to mold and flood-borne contaminants like sewage,



Section 04: Illustrative section of wet floodproofing measures. Drawing not to scale.

chemical, or other hazardous materials. Because of these potential costs and exposures, this measure may not be a suitable for structures that are subject to frequent flooding.

It is important to note that it may be challenging to allow for an ADA accessible means of egress during a flood event; however, elevators can be used below the Design Flood Elevation in flood zones to facilitate access and FEMA has developed design guidelines for these situations.

Advantages:

- Lower upfront costs compared to other techniques like dry floodproofing
- Can reduce structural damage to buildings from flooding, especially when used in combination with other measures like elevation
- Does not rely on advanced planning or preparation unlike some dry floodproofing techniques like deployable barriers
- May reduce flood insurance premiums and claims

Disadvantages:

- May become expensive over time because of clean up and replacement costs required after a flood event
- Can be challenging for older and historic structures with stone and brick foundations
- Only applicable for a limited number of uses and cannot be used for inhabited spaces or in certain areas with wave action or high velocity floodwaters
- Does not reduce exposure to mold or flood-borne contaminants and does not protect building contents
- Not suitable for frequently flooded structures

Standards for wet floodproofing are governed by the Federal Emergency Management Agency's National Flood Insurance Program, the Massachusetts State Building Code, and the referenced standard ASCE 24: Flood Resistant Design and Construction Standards.[101]

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE

Scale of Implementation	Building-level
Cost	$$$$
Maintenance	Low-Medium
Difficulty	Low
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Poor
Coastal Beaches / Dunes	Poor
Barrier Beaches	Poor
Coastal Banks*	Poor
Tidal River Floodplains	High
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	High

SUITABILITY High · Site-Dependent · Poor

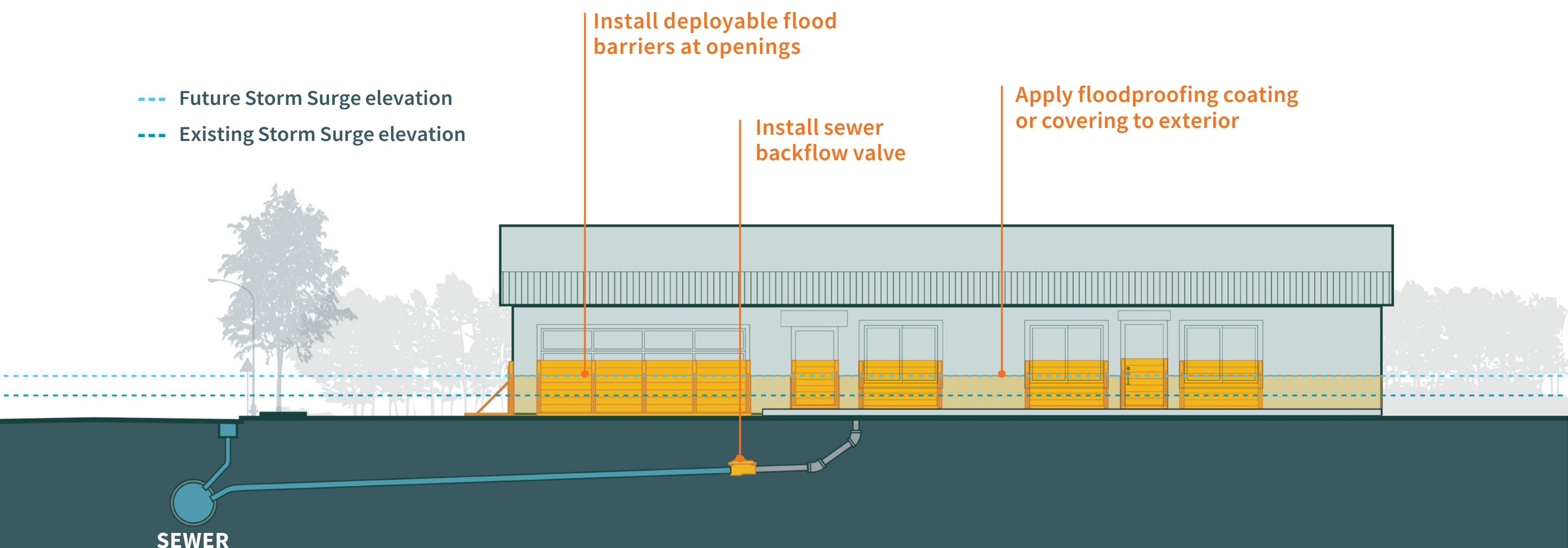
*Includes adjacent areas

BUILDING RETROFITS – Dry Floodproofing

Retrofit existing buildings to better withstand coastal impacts by dry floodproofing, raising utilities, and installing sewer backflow valves.

Existing buildings can be retrofitted using dry floodproofing, which works by sealing perimeter walls and openings to create a watertight structure. There are a variety of techniques that can be used to dry floodproof – permanent or temporary – such as physical barriers like shields or gates (often deployable), sealing techniques for utilities and building envelopes, installation of backflow valves to prevent sewer and drain back ups, and pumping techniques to remove any floodwater that does enter the building. This measure is best suited for commercial, mixed use, or community facility buildings and to address flood depths of no more than three feet above grade. Dry floodproofing cannot be used for new or substantially improved residential structures but may be used for non-substantial improvements to existing residential buildings to minimize flooding issues.

Dry floodproofing may be cost-prohibitive for low-rise retail or industrial buildings, especially for wood or steel framed buildings with wood, cladding, or cavity walls. It may be more cost effective for concrete or brick low rise retail or industrial buildings. It is also not recommended for areas that experience prolonged flood events because most sealing systems will begin to leak after prolonged exposure. Unlike wet floodproofing, the goal of dry floodproofing is to keep floodwaters out. This can help protect the building itself as well as building contents and minimizes exposure to flood-borne contaminants. However, if buildings are not designed to resist hydrostatic pressure and design loads are exceeded, buoyancy forces may cause more damage to a building than if it had been allowed to flood.



Section 05: Illustrative section of dry floodproofing measures. Drawing not to scale.

Advantages:

- Can prevent damages to a building and its contents by preventing flooding of interior spaces
- Allows for active use of the lowest floor, thereby avoiding impacts to pedestrian realm of streets (e.g., disconnection of streetscape primarily in urban areas and downtown areas of suburbs)
- Depending on technique(s) used, may have lower cleanup/ongoing maintenance costs than measures like wet floodproofing
- May reduce flood insurance premiums and claims
- May reduce economic damages to building and building contents

Disadvantages:

- May require more upfront cost than other measures like wet floodproofing and costs may increase as the height of the Design Flood Elevation increases
- May be challenging for older and historic structures with stone or brick foundations
- Can increase the risk of structural damage and failure if not designed properly to ensure the building's walls and foundation can withstand design flood loads and forces
- Techniques that require installation (like deployable flood shields and barriers), require advance planning and preparation and rely on human intervention before flood events
- Only applicable for flood depths up to three feet

Standards for dry floodproofing are governed by the Federal Emergency Management Agency's National Flood Insurance Program, the Massachusetts State Building Code, and the referenced standard ASCE 24: Flood Resistant Design and Construction Standards.[102]

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE

STORM SURGE

Scale of Implementation	Building-level
Cost	$$$$
Maintenance	Low
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Poor
Coastal Beaches / Dunes	Poor
Barrier Beaches	Poor
Coastal Banks*	Poor
Tidal River Floodplains	High
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	High

SUITABILITY High · Site-Dependent · Poor

*Includes adjacent areas

BUILDING RETROFITS – Elevate on Piers or Pilings

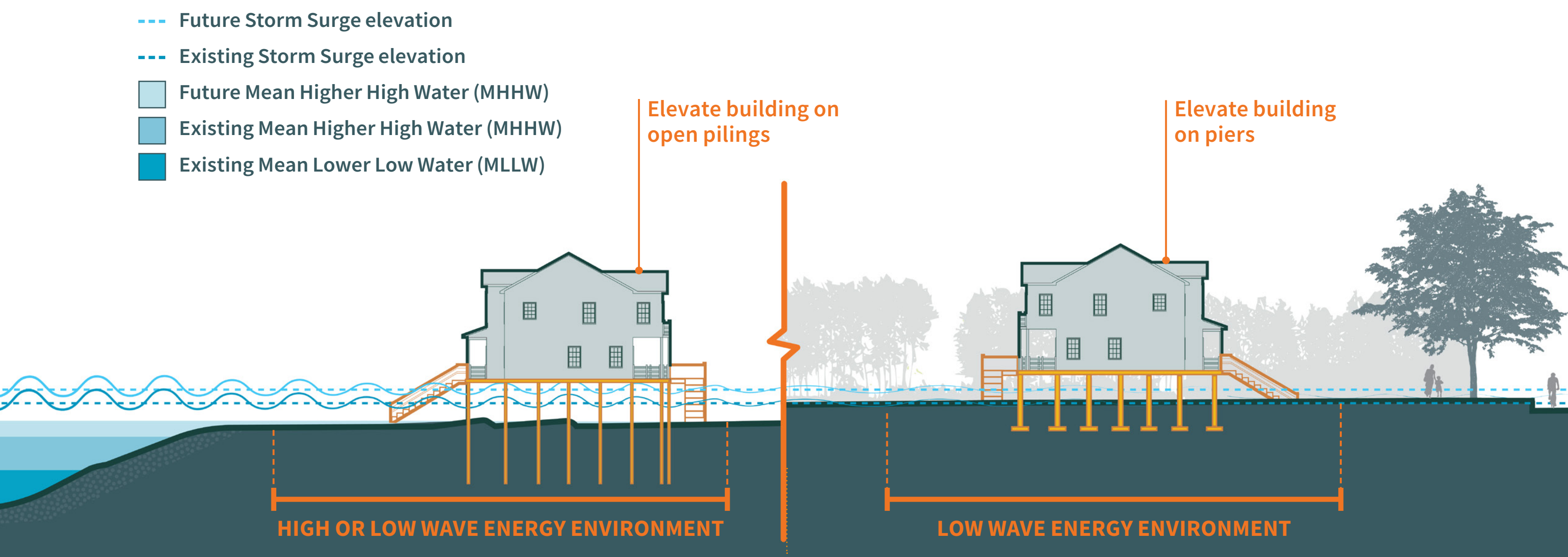
Elevate existing buildings on piers or pilings with open foundations.

As with new construction, existing buildings can be retrofitted so that the lowest floor elevation and all plumbing, electrical systems, and ductwork are at or above a Design Flood Elevation to prevent flood damage to the building and its contents.

Elevating a building on pilings with an open foundation involves driving or screwing piles (slender columns or long cylinders constructed of wood, concrete or steel) into the ground or jetting them in with a high-pressure stream of water. They are not supported by concrete footings or pads. When elevating an existing structure, a house is typically lifted and moved aside until the pilings have been installed and the existing foundation is removed. In some cases, if there is not enough space to move the house aside, it can be elevated high enough to drive or screw piles into the ground.

Because piles are driven deep, they are more resistant to greater flood loads, velocities, scour, and waves. Elevation on pilings is best suited for areas exposed to sediment transport, erosion, waves, wave overtopping, and moving water during storms. It is required under the Massachusetts State Building Code for new construction and substantial improvement in certain areas of the coast including FEMA V and Coastal A Zones, and coastal dunes. It is not currently required for AO Zones but would be highly effective in those areas as well. This measure can be used in the near-term as part of a transition strategy for highly vulnerable coastal typologies like coastal dunes, barrier beach systems, and low-lying coastal floodplains with waves and moving floodwater.

In contrast, elevation on piers uses grade beams or footings and are either attached to an existing foundation or into new concrete footings. Once the piers are in place, the structure is lowered and secured with appropriate fasteners. Any additions to a structure, including porches, chimneys,



Section 06: Illustrative section of constructing new buildings to a Design Flood Elevation (DFE). Drawing not to scale.

garages, etc., must either be removed and lifted separately or braced to stay in place. Piers are typically constructed of concrete masonry units or cast-in-place concrete reinforced with steel. Elevation on open piers is best suited for structures that experience shallow flooding and low-velocity water flow. It is not appropriate for areas exposed to erosion, waves and wave overtopping, or fast-moving water during storms.

Advantages:

- Helps reduce health/safety risks to building occupants during and after floods and reduces economic damages to building and building contents
- May reduce flood insurance premiums and claims
- Can reduce adverse impacts to adjacent buildings and infrastructure from redirection of moving floodwaters and waves
- In tidal floodplains where there is more hydraulic restriction, can help improve flood storage

Disadvantages:

- Can be expensive depending on size of structure, underlying soil/sediment, and materials used (e.g., wooden or concrete)
- May pose negative impacts on pedestrian realm of streets (e.g., disconnection of streetscape primarily in urban areas and downtown areas of suburbs) if not mitigated through thoughtful street design
- Below and at-grade utilities and vehicles are still exposed to flooding
- Requires sufficient space for access elements like stairs, ramps, and elevators
- May not be suitable for areas that experience regular flood events and can increase risks to first responders facing flood hazards when responding to emergencies at structure

To support this measure, ResilientCoasts proposes the establishment of a statewide home elevation grant or loan program to assist low-income property owners with the cost of elevating residential structures in high-risk areas. It also proposes the Division of Insurance prepare industry-wide guidance incenting Massachusetts homeowner's insurance companies to offer premium credits, reduced premiums, and deductible credits/waivers for homeowners who take steps to reduce risks to their homes.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE | WAVE ACTION

Scale of Implementation	Building-level
Cost	**$**$$$
Maintenance	Low
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Site-Dependent
Coastal Beaches / Dunes	Site-Dependent
Barrier Beaches	High
Coastal Banks*	Site-Dependent
Tidal River Floodplains	High
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	Site-Dependent

SUITABILITY High · Site-Dependent · Poor

*Includes adjacent areas

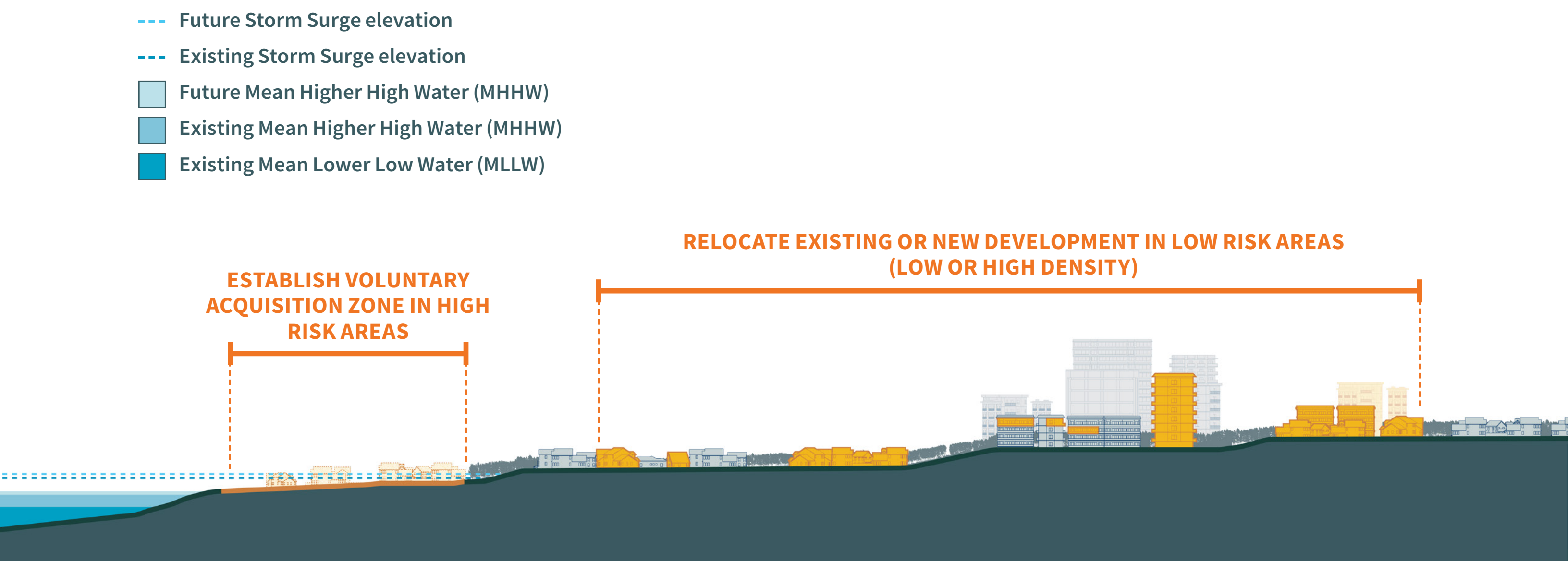
VOLUNTARY ACQUISITION – Relocate People and Housing

Establish voluntary coastal property acquisition programs including buyouts, estate planning, and conservation easements for existing residential development.

Strategic, voluntary acquisition of existing residential properties can help protect people and buildings from flooding entirely by removing them from vulnerable areas and restoring natural buffers. There are several approaches to acquisition that can be used including buyouts, estate planning, conservation restrictions, and conservation easements.

Buyout programs offer willing residential property owners an opportunity to sell their property and relocate to less risky areas. Those properties are then typically transferred to public ownership, either by a local or state government, and are permanently conserved, protected, and returned to a natural state to provide flood buffers and protection for adjacent and inland neighborhoods. These programs may be most cost-effective in areas with low density and/or low market values. They typically have the greatest impact when large contiguous areas can be bought out at once or over time. Buyouts are a good option for areas with multiple flood sources that make it challenging to mitigate flood and erosion damages to homes.

Similarly, conservation-based estate planning and conservation easements involve acquiring properties or property rights from willing private property owners. In the case of conservation-based estate planning, there are a variety of legal tools that a private property owner can use to restrict future use of the property for conservation purposes either during a conservator's lifetime or after death. In the case of easements, private property owners agree to protect, sell or otherwise transfer portions of their land, limiting future development. In some cases, the properties or conservation restrictions are held by a public entity like a local or state government and in other cases they are held by a mission-driven nonprofit entity like a land trust.



Section 07: Illustrative section of measures to relocate people and housing. Drawing not to scale.

Advantages:

- Avoids costs associated with rebuilding and rehabbing coastal structures and cleaning up marine debris and contamination after storms
- Helps preserve or enhance natural functions including flood control and sediment source of resource areas
- Can be used strategically to expand open space and restore natural areas and help protect landward areas from flooding and storm damage
- Helps reduce the risks of unplanned and involuntary displacement of people after storm events

Disadvantages:

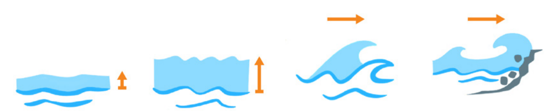
- May reduce or shift property tax base in some communities
- Can be expensive to purchase properties and take over ongoing maintenance and management after acquisition
- Process of acquiring properties can be lengthy, relies on voluntary sellers, and often times requires immediate alternate housing options

To support this measure, ResilientCoasts proposes the state undertake a study to evaluate the process of creating a statewide buyout program and based on the findings of the study, establish and capitalize a voluntary buyout program for at-risk residential properties. It also proposes state agencies assist cities and towns with tracking their repetitive loss properties (those with repeat flood damage claims), which could help inform the implementation of a voluntary buyout program.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low
Difficulty	High
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	●
Coastal Beaches / Dunes	●
Barrier Beaches	●
Coastal Banks*	●
Tidal River Floodplains	●
Coastal Floodplains	●
Ports & Working Waterfronts	○

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

AVOID RESTORE **ACCOMMODATE** PROTECT RETREAT

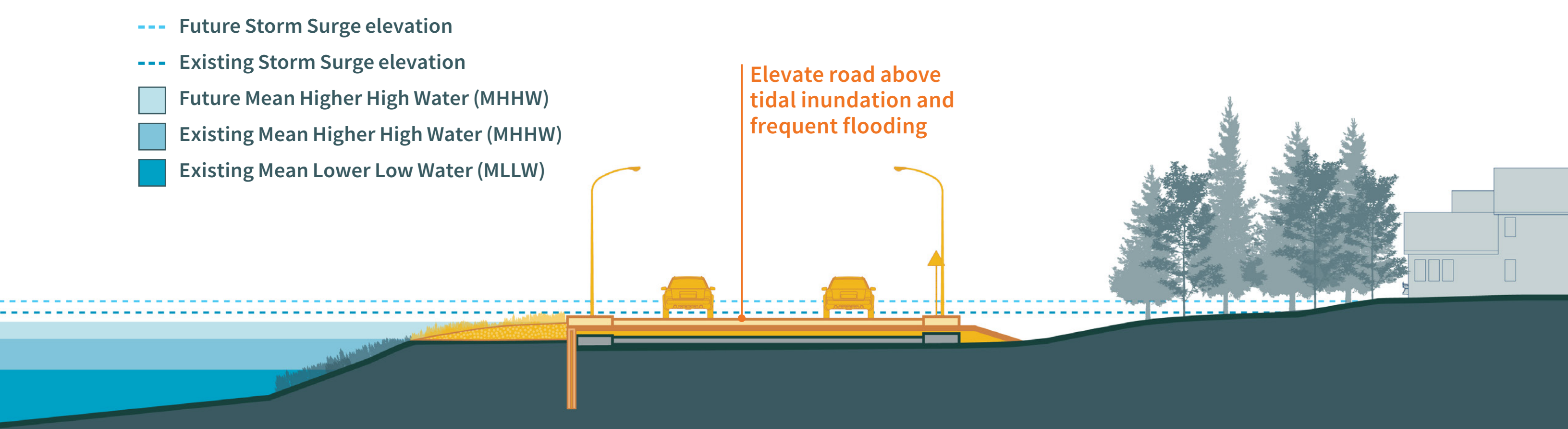
ROAD INFRASTRUCTURE – Elevate and Upgrade Associated Road Infrastructure

Elevate roadways and upgrade associated road infrastructure like culverts to create resilient transportation corridors and evacuation routes.

The planning and design of road projects should include a comprehensive vulnerability assessment of the project area for current and future coastal hazards. Elevating roads above the projected elevation and upgrading associated road infrastructure like culverts can help reduce impacts from coastal flooding. Because these projects often have large upfront capital costs, they typically work best when done on a large-scale. Prioritizing road elevation and infrastructure upgrades based on criticality may be a helpful first step before pursuing this coastal resilience measure. For example, prioritizing the elevation of roads that provide access to critical facilities or serve as evacuation routes.

The approach to road elevation requires consideration of asset criticality and adaptive capacity, considering the whole of the road network and vulnerability on different temporal scales. Depending on community goals and needs, it may be more cost-effective to allow certain road segments to temporarily flood in the near-term and focus efforts on recovery rather than adaptation. Some methods of road elevation, including raising roads on piles, can be more expensive than other measures and decision making should be driven by a cost-benefit analysis including potential ecological impacts. Every project should be designed by an engineer in accordance with best practices.

Road elevation changes must be carefully planned due to their impact on natural resources, nearby properties, and stormwater drainage systems. Coastal conditions may require measures to prevent erosion of embankments.



Section 08: Illustrative section of elevating a road above frequent flooding and tidal inundation. Drawing not to scale.

Some options include vegetated slopes and bioengineering which can offer stability where wave action is low, while sand dunes – formed with fencing and vegetation – can reduce overwash risks. All profile changes should be supported by studies evaluating alternatives and potential impacts. If elevating the roadway on an embankment creates a dam, blocks drainage and raises flood level inland, alternatives should be assessed to avoid impacts to buildings, infrastructure, and natural resources.

Culverts are tunnel structures constructed under roadways or railways to provide cross drainage from one side to the other, allowing water to flow in a controlled way. Culverts that are too small can be barriers to fish and wildlife movement, impair salt marsh habitat, limit marsh migration potential, and cause flood hazards for communities. Upgrading culverts based on current and projected hydraulic standards can allow larger flows to pass under the roadway without washing out the pavement. However, in tidal settings, this can also expose more properties to flooding. Careful consideration should be given to culvert design to ensure that projects to reduce flood hazards to roads are designed to avoid flooding of neighboring properties.

If the road is close to an eroding shoreline, elevating it may cause increased erosion of the side slope. In some situations, such as along the shoreline or in coastal dunes, where roads are prone to coastal erosion, it may be more effective to lower the road instead of elevating it, as floodwaters can wash over the road instead of the erosion undermining it and causing collapse of the roadway.

To support this measure, the state recently announced $200 million in funding for culvert and small bridge upgrades. In addition, the Massachusetts Department of Transportation is undertaking a criticality assessment that will help identify key evacuation routes statewide. ResilientCoasts proposes to build off these initiatives by undertaking a coastwide evacuation pilot study to evaluate and prioritize resources to increase resilience of road infrastructure. It also proposes adopting "build back standards" for cities and towns that receive funding from the state Disaster Recovery and Resilience Fund.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE | EROSION

Scale of Implementation	Neighborhood, Community
Cost	$$$$-$$$$
Maintenance	Medium
Difficulty	Medium-High
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	◐
Coastal Beaches / Dunes	◐
Barrier Beaches	◐
Coastal Banks*	○
Tidal River Floodplains	●
Coastal Floodplains	◐
Ports & Working Waterfronts	◐

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

Flood elevations along the immediate coast are often too high to elevate roads above the projected 1% annual chance floodplain; however, elevation can be effective at maintaining access under normal tidal conditions and minor storms. The criticality of the road should be considered in determining whether and how to elevate. Evacuation routes should be elevated above projected storm surge levels, but other roads may be raised out of the near-term chronic inundation zone (e.g., areas subject to frequent tidal flooding).

Advantages:

- Reduces health/safety risks of flooded roadways and bridge/culvert collapses
- Reduces costs of clearing and repairing flood damaged roads and operational costs of flood preparedness and response
- May maintain dry access during minor to moderate flood events
- Can improve stormwater drainage and reduce tidal and inland flooding
- Appropriately designed culverts may have habitat and biodiversity benefits associated with restored tidal flow

Disadvantages:

- Expense associated with fill, materials, utility modifications, and other costs
- May channelize or redirect floodwaters and waves to buildings at lower elevations if not properly designed
- May require stormwater pumps to remove excess water at lower elevations
- May require easement or acquisition of adjacent properties due to enlarged footprint of roadway

Low-lying road in Cohasset, MA , 2015 (Credit: CZM)

Road elevated approximately two feet in Cohasset, MA, 2025 (Credit: CZM)

AVOID RESTORE ACCOMMODATE PROTECT RETREAT

ROAD INFRASTRUCTURE – Relocate or Reroute

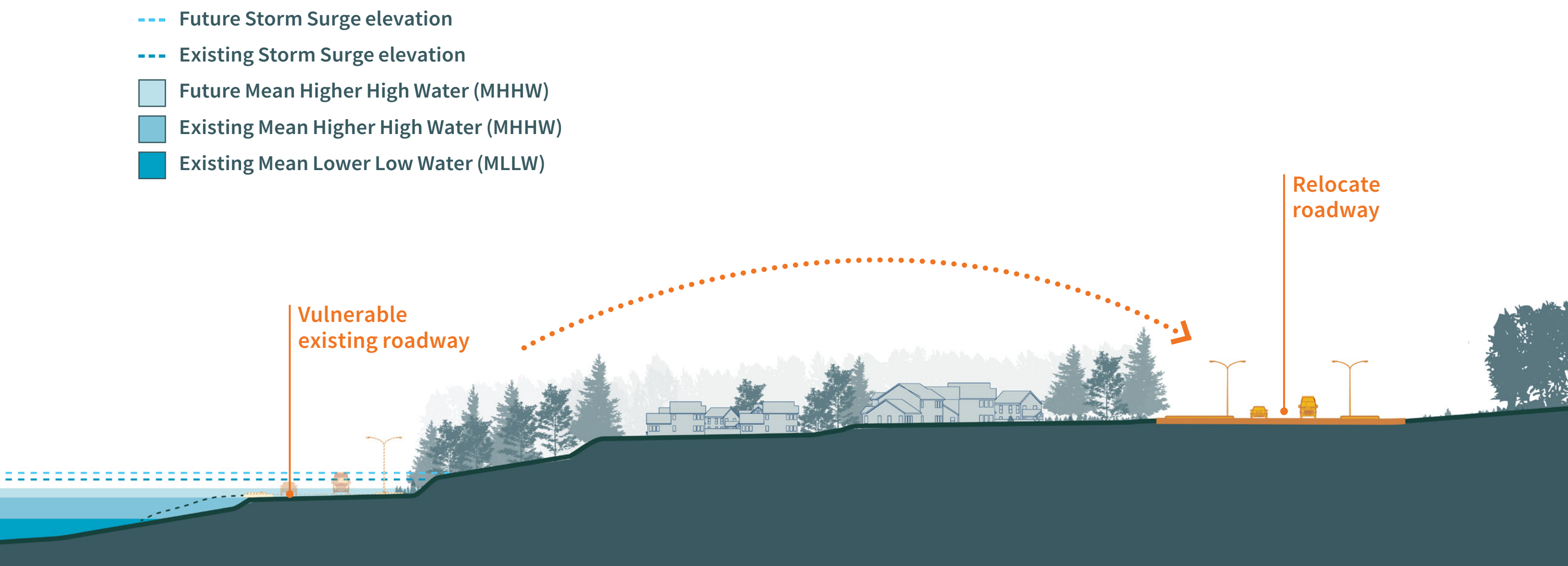
Relocate or reroute existing critical public roadways to create resilient transportation corridors and evacuation routes.

To reduce flooding on a roadway, the state and communities may consider relocating or rerouting certain high-risk roads away from flood-prone and erosion-prone areas. By relocating or rerouting the road, areas previously occupied by the road can be restored to their natural state to enhance flood protection and buffer functions.

This option may be more effective where roads are very close to an eroding and/or frequently flooded shoreline, resulting in high annual maintenance costs. This measure may also be considered where a short length of roadway is flooded and can be addressed in a targeted way.

Prioritizing relocation and rerouting of transportation corridors that are heavily used, serve as evacuation routes, or provide important or sole access to communities or critical services should be considered when evaluating this resilience measure. Relocation may also be an effective measure in areas subject to high rates of coastal erosion, permanent or frequent flood inundation, or where other measures like elevation are not feasible or cost-effective.

While the upfront capital cost of relocation can be significant, it is often more cost-effective than repairing or rebuilding roads that are exposed to regular erosion or inundation over the long-term. When evaluating relocation, communities may need to consider whether roads provide sole access to homes or infrastructure and whether alternative access can be provided.



Section 09: Illustrative section of relocating a road. Drawing not to scale.

Advantages:

- Avoids or reduces costs of repairing flood and storm damage
- Avoids loss of roadway access during and after storms
- Restores natural floodplain function in area from which the infrastructure was relocated, including space for salt marsh migration
- Can reduce new and redevelopment in hazard-prone areas

Disadvantages:

- Depends on availability and cost-effectiveness of acquiring alternative, less risky land
- May not be feasible for some critical roadways if there is not an alternative location available
- Depending on size of road segment to be relocated, can complex given the interconnected elements of infrastructure, development, and ownership

To support this measure, ResilientCoasts proposes state agencies partner with municipalities to identify priority areas for relocation of municipal infrastructure.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE | WAVE ACTION | EROSION

Scale of Implementation	Neighborhood, Community
Cost	$$$$
Maintenance	Low
Difficulty	High
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	●
Coastal Beaches / Dunes	●
Barrier Beaches	◐
Coastal Banks*	●
Tidal River Floodplains	●
Coastal Floodplains	●
Ports & Working Waterfronts	◐

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

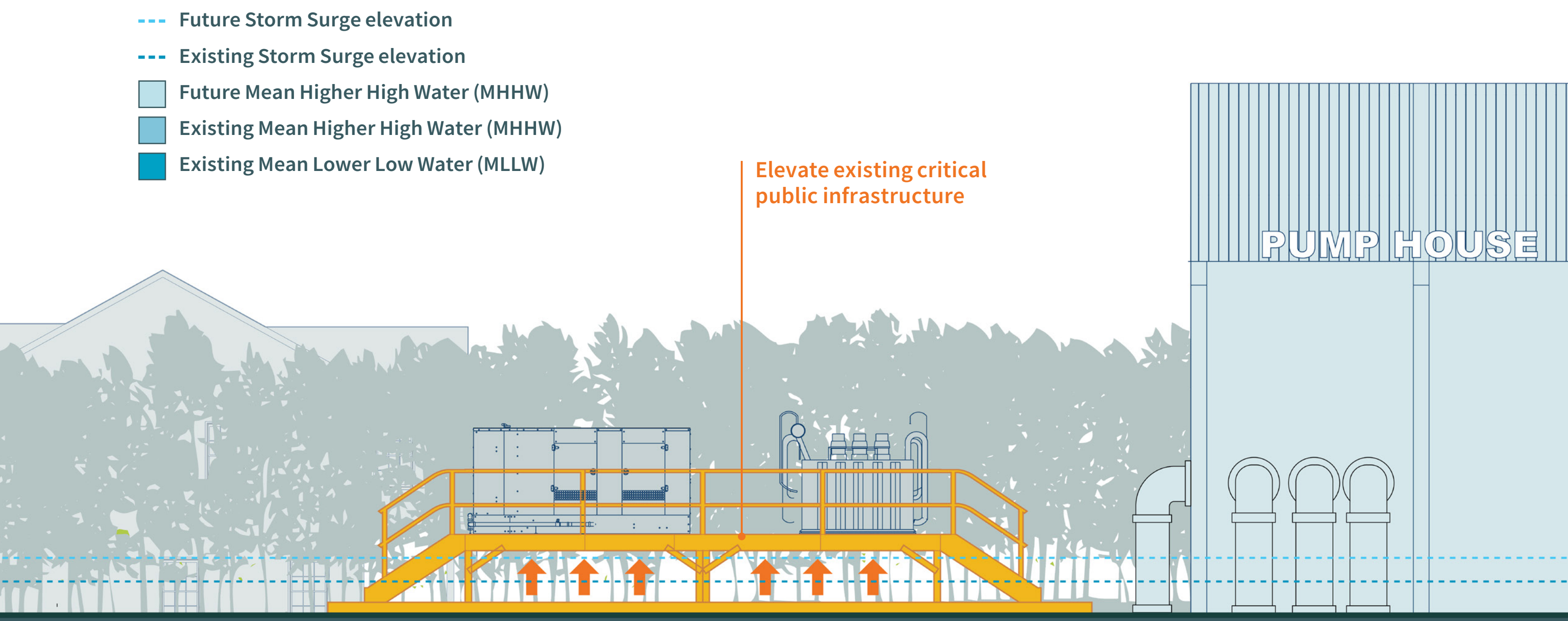
CRITICAL PUBLIC UTILITIES AND OTHER INFRASTRUCTURE – Elevate

Elevate existing critical public utilities and associated infrastructure (e.g., electrical generation, water infrastructure, telecommunications, etc.).

Critical public utilities and associated infrastructure provide essential services to residents such as drinking and wastewater treatment, electric power, and communications. Flooding of system components and facilities can damage them and cause them to stop working. Quickly flowing water can erode soil, putting structures at risk. Floodwaters carrying sediment and debris can clog screens and pumps. Hurricane winds can bring down power lines and cause other structures to collapse. Any of these impacts from hurricanes and floods can disrupt service, negatively impacting emergency management procedures and slowing the recovery process for communities.

Damage to critical public utilities and associated infrastructure can have far reaching consequences beyond the boundaries of one neighborhood or community. Many communities rely on and benefit from critical infrastructure that is sited outside of their community. Each type of infrastructure requires a tailored approach. However, when relocation is not a feasible option, communities should consider elevating these assets. In addition to structural measures, critical infrastructure systems should also have non-structural, emergency management and response measures in place.

Elevating buildings, equipment and other assets above the Design Flood Elevation can help protect them against flood damage. Elevation may be used in combination with other measures including hardening and floodproofing of buildings and facilities. For example, for wastewater treatment plants, communities can elevate control centers, equipment, and



Section 10: Illustrative section of elevating existing critical infrastructure. Drawing not to scale.

furnishings that are vital to operations to higher floors and elevate process tank pads, so they are above the Design Flood Elevation. Elevation of infrastructure requires adherence to asset-specific design standards and communities should consult an engineer to advise on the best approach based on asset-specific and site-specific circumstances of the project.

This strategy is suitable for situations where relocation to low-risk areas is too complex or costly, or where infrastructure/facilities must remain in close proximity to the areas they serve. Special consideration should be given to critical infrastructure serving densely populated areas and vulnerable populations. Elevation of certain infrastructure/facilities that need to maintain at-grade vehicular/equipment access may require elevation on fill which is not allowed in flood zones subject to high or moderate wave action and may increase runoff, displace floodwater, or have other negative impacts on adjacent buildings, properties, wetlands, and erodible surfaces.

Advantages:

- Reduces health/safety risks for residents and essential workers
- Reduces the costs of repairing flood and storm damage
- May avoid the loss of critical services during and after flood events

Disadvantages:

- Expense due to existing limitations, including structural conditions and need to modify other interconnected building systems and site infrastructure (e.g., pipes, wiring, routes, etc.)
- May facilitate or incentivize new and expanded development of flood-prone areas

To support this measure, the state is developing resilience design guidance for critical public infrastructure like wastewater treatment plants. ResilientCoasts proposes several actions related to electric and gas utility resilience including establishing resilience metrics to inform the development of state-mandated Climate Vulnerability and Resilience Plans. It also proposes a state revolving loan fund to assist municipalities with climate resilience projects and a study to assess the exposure of underground infrastructure to sea level rise.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE

STORM SURGE

Scale of Implementation	Neighborhood, Community
Cost	$$$$-$$$$
Maintenance	Low-Medium
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Site-Dependent
Coastal Beaches / Dunes	Site-Dependent
Barrier Beaches	Site-Dependent
Coastal Banks*	Poor
Tidal River Floodplains	High
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	High

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

CRITICAL PUBLIC UTILITIES AND OTHER INFRASTRUCTURE – Relocate

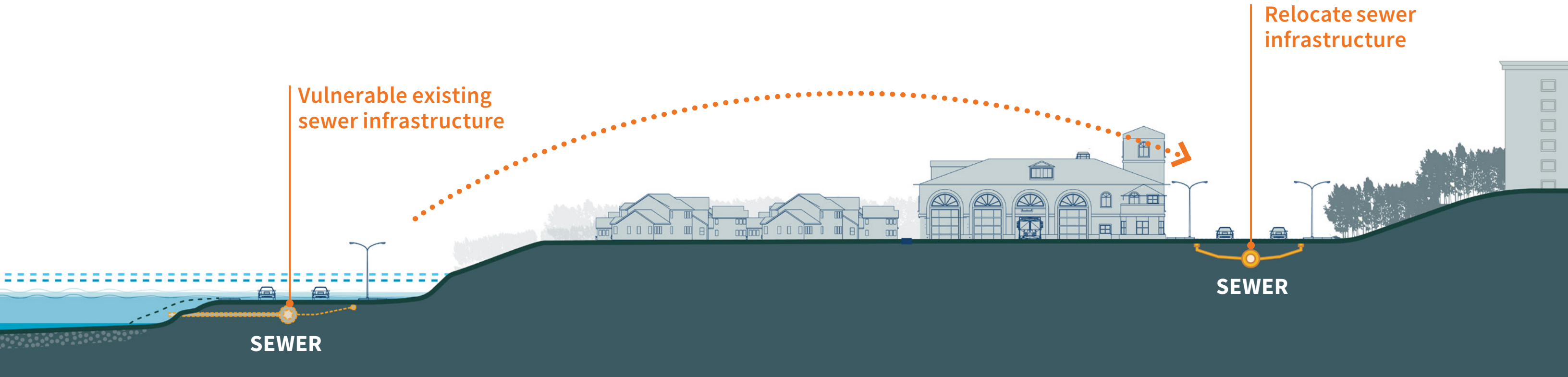
Relocate existing critical public utilities and associated infrastructure (e.g., electrical generation, water infrastructure, telecommunications, etc.) to areas with less exposure to coastal hazards.

Critical public utilities and associated infrastructure provide essential services to residents such as drinking and wastewater treatment, electric power, and communications. Erosion or flooding of system components and facilities can damage them and cause them to stop working. Waves and quickly flowing water can erode soil, putting structures at risk. Floodwaters carrying sediment and debris can clog screens and pumps. Hurricane winds can bring down power lines and cause other structures to collapse. Any of these impacts from hurricanes and floods can disrupt service, negatively impacting emergency management procedures and slowing the recovery process for communities.

Damage to critical public utilities and associated infrastructure can have far reaching consequences beyond the boundaries of one neighborhood or community. Many communities rely on and benefit from critical infrastructure that is sited outside of their community. Each type of infrastructure requires a tailored approach. However, relocation of these assets is the best way to avoid risks and reduce costs associated with repairing storm damage and the risks to health and safety of service outages.

Relocation is likely most feasible near-term in situations where infrastructure and facilities do not need to be in close proximity to the areas they serve (e.g., sewer infrastructure). In some cases, relocation of critical infrastructure may need to accompany complementary measures like relocation and people, buildings, and roads, in order to maintain services. Within coastal floodplains, relocation should be prioritized for areas with high erosion rates, repetitive damage, and FEMA V, AO, and Coastal A Zones.

- Future Storm Surge elevation
- Existing Storm Surge elevation
- Future Mean Higher High Water (MHHW)
- Existing Mean Higher High Water (MHHW)
- Existing Mean Lower Low Water (MLLW)



Section 11: Illustrative section of relocating critical public infrastructure. Drawing not to scale.

Advantages:

- Reduces health/safety risks for residents and essential workers
- Avoid costs of repairing flood and storm damage
- Avoids loss of critical public services during and after storm events
- Can restore natural floodplain functions in areas from which infrastructure is relocated, including space for salt marsh migration
- Can reduce or discourage new and redevelopment in flood-prone areas

Disadvantages:

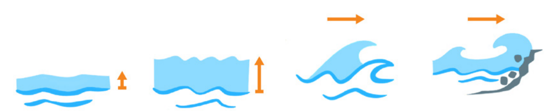
- Expense due to existing limitations, including structural conditions and need to modify other interconnected building systems and site infrastructure (e.g., pipes, wiring, routes, etc.), availability or cost of acquiring an alternative less risky property, and combined costs of decommissioning old infrastructure and new construction
- May redistribute environmental, public health, and other externalities associated with the infrastructure to other communities, which could be an environmental justice issue

To support this measure, ResilientCoasts proposes state agencies partner with municipalities to identify priority areas for relocation of municipal coastal infrastructure.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



Scale of Implementation	Neighborhood, Community
Cost	$$$$-$$$$
Maintenance	Low
Difficulty	High
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	High
Coastal Beaches / Dunes	High
Barrier Beaches	Site-Dependent
Coastal Banks*	High
Tidal River Floodplains	Site-Dependent
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	Site-Dependent

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

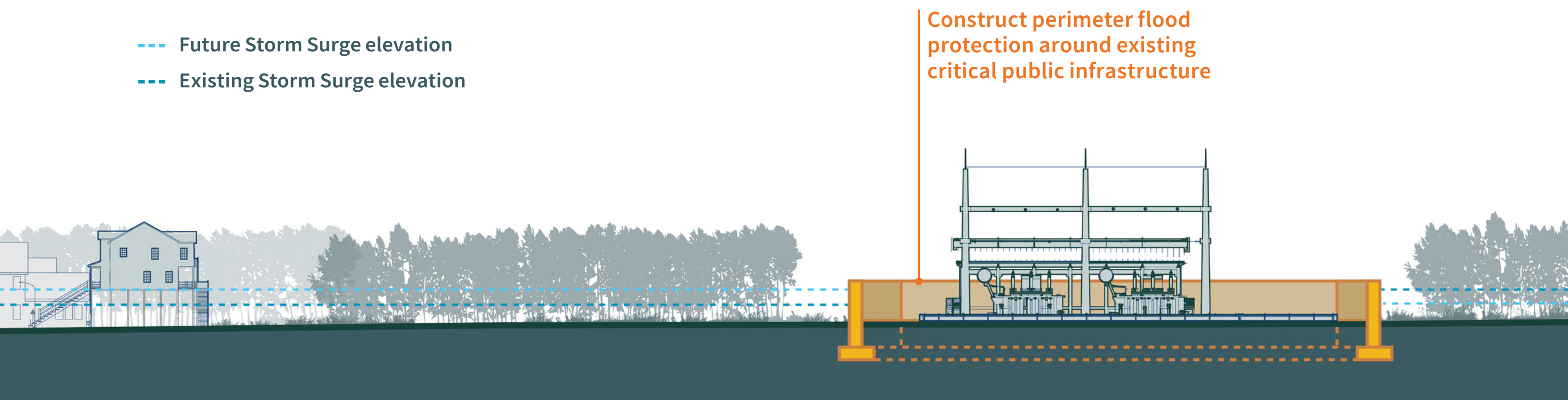
CRITICAL PUBLIC UTILITIES AND OTHER INFRASTRUCTURE – Harden / Floodproof

Implement hardening or floodproofing techniques for expanded or substantially renovated critical public utilities and associated infrastructure (e.g., electrical generation, water infrastructure, telecommunications, etc.).

Critical public utilities and associated infrastructure provide essential services to residents such as drinking and wastewater treatment, electric power, and communications. Flooding of system components and facilities can damage them and cause them to stop working. Quickly flowing water can erode soil, putting structures at risk. Floodwaters carrying sediment and debris can clog screens and pumps. Hurricane winds can bring down power lines and cause other structures to collapse. Any of these impacts from hurricanes and floods can disrupt service, negatively impacting emergency management procedures and slowing the recovery process for communities.

Damage to critical public utilities and associated infrastructure can have far reaching consequences beyond the boundaries of one neighborhood or community. Many communities rely on and benefit from critical infrastructure that is sited outside of their community. Each type of infrastructure requires a tailored approach. However, when relocation and elevation are not feasible, communities should consider using other measures to "harden" these assets to limit or reduce damage from coastal hazards. Hardening can be used in combination with other measures like elevation to further increase the resilience of assets. In addition to structural measures, critical infrastructure systems should also have non-structural, emergency management and response measures in place.

"Hardening" is a catch-all term for a wide range of physical improvements and techniques used to make infrastructure more resistant to damage from storms and flooding, including undergrounding utility wires, using stronger waterproof materials, updating design standards for things like wires and poles, adding system redundancy, and using the latest technology for things like meters, monitoring equipment, and switches. Some of these measures may incorporate previously discussed dry and wet floodproofing techniques for support buildings.



Section 12: Illustrative section of hardening/protecting existing critical public infrastructure. Drawing not to scale.

This strategy may be suitable for situations where relocation to low-risk areas is too complex or costly, or where infrastructure/facilities must remain in close proximity to the areas they serve. It can, and often is, implemented in combination with elevation. The use of dry and wet floodproofing as part of a hardening strategy is highly dependent on the type of infrastructure or facility. Dry and wet floodproofing is prohibited for residential structures or residential areas of mixed-use structures. Wet floodproofing is only allowed for enclosures used solely for parking, access, storage, or functionally dependent structures due to proximity to water.

Advantages:

- Reduces health/safety risks for essential workers
- Reduces costs of repairing flood and storm damage
- Avoids or minimizes loss of critical services during floods and increases the speed of service recovery afterwards
- Can be a more cost-effective alternative when relocation is prohibitive

Disadvantages:

- Expense due to existing limitations including structural conditions and the need to replace building materials or modify building systems
- Certain outdoor infrastructure and facilities may require installation of temporary or permanent floodwalls which can channelize flow and increase flood velocities, negatively impacting adjacent structures, properties, natural resources, and erodible surfaces
- May provide an incentive for new development or expansion of existing development in flood-prone areas

To support this measure, the state is developing resilience design guidance for critical public infrastructure like wastewater treatment plants. ResilientCoasts proposes several actions related to electric and gas utility resilience including establishing resilience metrics to inform the development of state-mandated Climate Vulnerability and Resilience Plans. It also proposes a state revolving loan fund to assist municipalities with climate resilience projects and a study to assess the exposure of underground infrastructure to sea level rise.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE

STORM SURGE

Scale of Implementation	Neighborhood, Community
Cost	$$$$-$$$$
Maintenance	Medium
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*

Coastal Beaches / Dunes

Barrier Beaches

Coastal Banks*

Tidal River Floodplains

Coastal Floodplains

Ports & Working Waterfronts

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

AVOID RESTORE ACCOMMODATE PROTECT RETREAT

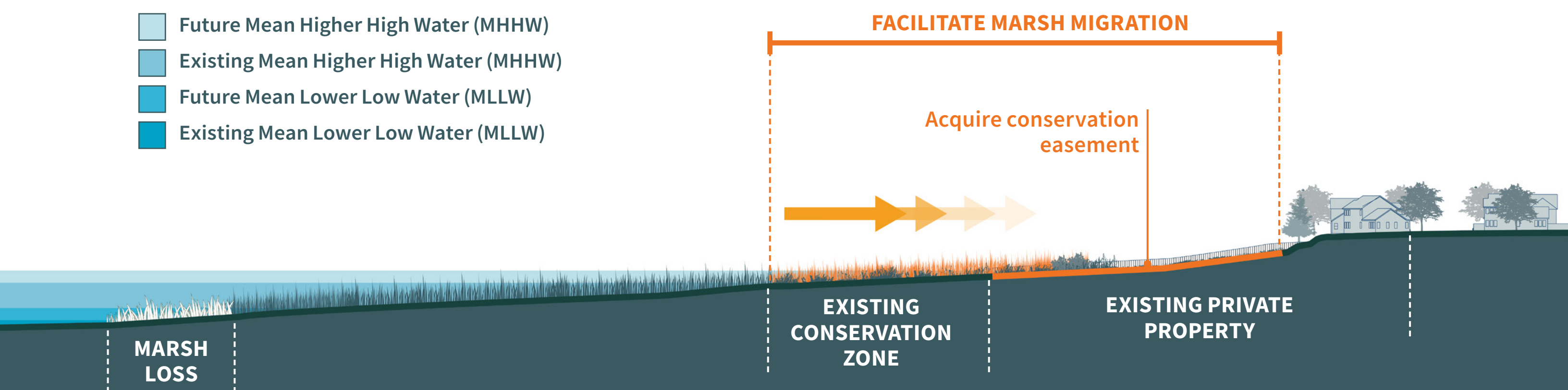
LAND PROTECTION – Protect Natural Resource Areas, Migration Pathways, and Enhance Buffers

Protect natural resource areas, migration pathways, and enhance buffers through land acquisition, rolling easements, and other mechanisms to protect land from coastal hazards and leverage land for coastal resilience.

Similar to the voluntary acquisition of residential properties, protection of natural resource areas, migration pathways and buffers involves acquiring privately-owned land outright or protecting it through other legal mechanisms like rolling easements. Unlike the voluntary acquisition measure, which is in part aimed at relocating people and structures or supporting infrastructure at risk, this strategy is primarily aimed at natural resource protection and migration.

Properties may be acquired outright and held by public, private, or nonprofit entities with the goal of protecting and conserving the land. Enhancing present and future connectivity of ecosystems requires a coordinated approach. This can be maximized by using strategic land acquisitions to connect already protected lands and waters. Not all adjacent areas are suitable for natural resource migration but are likely important buffers for resource areas. Enhanced incentives to support coastal land acquisition may be necessary to offset costs and encourage set asides for conservation purposes instead of development. Analysis and prioritization of important migration areas at the municipal and district level will help support strategic acquisition.

Rolling conservation easements, as opposed to outright land acquisition, affects a portion of a property and reflects the dynamic nature of the shoreline and/or resource areas. A rolling easement is a legally enforceable expectation that the shoreline or resource area can migrate inland instead of being squeezed between rising sea levels and a fixed property line or physical structure. The term refers to a broad collection of legal options, many of which do not involve actual easements. A rolling easement can take many forms including a law that prohibits shore protection or a property



Section 13: Illustrative section of example measures to facilitate marsh migration. Drawing not to scale.

right to ensure that wetlands, beaches, barrier islands, or access along the shore moves inland with the natural retreat of the shore. Rolling easements allow for limited development of upland areas of the property but restrict development along the shoreline or resource area. Therefore, the use of the property “rolls” upland as sea levels rise and shorelines change, facilitating the migration of buffers, beaches, dunes, barrier beaches and wetlands.

Advantages:

- Preserves natural functions including storm damage prevention and flood control to protect landward areas and sediment resource areas
- Protects biodiversity and ecosystem services
- Reduces need for regular response and recovery for hazard-prone development

Disadvantages:

- Expense of acquiring coastal properties
- May be complex to institute requirements that affect private property rights
- Relies on participation of private property owners and may reduce tax base in some communities

To support this measure, the state’s Resilient Lands Initiative is working to speed up land conservation through a collaboration between government agencies and nonprofit land trusts to achieve the goal of conserving 30 percent of land statewide by 2030 and 40 percent by 2050. ResilientCoasts proposes to build on this work by forming a stakeholder group to inform the prioritization of state funding for acquisition and restoration of salt marshes and identify marsh migration zones coastwide.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE

EROSION

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low
Difficulty	Medium
Design Life	Long-term

COASTAL TYPOLOGIES

Salt Marshes*	●
Coastal Beaches / Dunes	●
Barrier Beaches	●
Coastal Banks*	◐
Tidal River Floodplains	●
Coastal Floodplains	◐
Ports & Working Waterfronts	○

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

NATURE-BASED SOLUTIONS – Waterfront Parks and Open Spaces

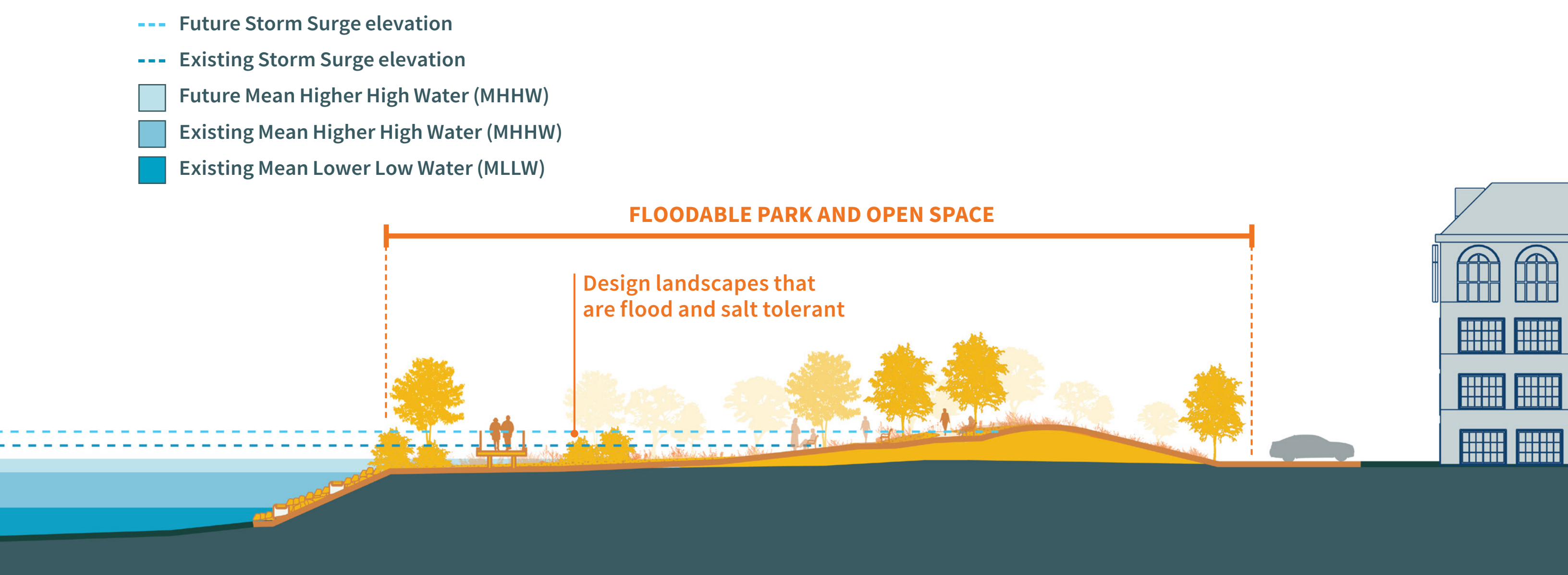
Design waterfront parks and open spaces to absorb and accommodate flooding.

Waterfront parks and open spaces can be designed to incorporate landscape features such as green infrastructure like rain gardens and bioswales, drainage systems, detention and infiltration basins, native plantings that can tolerate inundation and changing water levels, and other adaptive measures that can help areas to recover more quickly from coastal flooding and storm events. Along shorelines, parks and open spaces can be designed to gradually slope or have natural buffers like salt marsh or vegetated banks.

By intentionally designing waterfront parks to be floodable with minimal damage, these spaces can serve as a waterfront buffer and provide flood protection to upland and adjacent areas as well as numerous other co-benefits like public waterfront access and recreational use.

Waterfront parks and open spaces also promote community health and well-being. In addition to coastal flooding, waterfront parks and open spaces can help manage stormwater flooding and the impacts of compound flooding – in some cases collecting and storing stormwater. Other elements like grading, terracing, and berms can help slow floodwaters and block storm surge from inundating surrounding site and neighborhoods. They can be designed to block flood pathways from homes and infrastructure and redirect water to existing water bodies or infiltration or retention areas.

Communities should consider that one unintended consequence of park and open space improvements can be the potential for gentrification and displacement due to rising property values that occur as a result of improvements. While rising property values is not inherently bad, communities can consider appropriate guardrails that help address this potential.



Section 14: Illustrative section of floodable waterfront open spaces. Drawing not to scale.

Advantages:

- Provides protection to adjacent upland areas
- Can be incorporated into the redesign of existing waterfront open spaces and underused waterfront areas making it more cost effective than purchasing new waterfront property
- Provides numerous co-benefits including recreational and public access opportunities
- Allows for the integration of stormwater infrastructure to treat coastal contaminants in runoff

Disadvantages:

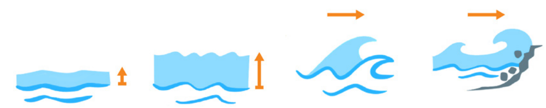
- Requires preservation of undeveloped space or removal or relocation (undevelopment) of existing properties along the shoreline
- Requires ongoing maintenance and operation
- May not be feasible in dense areas where land availability is limited and there is high competition for other land uses

To support this measure, the state administers several grant programs that financially support municipalities in the acquisition of recreation land, development of new parks, or the renovation of existing parks, including the Municipal Vulnerability Preparedness Grant Program and the Parkland Acquisitions and Renovations for Communities Grant Program. ResilientCoasts proposes new grant criteria and funding opportunities focused on district-scale resilience measures, which may include leveraging waterfront parks and open spaces.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



Scale of Implementation	Parcel, Neighborhood
Cost	\$\$\$\$-\$\$\$\$
Maintenance	Medium
Difficulty	Low
Design Life	Medium-term to Long-term

COASTAL TYPOLOGIES

Salt Marshes*	Site-Dependent
Coastal Beaches / Dunes	High
Barrier Beaches	High
Coastal Banks*	High
Tidal River Floodplains	High
Coastal Floodplains	High
Ports & Working Waterfronts	Site-Dependent

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

AVOID RESTORE ACCOMMODATE PROTECT RETREAT

NATURE-BASED SOLUTIONS – Beach and Dune Restoration

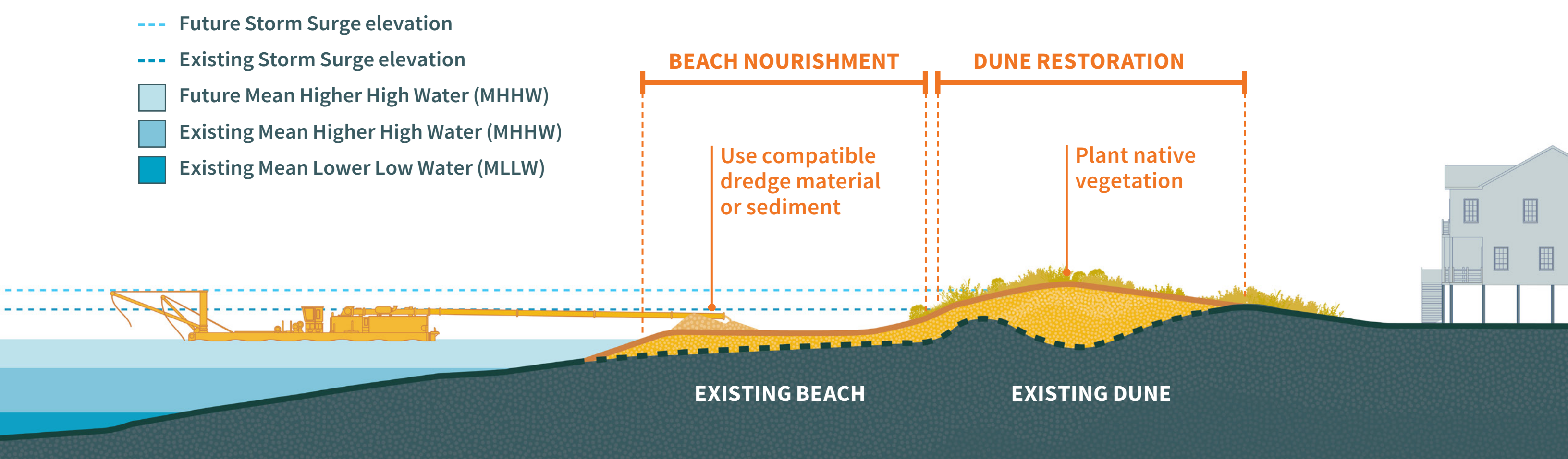
Implement beach and dune restoration/ nourishment projects using compatible sediment to mitigate erosion and reduce wave energy.

Beach and dune nourishment are types of living shoreline projects. Both project types require suitable sediment which may be sourced from inland/upland mining, dredge materials, and/or offshore mining. Nourishment should be carefully designed in areas with nearby salt marsh, rocky intertidal habitat, threatened or endangered species habitat or nearshore eelgrass.

Beach nourishment refers to the process of adding sediment (compatible sand or mixed sediment) to an eroding, narrow or low beach to protect the shoreline from erosion, flooding, and storm damage. Sediment is added to widen or elevate the beach to maintain or advance the shoreline seaward. Beach nourishment is most suitable for sites with a gentle slope and minor upland erosion, on existing beaches with some sand present, areas in close proximity to planned channel dredging projects, and areas with development and/or infrastructure at risk from erosion and flooding behind the beach.

Dune restoration is often carried out as part of a beach nourishment project. Existing dunes may be enhanced, or new artificial and sacrificial dunes may be created to improve the flood protection to landward areas. Dunes often need stabilization, which can be done using dune fencing or planting vegetation to trap the sand. This can also help reduce trampling of dune areas. When restoring dunes, native, deep-rooted vegetation should be used to enhance stability.

Economical sediment sourcing is a constraint for large nourishment projects, but large projects are typically the most technically effective and require less frequent maintenance. Nourishment is also most suitable for supplementing beach/ dune areas with existing sources of sand and sediment transport systems. It is not suitable on a shoreline with very high erosion rates because maintenance is typically cost prohibitive. The lifespan of beach projects varies based on erosion and long-shore sediment transport rates, the nourishment cycle and the frequency of major storms.



Section 15: Illustrative section of beach and dune restoration. Drawing not to scale.

Beach and dune nourishment is often used in combination with other coastal resilience measures like elevating buildings or redesigning or retrofitting existing seawalls. Some communities may use beach nourishment as a transitional strategy, recognizing that it is not a sustainable strategy long-term due to costs and availability of sediment, but provides some protection in the near-term and has secondary community benefits such as recreation or habitat enhancement. This is particularly true in places with heavily developed or altered beaches, where the combination of sea level rise and the fixed location of development and infrastructure inhibits the dynamic movement of the beach, causing the beach to erode and narrow.

Advantages:

- Mitigates lack of natural sediment supply or where sediment has been cut off from the beach by a coastal engineering structure
- Can expand usable beach area, increasing public access and recreational use
- Can help protect public and private infrastructure from wave overtopping
- Fewer environmental impacts compared to hard coastal engineering structures (except where nourishment covers rocky intertidal shoreline in areas where sediment starvation has resulted in significant loss of beach)
- Can be a beneficial reuse of dredge material

Disadvantages:

- Requires periodic renourishment and replanting, especially after major storm events
- Sediment sourcing can make projects more expensive and less feasible over time
- May not be a long-term solution in all locations and requires site-specific analysis to determine benefit-cost

To support this measure, the state administers a number of grant programs that provide funding for beach nourishment, including the CZM Coastal Resilience Grant Program. The state is also studying sediment sources including a sampling of key offshore sand areas. ResilientCoasts proposes to build on these efforts by investing in regional sediment management, undertaking a benefit-cost analysis of sand placement to inform policies on the use of offshore sediment, identifying priority areas for beach nourishment, and developing criteria to inform limitations on state-supported emergency sand placement.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE | STORM SURGE | WAVE ACTION | EROSION

Scale of Implementation	Neighborhood
Cost	$$$$-$$$$
Maintenance	Medium-High
Difficulty	Medium-High
Design Life	Short-term to Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Site-Dependent
Coastal Beaches / Dunes	High
Barrier Beaches	High
Coastal Banks*	Site-Dependent
Tidal River Floodplains	Poor
Coastal Floodplains	Poor
Ports & Working Waterfronts	Poor

SUITABILITY High · Site-Dependent · Poor

*Includes adjacent areas

NATURE-BASED SOLUTIONS – Bank Stabilization

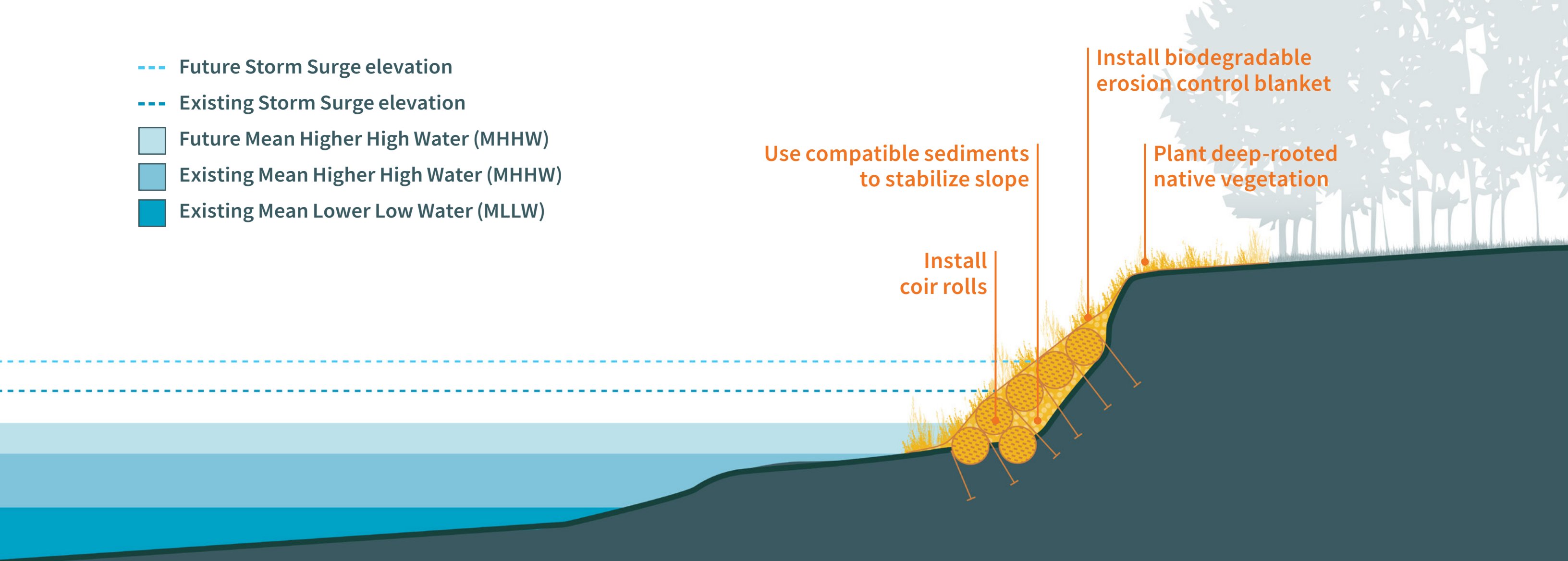
Implement nature-based stabilization using compatible sediments, biodegradable materials, and erosion control plantings with deep roots to stabilize banks.

Coastal banks act as vertical buffers to tides, waves, and storm surge. A rapidly eroding coastal bank endangers property at the top and landward of the bank. An unstable slope is extremely vulnerable and can result in slumping or collapse. Bioengineering projects stabilize eroding coastal banks using a combination of regrading, deep-rooted plants, and erosion-control products that are made of natural, biodegradable materials. Nature-based bank stabilization is a type of living shoreline project.

Here are two common bioengineering products:

- **Natural Fiber Blankets** - Mats made of natural fibers, such as straw, burlap, and coconut husk, which is also called coir. Some natural fiber blankets are made of loosely woven coir twine and others are made of straw, coconut, or a mix of fibers held together with netting made from coir or other materials. The blankets are used to help reduce erosion of exposed soil, sand, and other sediments from wind, waves, and overland runoff.
- **Coir Rolls** - Cylindrical rolls composed of coir fibers and held together with fiber mesh. The rolls typically span 12-20 inches in diameter and 10-20 feet in length. They can be stitched together to provide continuous coverage at the toe of the bank. Coir rolls should not be confused with coir envelopes, which are coir fabric filled with sand. Coir envelopes have very different impacts and design considerations.

For coastal bank projects, natural fiber blankets and coir rolls can be used on both sheltered sites and sites exposed to wave energy. However, they are most effective in areas with higher beach elevations with some dry beach at high tide, where the rolls are not constantly subject to erosion from tides and



Section 16: Illustrative section of bank stabilization. Drawing not to scale.

waves. If the dry beach is narrow, the beach elevation is relatively low, and/or the site is exposed to moderate wave energy, more than one row of coir rolls will likely be needed on the face of the bank, as well as at the base.

Natural fiber blankets will not prevent erosion on unstable slopes or in areas subject to erosion from high tides or storm waves. On banks where the toe is subject to erosion from tides or storm waves, it may be appropriate to combine natural fiber blankets and vegetation with other shoreline stabilization options, including beach nourishment.

Coir rolls can be installed to protect the base of the bank. In these exposed conditions, the rolls will likely have a shorter lifespan and will require more frequent maintenance such as resetting, anchoring, or replacement. Sediment can also be brought in from off-site sources to increase beach width and dune volume to help dissipate wave energy before it reaches the bank.

Advantages:

- Fewer environmental impacts than coastal engineering structures
- Provides direct physical protection from erosion while allowing limited natural erosion to supply down-drift beaches
- Use of native vegetation provides habitat co-benefits

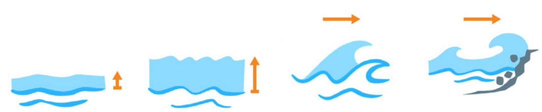
Disadvantages:

- Requires ongoing maintenance, especially after storms
- Is not likely to be effective in areas with high-energy wave climate, high current velocities, or significant vessel wakes
- Highly susceptible to changes in inundation level resulting from sea level rise, storm surge, or other protection measures

The Massachusetts Office of Coastal Zone Management's (CZM) StormSmart Program has developed fact sheets for property owners to learn more about bank stabilization techniques including bioengineering/coir rolls/natural fiber blankets on coastal banks.[103]

CONSIDERATIONS

Coastal Hazards



Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Medium
Difficulty	Medium
Design Life	Short-term to Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	○
Coastal Beaches / Dunes	○
Barrier Beaches	○
Coastal Banks*	●
Tidal River Floodplains	●
Coastal Floodplains	●
Ports & Working Waterfronts	○

SUITABILITY ● High ◐ Site-Dependent ○ Poor

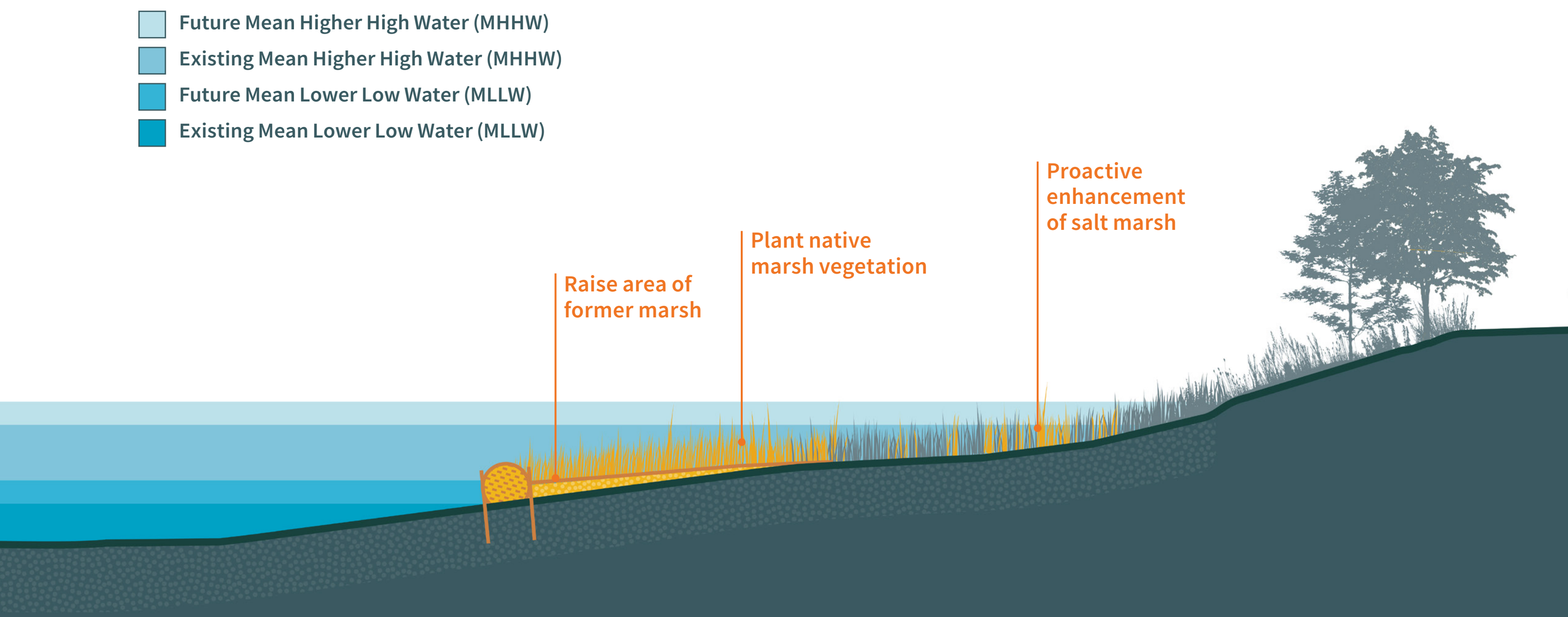
*Includes adjacent areas

NATURE-BASED SOLUTIONS – Enhance Fringing Salt Marsh

Implement nature-based techniques to enhance natural patchy or contiguous marsh fringes to reduce coastal hazards and protect critical infrastructure.

Enhancing and restoring fringing marsh, a type of living shoreline project, presents an opportunity to implement nature-based techniques to enhance the function of these habitats and reduce coastal hazards. In contrast with other ecological restoration techniques, the primary goal of this method is to reduce coastal hazard risks to critical infrastructure. Enhancing areas of former salt marsh and/or existing but degraded fringing salt marsh also provides important habitat co-benefits, particularly in areas with limited salt marsh extent. Techniques may include restoring hydrology, managing invasive plants, planting native marsh vegetation, and/or using toe protection such as coir logs to hold the toe of the enhanced marsh platform in place as needed. However, toe protection may be more likely and needed in projects where more marsh area or elevation is being created.

This strategy is likely to be most effective in areas where salt marsh is currently or was formerly present on the shoreline. It is generally used to protect adjacent infrastructure, control erosion, and stabilize the shoreline, but may also provide wave attenuation benefits if the area is large enough. It is best suited for low energy areas with flat to moderate slopes, and smaller tidal ranges, to allow for structural stability and a surface where vegetation can be established.



Section 17: Illustrative section of salt marsh enhancement measures. Drawing not to scale.

Advantages:

- Restores or maintains habitat and allows for links between marine, intertidal, and upland habitats
- Maintains natural shoreline dynamics and sand movement
- Provides more potential to improve water quality at a site scale compared to traditional grey infrastructure by replicating or enhancing habitat function
- Can help maintain ability of salt marshes to buffer impacts, stabilize shorelines, and/or reduce erosion

Disadvantages:

- Not suitable for high wave energy environments
- Installations in higher tidal ranges may require larger structural elements for stability of the enhanced shoreline, increasing erosion, scour, and habitat concerns

To support this measure, ResilientCoasts proposes to build on this work by forming a stakeholder group to inform the prioritization of state funding for acquisition and restoration of salt marshes and identify marsh migration zones coastwide.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low
Difficulty	Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	●
Coastal Beaches / Dunes	◐
Barrier Beaches	◐
Coastal Banks*	○
Tidal River Floodplains	◐
Coastal Floodplains	◐
Ports & Working Waterfronts	○

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

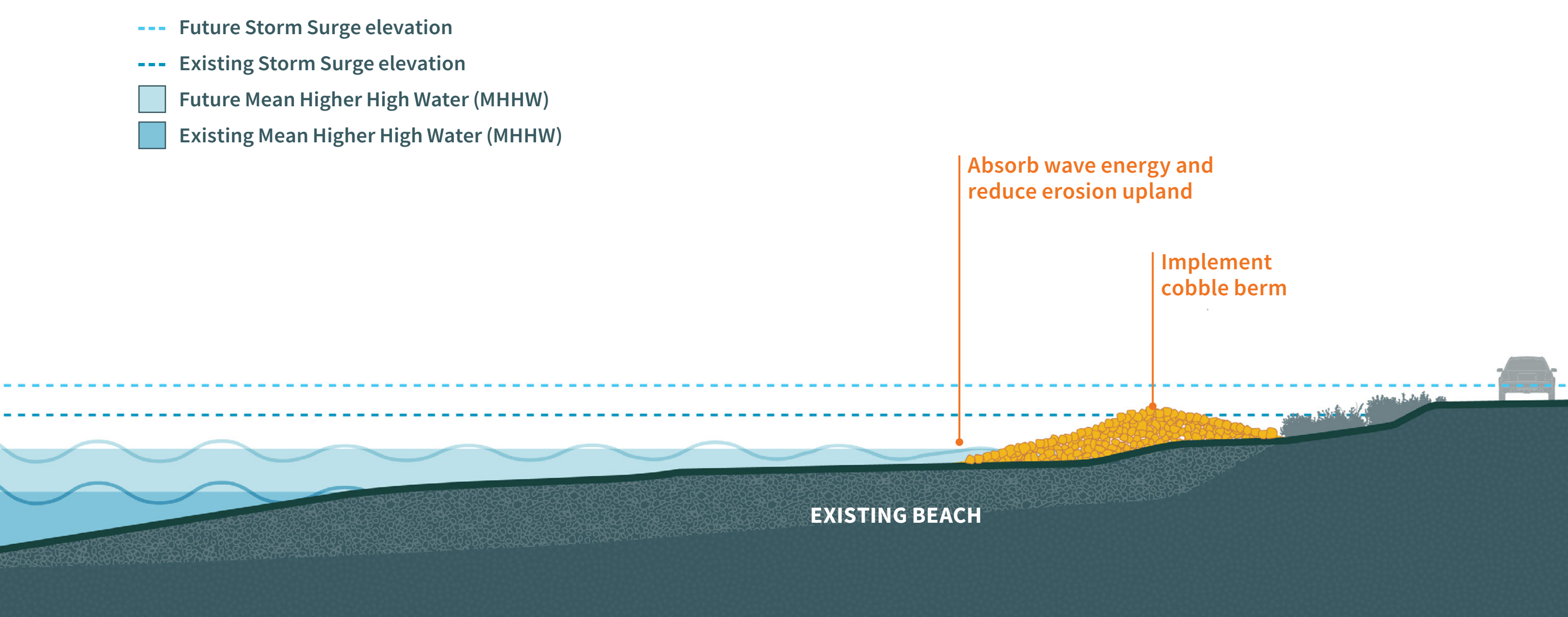
NATURE-BASED SOLUTIONS – Cobble Berms

Implement cobble berms to complement the natural system, absorb wave energy, and reduce erosion.

Cobble berms, a type of living shoreline project, absorb and dissipate wave energy and reduce the impacts of waves on the coastal bank or dune, helping to prevent further erosion. A cobble berm is a mound of cobble-sized sediment typically constructed at the base of a coastal bank or to enhance a coastal dune to reinforce and protect it from erosion caused by waves and storms. This technique is similar to nourishing a coastal dune as it involves adding compatible sediments. They may be used as an alternative to coastal engineering structures like seawalls and revetments.

In places with existing seawalls and revetments, cobble berms may be added to reduce wave energy at the base of the structure.

Cobble berms are better suited in areas where there is existing gravel and cobble. This measure may be more effective at a large scale than at the individual parcel level. Depending on the size and location, building a cobble berm can be costly due to the need for large quantities of cobbles and labor costs. Early coordination with sand and gravel pits allows them to stockpile the material they are already separating from the sand and save it instead of crushing it for other products.



Section 18: Illustrative section of a cobble berm. Drawing not to scale.

Advantages:

- Highly resilient to wave action and weathering
- Designed to naturally shift and move, adding complexity to the intertidal zone which provides habitat benefits for species moving into the area at high tide
- Requires stone sizes that are smaller than those required for a revetment
- Construction is typically simpler with lower maintenance costs than hard-engineered alternatives

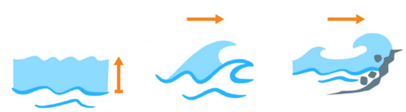
Disadvantages:

- Potential to disrupt natural sediment movement if cobble size is not compatible with the system
- Requires periodic monitoring, maintenance, and repair
- Finding suitable, cost-effective, and sufficient cobble sources for construction and maintenance can be challenging
- May conflict with critical habitats (e.g., nesting shorebirds)

To support this measure, the Massachusetts Office of Coastal Zone Management has partnered with the Woods Hole Group and Stone Living Lab on a cobble berm monitoring project that aims to evaluate the performance, effectiveness, and ecological impacts of cobble berms as a nature-based solution for coastal resilience.[104]

CONSIDERATIONS

Coastal Hazards



STORM SURGE | WAVE ACTION | EROSION

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$
Maintenance	Low
Difficulty	Medium
Design Life	Short-term to Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	○
Coastal Beaches / Dunes	●
Barrier Beaches	◑
Coastal Banks*	●
Tidal River Floodplain s	◑
Coastal Floodplains	◑
Ports & Working Waterfronts	○

SUITABILITY ● High ◑ Site-Dependent ○ Poor

*Includes adjacent areas

NATURE-BASED SOLUTIONS – Other Restoration and Enhancement

Implement restoration techniques such as restoring tidal exchange, restoring previously developed areas, managing invasive species, sediment-based restoration techniques, and repurposing areas of former development or agricultural lands.

Other nature-based techniques to restore and enhance floodplains, salt marshes, and other natural areas can help preserve their ability to provide a natural defense system to protect people, homes, and infrastructure from coastal hazards. This measure has a wide potential range of techniques depending on the coastal resource area, including restoring previously developed areas, restoring salt marshes through management of invasive species, restoring tidal exchange, and sediment-based techniques, and repurposing areas of former development of agricultural land, including cranberry bogs. This measure is best suited to naturally occurring areas that have been degraded over time and where enhancement activities promote both resilience and ecosystem function.

Many of these techniques can work in combination with each other to address multiple stressors. For example, restoring tidal exchange by removing improperly placed or historic water-control structures like tide gates, berms, and pumps, and replacing undersized culverts and bridges, helps to restore appropriate flow conditions for wetland and salt marsh systems. Designs must be carefully engineered to ensure the project doesn't increase flooding of upstream development or infrastructure.

It is important to note that enhancement of resource areas solely to support resilience functions can result in habitat conversion, loss of biodiversity, and reduction in other ecosystem services. The amount of restoration should be balanced with the potential to increase flooding of existing development and infrastructure.

Salt marsh restoration techniques like runneling and runneling combined with ditch remediation seek to restore the natural hydrology of the marsh platform to reduce processes leading to subsidence and support marsh function, including vegetation growth and accretion of sediment to keep pace with sea level rise. Other restoration techniques include the application of sediment on or adjacent to the marsh like thin layer placement or passive sediment augmentation. Multiple techniques are currently being studied to better understand effectiveness in helping marshes maintain ecosystem function, including building elevation to keep pace relative to sea level rise.

Retired cranberry bogs present a significant opportunity to improve tidal exchange, facilitate salt marsh migration, and restore coastal habitat. Massachusetts has the nation's longest history of growing cranberries with approximately 12,000 acres of commercial cranberry bogs in the state. However, falling prices and other factors are leading some farmers to consider other alternatives for their land. In these situations, communities can leverage abandoned or retired cranberry bogs by converting them back to coastal wetlands.

Advantages:

- Improves drainage and slows runoff
- Promotes biodiversity
- Helps reduce risks to adjacent land and buildings from flood impacts by leveraging and optimizing functions of natural systems to store and filter floodwaters (e.g., removing and restoring structures and reducing velocity of floodwaters)
- Can help maintain ability of salt marshes to buffer impacts and stabilize coastal shorelines to reduce or prevent erosion thereby reducing or eliminating the need for coastal engineering structures
- Promotes carbon sequestration

Disadvantages:

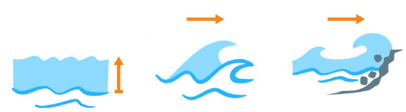
- May conflict with transportation infrastructure goals or requirements
- Effective restoration of native vegetation through management of non-native species alone may be challenging or limited in some marsh systems
- Restored or created tidal marshes may require adaptive management, maintenance, and monitoring over the long-term to ensure success, adding to costs and capacity needs
- May require acquisition of land depending on technique used, which can be costly

To support this measure, ResilientCoasts proposes streamlining and/or creating regulatory pathways for existing restoration techniques as well as new restoration strategies. It also proposes providing resources for monitoring of ecological and landform processes and evaluation of restoration outcomes.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards



Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low-Medium
Difficulty	Medium
Design Life	Medium-term to Long-term

COASTAL TYPOLOGIES

Salt Marshes*	High
Coastal Beaches / Dunes	Site-Dependent
Barrier Beaches	Site-Dependent
Coastal Banks*	Site-Dependent
Tidal River Floodplains	High
Coastal Floodplains	High
Ports & Working Waterfronts	Poor

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

HYBRID SOLUTIONS – Floodwalls and Berms

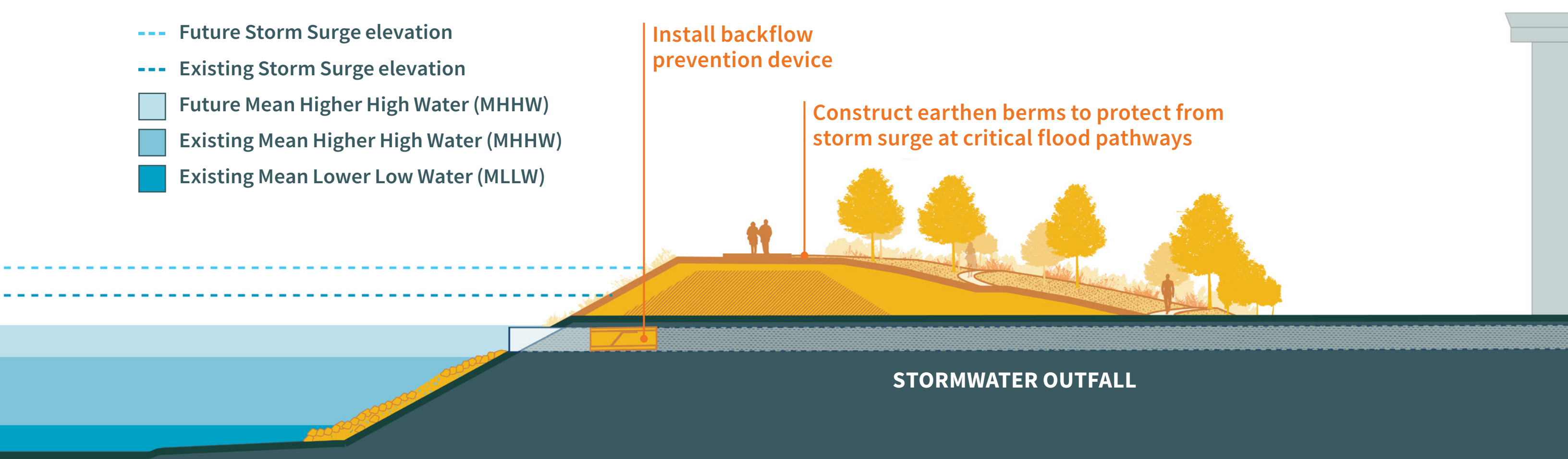
Mitigate flood pathways by constructing floodwalls, earthen berms, or hybrid green/gray systems and installing backflow prevention devices on outfalls.

Floodwalls and berms can be used as a barrier to reduce or prevent flooding in some areas. Floodwalls are permanent or deployable physical barriers used at the shoreline or upland to prevent flooding. Floodwalls are typically engineered structures made of reinforced concrete or riprap, or natural materials like soil, rock, and vegetation. Berms are flat or raised strips of land used as a flood barrier. They can be vegetated or unvegetated and are typically made of compacted earthen materials.

Permanent floodwalls are most suitable for sheltered areas that experience less wave action or erosion. Flood walls and berms, if overtopped, can trap water behind them increasing the duration of flooding unless they are designed with mechanisms for drainage of impounded floodwaters. Therefore, they must be designed with complementary drainage system improvements to prevent coastal floodwaters from backflowing and stormwater and residual wave overtopping from accumulating to dangerous levels in landward areas.

In contrast to permanent floodwalls, deployable flood barriers are temporary, flexible structures designed to prevent or mitigate flooding. Some types of floodwalls require wall slats to be installed in preparation for a coming flood event and can be inserted into either permanent ground fixtures or vertical posts. Deployable floodwalls are most suitable for low to moderate surge events and in areas that experience low to moderate wave action in the event of a storm. They are not suitable for areas along oceanfront.

Floodwalls and berms may require acquisition of adjacent property based on footprint and requires siting outside of wetland resources, which can be challenging to accommodate. If not designed aesthetically, they can impact visual and physical access to the waterfront. They may also require pump systems to release floodwaters that accumulate behind the barrier, resulting in increased costs and water quality concerns. They should be designed to avoid redirection of floodwaters onto adjacent areas. Alternatively, deployable floodwalls must be installed prior to



Section 19: Illustrative section of a berm that provides flood protection. Drawing not to scale.

an event and are not suitable to protect against daily tidal inundation. They may require significant labor, training, lead time to install, equipment, and associated costs to install in advance of a storm.

Advantages:

- Reduces public health/safety risks, reduces costs of flood damage and exposure of inland people, buildings, and/or infrastructure to high tide and storm surge flooding up to the design flood elevation, wave action, and wave overtopping
- Avoids or reduces the duration of service disruptions
- Avoids cost and complexities of adapting individual structures and assets
- Can be combined with waterfront access and recreational improvements
- Deployable flood barriers allow areas to remain accessible and unobstructed from the waterfront during normal, non-emergency conditions

Disadvantages:

- May encourage further development in areas vulnerable to flooding and give a false sense of protection from coastal hazards
- Limited applicability immediately along the shoreline where they frequently interact with waves and erosion
- May fail or be exceeded by big flood events, which can lead to catastrophic, high velocity flooding with extreme consequences for landward people, buildings, and/or infrastructure
- May be expensive due to fill, material, utility modification, and other costs
- Berms may require large footprints and heights, making them difficult to site in dense areas where buildings and development are minimally setback from the shoreline

To support this measure, the state is developing guidance on techniques for **flow path analysis** where coastal floodplain alterations (fill, retaining walls, etc.) could negatively impact adjacent buildings and infrastructure. ResilientCoasts proposes to build on this work by identifying and investing in **district-scale flood protection** in strategic coastal locations and expediting permitting for resilience projects.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

SEA LEVEL RISE

STORM SURGE

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low-Medium
Difficulty	Low-Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	○
Coastal Beaches / Dunes	○
Barrier Beaches	○
Coastal Banks*	○
Tidal River Floodplains	◐
Coastal Floodplains	●
Ports & Working Waterfronts	●

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

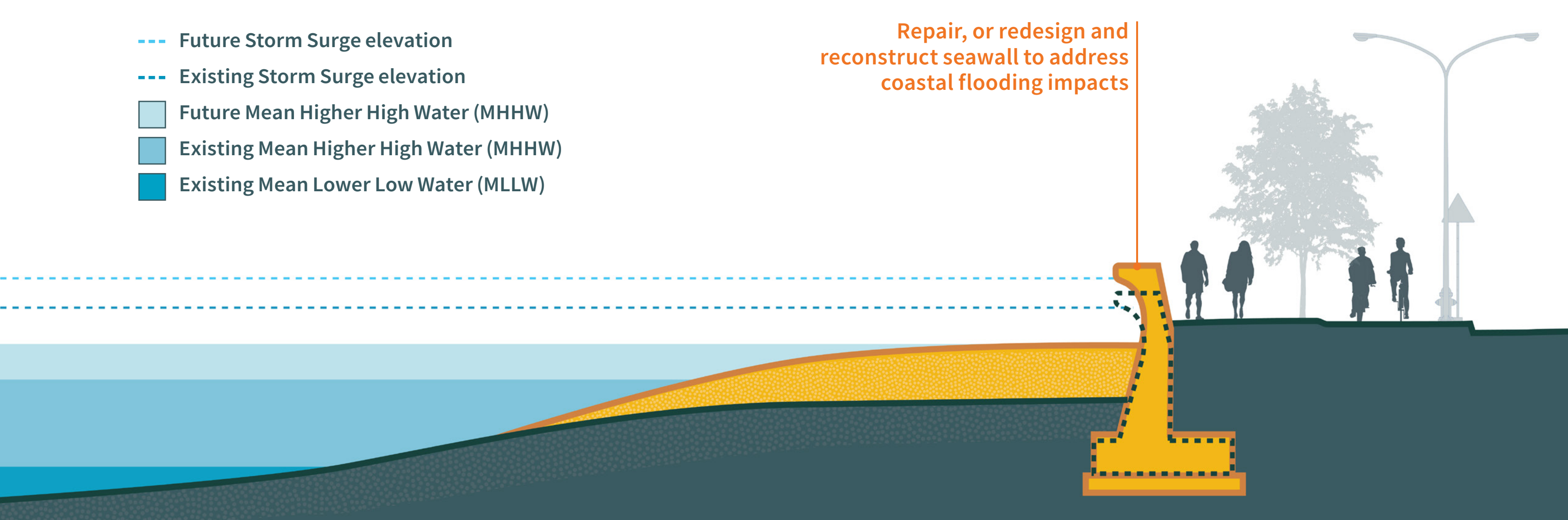
COASTAL ENGINEERING STRUCTURES – Retrofit and Redesign Seawalls

Retrofit or redesign and reconstruct seawalls to better address current and future flood conditions, and minimize erosion effects.

Seawalls are coastline engineering structures made of stone, rock, or concrete that are built parallel to the shore with vertical or sloped walls to reinforce the shoreline against forces of wave action and erosion. They also help prevent storm surge from flooding upland areas. They can be used in both exposed areas with high wave energy, as well as in areas with more sheltered conditions (e.g., relatively low wave energy). Seawalls are considered “armoring” or “hard structures” that provide a physical barrier that directly protects inland areas.

Retrofitting and redesigning seawalls is an opportunity to incorporate best practices to reduce potential negative impacts, improve structure longevity, and reduce maintenance costs. For example, seawalls should be located as far landward as possible to minimize interaction with waves and tides and therefore reduce erosion to the fronting beach and adjacent areas. If erosion is occurring behind an existing structure, to minimize impacts, it should be pulled back to the base of the landward landform to prevent continued erosion from undermining the structure. Seaward encroachment of coastal engineering structures can increase the frequency, duration, and intensity of wave action, exacerbating coastal erosion and potentially undermining the structures.

Projects should include improvements to the drainage system to prevent pressure from building up behind the wall due to wave overtopping or ponding of rainwater. This pressure is one potential cause for structural failure. To minimize soil erosion behind seawalls —which can compromise



Section 20: Illustrative section of seawall retrofit and redesign measures. Drawing not to scale.

the integrity of the structure and potentially cause it to fail—woven filter fabric can be placed between the structure and the ground surface during construction. The fabric holds the sediment in place, while the water drains.

Vertical seawalls reflect waves seaward, while also redirecting a portion of the wave energy both downward and upward. The wave energy that is reflected downward erodes the beach and causes scour at the base of the structure. The wave energy that goes up into the air can overtop the structure and cause erosion behind the wall, potentially damaging the development or infrastructure being protected. Using a curved face on the top of a vertical concrete seawall can help redirect some of the reflected waves seaward to reduce overtopping.

While seawalls can be retrofitted or redesigned to better address coastal hazards, this may not be the best solution in all cases. Communities should consider whether a seawall is still the most appropriate or effective shoreline intervention and whether there are alternative, lower-impact solutions that could replace the existing structure. Coastal engineering structures like seawalls may be more appropriate in places with altered, urban shorelines adjacent to high density residential development or critical public infrastructure.

Beach nourishment can be used in combination with seawalls to provide better results. Because beaches and dunes help naturally dissipate energy associated with waves, tides, and currents, the best way to reduce the wave energy that hits seawalls is to maintain the beach in front of these structures. In areas where there is a wide enough beach, dunes can provide additional protection.

To support this measure, the state is developing **design guidance for retrofitting** seawalls and revetments.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Medium
Difficulty	Medium-High
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	○
Coastal Beaches / Dunes	◐
Barrier Beaches	○
Coastal Banks*	◐
Tidal River Floodplains	●
Coastal Floodplains	●
Ports & Working Waterfronts	●

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

With an older seawall, the beach in front of the structure has often eroded over time. Replacing and maintaining these natural buffers can prolong the structure's longevity, minimize its adverse impacts, increase the overall resilience of the area, and provide a recreational beach. After the initial nourishment project is completed, sediment is periodically added to maintain the desired beach and/or dune volume according to a monitoring and maintenance plan that includes details for determining when, how much, and what type of sediment should be added. Depending on erosion rates and storm impacts, sediment could be required on an annual basis and will likely be necessary after coastal storms.

The higher the seawall, the more surface area there is to reflect wave energy. Therefore, projects that raise the height of an existing seawall or revetment must be considered carefully in light of the additional erosion that may be caused by wave energy reflected downward. Raised seawalls must be designed with complementary drainage systems to prevent coastal floodwaters from backflowing and stormwater and residual wave overtopping from accumulating to dangerous levels in landward areas. For sites with high coastal banks, the bank itself also serves as a vertical buffer to waves and storm surge. Rather than increasing the height of the structure in these areas, efforts can be made to stabilize the upper bank using erosion control vegetation, natural fiber blankets, and/or coir rolls.

Advantages:

- Can help prevent erosion of retained land if structure remains in good repair
- Provides or contributes to district-scale flood control
- Under the right circumstances, can be constructed with public esplanades, boardwalks, or roadways on top or alongside allowing for public access, recreation, and transportation along the shoreline

Disadvantages:

- Expense due to specialty construction, materials, utility modifications, and other costs
- Can increase the erosion of the landform seaward of the structure, lowering beach elevations and reducing the intertidal zone, leading to erosion of the shoreline and adjacent properties
- May encourage further development in areas vulnerable to flooding and give a false sense of protection from coastal hazards
- May fail or be exceeded by big flood events, which can lead to high velocity floodwaters and storm damage landward of the structure
- May be a barrier to resource area migration
- Aesthetic considerations, including impacts to cultural and historical characteristics that result when seawalls are significantly elevated above existing grades

What is a “Living Seawall”?

Living seawalls are a technique attaching panels or textured surfaces to existing seawalls in low-energy environments to enhance coastal habitat by encouraging colonization of marine life. This technique is being tested to explore whether it results in improved habitat in otherwise highly altered areas. However, living seawalls have not been demonstrated to increase resiliency or provide flood protection benefits, though this is also being investigated.

Fan Pier East Boston, 2024 (Credit: WHG)

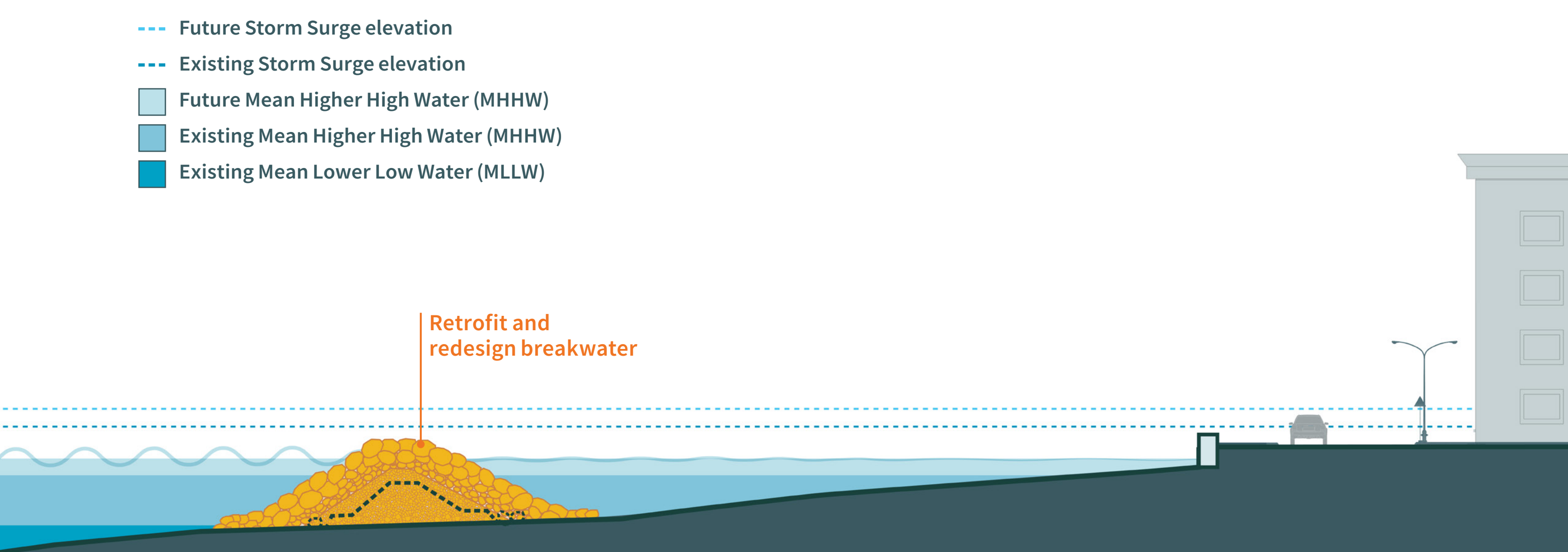
COASTAL ENGINEERING STRUCTURES – Retrofit and Redesign Breakwaters

Retrofit or redesign and reconstruct breakwaters to better address current and future wave energy and minimize erosion effects.

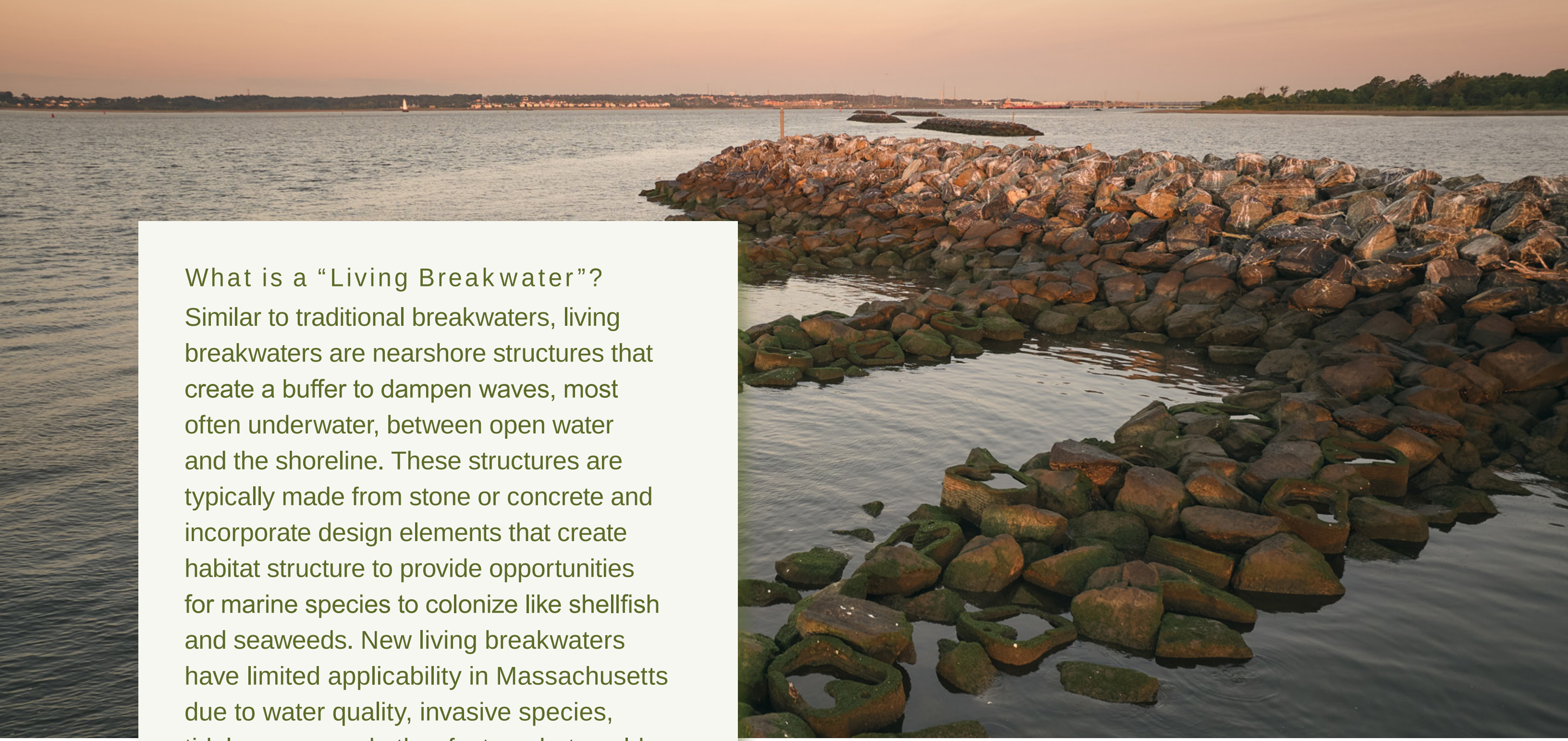
Breakwaters are constructed nearshore and offshore to, as the name suggests, break waves and reduce the force of wave action on the shore. However, breakwaters don't address a lack of sediment supply and may exacerbate down-drift sediment starvation. Existing breakwaters in Massachusetts are fixed as opposed to floating. These structures are fixed to the ocean floor, attached to the shore or not, and continuous or segmented. They may be submerged or above water ("emergent").

To continue to provide protection from coastal hazards, breakwaters should be maintained in a state of good repair. This may require reconstructing revetment damage or increasing the size of the stone. However, maintenance should generally stay within the previously authorized footprint. In order to limit frequency of future repair work and increase durability of the structure, a coastal engineer should evaluate the integrity of the structure relative to the best available wave climate and sea level rise data. Larger stones may be needed if the structure is not standing up to storms.

To withstand the impacts of rising seas and more severe storms, breakwaters may also need increased elevation. Increasing the height of a breakwater requires expanding its footprint. In order to expand the footprint of an existing breakwater, wave and sediment transport analysis would need to be conducted to ensure that the changes would not increase wave focusing, increase erosion on adjacent shorelines, or adversely affect sediment transport patterns. In addition, the adjacent seafloor habitat would need to be characterized to determine if changes would adversely impact sensitive fisheries habitats, such as eelgrass, hard bottom, etc.



Section 21: Illustrative section of breakwater retrofit and redesign measures. Drawing not to scale.



What is a “Living Breakwater”?

Similar to traditional breakwaters, living breakwaters are nearshore structures that create a buffer to dampen waves, most often underwater, between open water and the shoreline. These structures are typically made from stone or concrete and incorporate design elements that create habitat structure to provide opportunities for marine species to colonize like shellfish and seaweeds. New living breakwaters have limited applicability in Massachusetts due to water quality, invasive species, tidal ranges, and other factors, but could be effective in select areas. In an area with a high tide range, a much bigger structure would be needed to dissipate wave energy, which can substantially increase cost, have greater environmental impacts, and interfere with navigation. Living breakwaters work best in sheltered environments with lower tide ranges, as opposed to open water conditions.

Living Breakwaters, New York Harbor, 2024
(Credit: Ty Cole for SCAPE Landscape Architecture)

Advantages:

- Can provide some protection from lower wave heights, as well as wakes, in sheltered water bodies
- Increases longevity of beach nourishment projects
- Creates calm waters for boating and recreational purposes
- Can build up and adapt to sea level rise

Disadvantages:

- Can trap sediment moving alongshore leading to erosion of down-drift shorelines if not properly designed
- Can reduce water circulation leading to water quality problems
- Require substantial height and width to be effective in areas with a high tidal range
- Aesthetic considerations in areas with a high tidal range like Boston Harbor

CONSIDERATIONS

Coastal Hazards

WAVE ACTION

EROSION

Scale of Implementation	Neighborhood
Cost	$$$$
Maintenance	Low
Difficulty	Medium-High
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	○
Coastal Beaches / Dunes	◐
Barrier Beaches	◐
Coastal Banks*	◐
Tidal River Floodplains	○
Coastal Floodplains	◐
Ports & Working Waterfronts	●

SUITABILITY ● High ◐ Site-Dependent ○ Poor

*Includes adjacent areas

COASTAL ENGINEERING STRUCTURES – Retrofit and Redesign Revetments

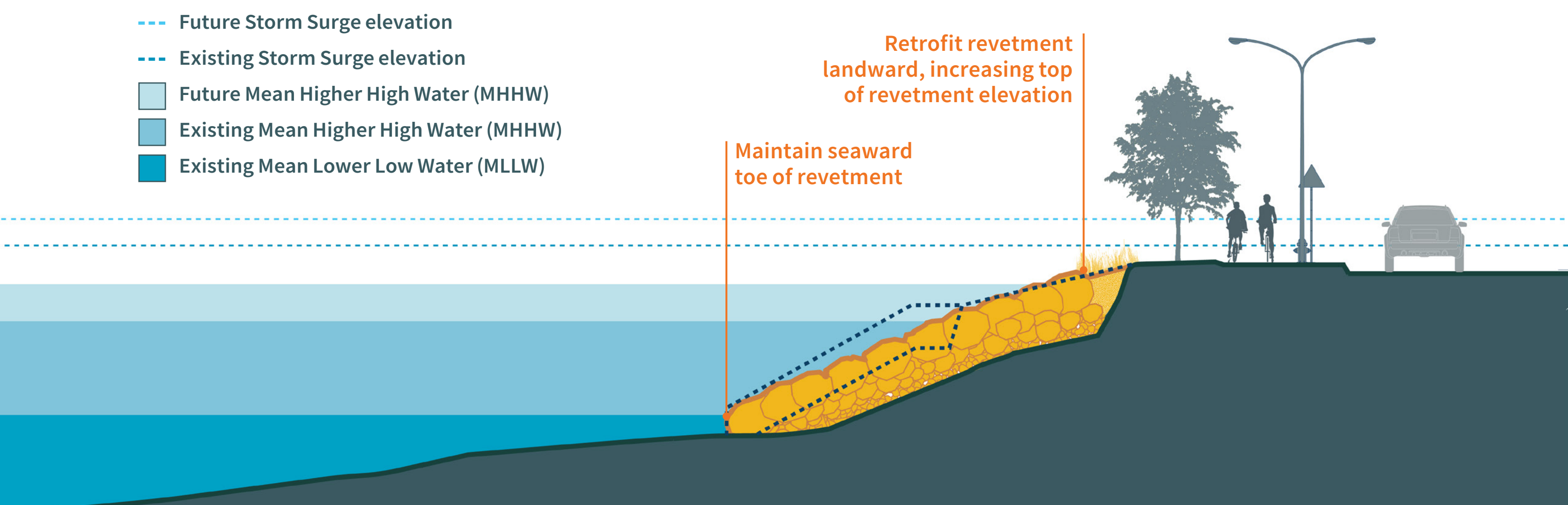
Retrofit or redesign and reconstruct revetments to better address current and future wave energy and minimize erosion effects.

Revetments are shoreline structures typically made of stone rubble, armor stone, rock-filled gabion baskets, or concrete blocks that are placed on a sloped surface or in front of existing seawalls to protect the underlying soil from erosion, helping to stabilize the coast, and reduce the forces of wave action. Revetments are considered armoring and provide a physical barrier that directly protects landward infrastructure and inland areas.

Historically, revetments were placed in front of pre-existing seawalls where an eroding beach with decreasing beach elevation had resulted in de-stabilization of the seawall. Revetments were installed as a temporary measure to provide lateral support to the seawall to prevent the structure falling seaward. This stabilization process resulted in incremental seaward expansion of hard structures on coastal beaches.

When properly designed, revetments are typically more resilient than vertical seawalls because they are better able to absorb and dissipate wave energy. However, revetments can have negative impacts on adjacent and downdrift properties, decrease sediment supply for resource areas, reduce habitat value of the shoreline, and scour out the fronting and adjacent beaches, potentially undermining the structure and increasing overwash. For these reasons, they should be avoided unless there are no other options.

Revetments are most suitable for sites with pre-existing hard armored shorelines and are not suitable for salt marshes or sandy shorelines where they may lead to loss of intertidal habitat or accelerate erosion of adjacent shorelines. Because they are able to absorb some wave energy, they are most commonly used on ocean-facing shorelines. However, they are most suitable for areas



Section 22: Illustrative section of revetment retrofit and redesign measures. Drawing not to scale.

without high wave energy and erosion that will undermine them, necessitating reconstruction and enlargement. Coastal processes should also be considered when determining the feasibility of a revetment for a given location. Coastal beaches with a narrowing dry beach width or elevation due to erosion or sediment starvation are poor candidates for revetment installation as the loss of sediment supporting the revetment will lead to slumping, unraveling, and failure of the structure.

Retrofitting and redesigning revetments offers an opportunity to incorporate best practices to promote resilience. For example, reconstruction offers an excellent opportunity to reduce the steepness of a revetment. Slopes should ideally be no steeper than 1.5:1 to limit erosion of fronting beaches and adjacent properties. To achieve a shallower slope without extending the structure farther seaward, the bank or other landform behind the revetment can be regraded and the top of the structure moved landward. Though this landward extension results in a loss of ground surface between the revetment and the development or infrastructure behind it, the property will be better protected through the increased longevity of the structure and reduced erosion rates. A coastal engineer can recommend an appropriate slope based on site-specific conditions, including beach width and elevation, bank height, erosion rate, wave energy, and integrity of the structure.

To minimize interaction with waves and tides and therefore reduce erosion to the fronting beach and adjacent areas, revetments should be located as far landward as possible. If erosion is occurring behind an existing structure, the structure should be pulled back to the base of the landward landform to reduce

To support this measure, the state is developing **design guidance for retrofitting** seawalls and revetments.

For more information on ongoing and proposed state-led strategies and actions, see Chapter 8 (page 232).

CONSIDERATIONS

Coastal Hazards


WAVE ACTION


EROSION

Scale of Implementation	Parcel, Neighborhood
Cost	$$$$-$$$$
Maintenance	Low
Difficulty	Medium
Design Life	Medium-term

COASTAL TYPOLOGIES

Salt Marshes*	Poor
Coastal Beaches / Dunes	Poor
Barrier Beaches	Poor
Coastal Banks*	Site-Dependent
Tidal River Floodplains	Site-Dependent
Coastal Floodplains	Site-Dependent
Ports & Working Waterfronts	High

SUITABILITY High Site-Dependent Poor

*Includes adjacent areas

continued erosion. Depressing the revetment structure deeper within the coastal beach can also provide toe protection while reducing the amount of structure above the beach face which is available to interact with wave energy.

While revetments can be retrofitted or redesigned to better address coastal hazards, this may not be the best solution in all cases. Communities should consider whether a revetment is the most appropriate or effective shoreline intervention and whether there are alternative, lower-impact solutions that could replace the existing structure. Coastal engineering structures like revetments may be more appropriate in places with altered, urban shorelines adjacent to high density residential development or critical public infrastructure.

Advantages:

- May be less expensive and require less maintenance than other coastal engineering structures
- Can be used as a remedial stop gap to stabilize failing seawalls where the beach has eroded/lowered to the point it is causing structural instability
- Can reduce exposure of landward areas to wave overtopping when fronting seawalls or bulkheads when properly designed

Disadvantages:

- May accelerate erosion of adjacent shorelines and disrupt sediment transport, starving beaches downdrift or hardened edges
- May lead to loss of intertidal habitat and adjacent low-lying sites
- May encourage further development in areas vulnerable to flooding and give a false sense of protection from coastal hazards
- May require land acquisition and associated costs as compared to other vertical shoreline structures like seawalls because of slope design requirements
- May require regular maintenance as sea level rises and if erosion occurs at the toe
- Can increase wave runup and overtopping if not properly designed

Revetment in Winter Island, Salem, MA, 2024

Scenarios of Phased Adaptation

Diverse landscapes across the coast will respond in different ways over time to changing patterns of flooding and erosion. This ongoing state of flux requires a phased and layered approach to coastal resilience to optimize outcomes based on community goals and needs, unique physical geography, and varying risk tolerances. Phased adaptation provides a mechanism for responding to changing conditions in the natural and built environments. The following scenarios of phased adaptation demonstrate how communities can navigate uncertainty by embracing flexibility and combining coastal resilience measures in the near-, mid-, and long-term.

This conceptual landscape is a composite of several coastal typologies common to the Massachusetts shoreline, including various coastal habitats and floodplain configurations. The following section showcases how coastal resilience measures can be layered and phased over time and space to optimize financing and resilience outcomes.

PHASED ADAPTATION IN SALT MARSHES

Salt marshes face ongoing threats from development, fragmentation, tidal restriction, and nonpoint source pollution, as well as increasing pressures from sea level rise, coastal storms, and other climate impacts. When planning for the future, coastal communities should work to maximize the footprint and lifespan of existing salt marshes while optimizing corridors for future migration. Protection and restoration of these areas will help ensure salt marshes continue to serve essential functions for adjacent development and infrastructure like decreasing wave energy and absorbing floodwaters.

Phased planning for salt marshes should begin with a focus on preserving existing resource areas and repairing damage caused by prior development decisions. Near-term strategies should center on pollution remediation and improvements to hydrology on a variety of scales, from ditch remediation and runneling to basin-wide tidal flow restoration.

At the same time, communities must prepare for the eventuality of marsh loss as sea level rise shifts tidal ranges higher and marshes encounter steep slopes and impervious surfaces that inhibit migration. Since the magnitude and timing of highly impactful sea level rise is uncertain, protecting space for marsh to migrate should be an immediate priority.

As accelerated sea level rise increases these pressures on existing salt marsh habitat, high-tide flooding will also impact low-lying development and infrastructure. This presents an opportunity to gradually relocate the most vulnerable developed areas to provide room for marshes to migrate while reducing risk to the relocated assets. Where marshes have less lateral space to move, careful addition of sediment to maintain the elevation of the marsh platform can enhance the adaptive capacity of the system.

Salt marsh measures in the near-term may focus on protecting the existing resource area, restoring currently degraded habitat and laying the foundation for habitat to migrate with sea level rise. Baseline assessments of salt marsh health can help identify degraded areas to target restoration efforts. In tandem, efforts to reduce nonpoint source pollution will enhance the existing habitat and prevent further degradation. Undertaking planning initiatives to enhance protections in the buffer zone and identify areas suitable to accommodate future salt marsh will enable the resource area to persist and adapt to future conditions. Actions in the near-term to remove barriers to tidal flow (like undersized culverts) can both restore degraded upstream habitat and pre-position marshes to migrate as the tidal range shifts higher and influences more landward areas.

Salt marsh measures in the mid-term may focus on restoring and enhancing habitat resilience and initiating efforts to help facilitate the relocation of development and infrastructure out of high-risk areas that are likely to experience frequent and eventually daily flooding. Interventions that repair and enhance the marsh platform enable salt marshes to stabilize laterally and grow vertically, capabilities that are often impaired where development limits sediment supply. At scale, healthy marsh systems contribute to the protection of landward development by reducing storm surge and wave action in certain conditions. Some of the most vulnerable developed areas, however, may need to begin the process of relocation to safer locations with the onset of accelerated sea level rise impacts. Identifying and enabling nearby upland areas to accommodate these relocations through upzoning (increasing allowable densities) helps keep communities intact despite these shifts. It also makes more room for the resource area to recolonize or migrate, which can enhance protection of remaining development.

Salt marsh measures in the long-term may focus on further maintenance and migration of the resource area and additional consolidation of communities away from high-risk areas. Adaptive management approaches to habitat restoration can help salt marshes adapt to future conditions and help the marsh platform keep pace with sea level rise through an evolving, iterative process. As communities work to prolong the life of existing salt marsh, losses may be offset because early planning has made space for and removed barriers to marsh migration to the greatest extent practicable in the context of community continuity. Additional voluntary acquisitions in areas of increasing risk will eventually warrant higher density development of upland relocation areas. Ultimately, this process is a balancing act and layering of risk reduction through iterative relocation and investment in salt marsh sustainability.

PHASED ADAPTATION IN BARRIER BEACHES

Barrier beaches face ongoing threats from flooding and coastal erosion, and these pressures are expected to intensify with future sea level rise and coastal storms. Coastal communities should investigate how long it is feasible to maintain the barrier beach in place, and work to restore natural coastal processes so that the system can migrate and evolve as intended. Only then will the barrier beach continue to provide safe enjoyment and protection for landward areas.

The process will typically start with a nourishment project to replenish eroded sediment and provide an initial level of protection for developed areas of the barrier beach. The feasibility of this measure will depend on cost-effectiveness in a given location and availability of suitable sediment. Given that beach and dune nourishment is not a permanent solution, it is critical that communities undertake parallel initiatives to identify the most at risk developed barrier beach areas (both on the front and back sides of the barrier) and identify options for reducing risk to community assets and private property (like elevating buildings on pilings and voluntary buyout programs).

Acknowledging the economic benefits of barrier beaches as well as the ecosystem services they provide, communities will need to grapple with change in these highly dynamic systems. Best practices for managing developed barrier beach areas will likely center on an iterative process whereby infrastructure and private property adapt in place for as long as feasible given sea level rise and intensifying storm events and then opt in to relocation.

Relocation phases, which may be activated either by catastrophic storm damage or by inundation impacting daily use, provide an opportunity for additional nourishment and function of coastal processes. Communities should consider what the threshold is for triggering these relocation phases (e.g., at what point is living with increased frequency and severity of coastal hazards no longer feasible). In some cases, it may be possible to consolidate development along a higher elevation area of the barrier beach that can weather future storms due to resilient building practices and restored natural protective features. However, stationarity is anything but guaranteed in these dynamic environments.

Barrier beach measures in the near-term may focus on balancing support for sustaining existing development with the need to accommodate natural beach evolution and plan for a future where both systems will experience change. Maintaining access for these otherwise isolated areas is important for life and safety as well as community continuity. Nature-based solutions like beach and dune restoration can temporarily provide a designed level of flood and erosion protection for properties along the front of the barrier beach, while elevating homes on the back side can reduce risk from a longer period of storm surge. Communities can support coastal processes by allowing barrier beach overwash to feed sediment to the salt marsh behind and begin to relocate municipal infrastructure to less vulnerable areas. Setting up a framework for voluntary acquisition provides a signal to communities that, while long term occupation may not be feasible in all areas, healthy barrier beaches are valuable in terms of providing protection and recreation opportunities for landward communities.

Barrier beach measures in the mid-term may focus on responding to evolving risk in the natural and built environment and supporting continued use and access for communities in more consolidated, less vulnerable zones. Voluntary acquisition of the most vulnerable areas reduces overall physical and financial risk of the community, while providing space for interventions that simultaneously provide publicly accessible open space and protection for remaining portions of the community. Maintaining elevation and volume of nourished beaches and dunes continues to provide a buffer for remaining developed areas on barrier beaches from storm surge and wave action. Additional phases of relocation for municipal facilities and infrastructure can reduce risk and ensure that key services continue.

Barrier beach measures in the long-term may focus on returning more of the barrier beach to its natural function and using these restored systems to protect core zones of remaining consolidated development. As more properties opt into voluntary acquisition, communities can begin to pull back public infrastructure like roads to reduce public safety risks, maintenance costs, and capital investment needs. Infrastructure relocation allows for more comprehensive barrier beach and dune ecosystem restoration. When backed by adaptive management programs, it can provide protection to landward areas while allowing the barriers to naturally roll over and evolve without the pressures of preserving unsustainable land use practices. As sea level rise begins to impact existing parcels on the marsh side, additional provisions for voluntary acquisition can augment potential for salt marsh migration.

PHASED ADAPTATION IN COASTAL FLOODPLAINS

Coastal floodplains, particularly low-lying areas liked filled tidelands, face increasing coastal hazards as sea level rises and storms become more frequent and severe. When planning for the future, coastal communities should consider the vulnerabilities and circumstances of these areas. Some portions of coastal floodplains face heightened risks due to high-velocity wave action, overwash of material and/or fast-moving water during storms. High-hazard portions of coastal floodplains should be targeted first for interventions, though there may be fewer suitable resilience measures for these areas than in more upland areas of the floodplain.

The development character of coastal floodplains can vary greatly. While many coastal floodplains in Massachusetts are densely developed with highly altered shorelines, there are other areas with much less development and alteration. The suitability of coastal resilience measures in the near-, mid-, and long-term will be highly influenced by existing conditions.

Best practices for managing densely developed coastal floodplains will likely center on a combination of building-scale and district-scale interventions that protect people, buildings, and infrastructure from floodwaters or accommodate flooding where possible. Some strategic relocation of people, housing, and critical infrastructure may be required in the long-term and communities should set the stage for this by prioritizing new and denser construction in upland areas that are less prone to coastal flooding, wave action, and erosion.

Some areas of coastal floodplains may have land uses that require proximity to the water, such as ports and working waterfronts; and, therefore, have different risk tolerances and require tailored, adaptive management approaches to resilience.

Coastal floodplain measures in the near-term may focus on protective features to reduce flood risks, particularly in densely developed areas, and adopting policies that prepare properties for future conditions. As communities confront current and future flood risk, needs and opportunities may initially coalesce around constructing protective alignments along the coastal edge (e.g., berms, flood walls, etc.). The configuration and scale of these interventions should be informed by community goals, land use patterns, and projected exposure. Working waterfronts are likely to target interventions with lower elevations to ensure they do not preclude daily access to the water. Other alignments, especially those that address flood pathways affecting larger developed floodplains, aim for higher elevation interventions to address present and future flood risk. Where the potential for increased infrastructure damage threatens upland adjacent development, measures to reduce wave energy, such as cobble berms, can help without reflecting waves on neighboring properties.

Coastal floodplain measures in the mid-term may focus on protecting communities and critical facilities facing new and increased levels of flooding. For working waterfront areas previously adapted to preserve access to the water, storm surge impacts can be addressed for critical facilities through temporary relocation of mobile assets, elevation, or floodproofing. This approach allows for normal operations to continue while ensuring that facilities can quickly return to normal operations after a flood event.

As flooding is projected to reach further inland impacting developed areas, communities may opt to adapt at the building scale or district scale. Floodproofing at the building level makes sense where flood patterns are diffuse, or interventions are difficult to integrate with existing development. District scale strategies like landscape berms can be used in alignments where more space is available and provide co-benefits like urban wildlife and publicly accessible open space.

Coastal floodplain measures in the long-term may focus on closing additional flood pathways (building off of prior interventions), adapting in place where district solutions are not viable (e.g., floodproofing and elevation), and facilitating the migration of coastal habitat like salt marshes. Working waterfronts, that previously engaged in building-level adaptations to maintain water access, will wane over time as storm surges open up new pathways. These areas can integrate flood protection systems behind working waterfront operations to close flood pathways. Depending on design flood elevations and existing tie-ins, structural protection within the urban landscape can include road elevation and/or flood walls with operable gates. In both cases, managing stormwater behind these protective features will be a critical component of design. Where flood protection alignments are inland of developed areas, building level elevation will be required. As floodable parks mature and experience changes in the tidal range, adaptive management frameworks should anticipate the need to facilitate salt marsh migration.

Chapter 8

State-led Strategies

The State's Role

The scale and complexity of coastal vulnerability necessitates state leadership. In addition to leading by example, the state can provide critical coordination, guidance, and technical, financial, and capacity-building support for local and regional efforts on coastal resilience.

State Leadership

For over a decade, coastal communities in Massachusetts have undertaken local efforts to build resilience. These efforts have laid an important foundation and will continue to be a critical component of the state's approach to coastal resilience. However, current and projected vulnerabilities on the coast are significant and widespread necessitating a comprehensive statewide strategy for coastal resilience to avoid the worst damage and economic losses and to protect residents, businesses, and coastal ecosystems from harm.

State leadership on coastal resilience can help navigate jurisdictional complexity, objectively evaluate and prioritize projects and funding needs across coastal regions, secure and allocate limited resources, and provide technical assistance and capacity-building for local implementation. Most importantly, the state can lead by example – proactively embedding coastal resilience into state regulations, policies, investments, and decision making to reduce, adapt, and avoid exposure to coastal hazards.

Bringing a statewide lens to coastal resilience can also help address coastal challenges more holistically, integrating state priorities and initiatives designed to address larger scale trends that put pressure on coastal communities. Housing and insurance, transportation, the marine economy, and biodiversity all intersect with efforts to make our coast more resilient. A comprehensive statewide approach can help stabilize local economies, housing and insurance markets; protect critical natural and built infrastructure; and avoid losses and more expensive costs later.

- **Housing and Insurance:** Massachusetts faces a housing crisis with production of new homes failing to keep pace with demand. Changes in insurance, banking, and real estate markets as they respond to growing risks along the coast could further exacerbate access to and affordability of homes. This necessitates a statewide approach to reducing risk to existing housing and ensuring new development meant to meet this demand is resilient to current and future coastal hazards.

- **Transportation:** Coastal hazards threaten to exacerbate ongoing challenges related to access, reliability, connectivity, and safety of transportation infrastructure. Efforts to increase resilience of these systems should be integrated with ongoing work to upgrade, maintain, and improve them. Improvements to transportation can also influence where and how communities develop; therefore, resilience should be a consideration in these decisions as well. Conversely, decisions about community resilience impact the viability of transit and risk creating stranded assets.

- **Marine Economy:** Efforts to sustain and grow the state's marine economy, including becoming a global leader in BlueTech, depends, in part, on the resilience of the coast to current and future conditions and disruptions. Maintaining and upgrading coastal infrastructure, including port infrastructure, is critical to remaining competitive in these and other industries. There is also a significant opportunity to leverage investment in the marine economy to generate high quality jobs for Massachusetts residents, but those workplaces must remain safe from coastal hazards.

- **Biodiversity Conservation:** Massachusetts has set nation-leading biodiversity conservation goals to halt and reverse biodiversity loss and build a resilient future for people and wildlife. Nature-based solutions for coastal resilience support this work. From restoring salt marshes and estuaries, to removing defunct dams and upgrading tidal crossings, to stabilizing shorelines and protecting important shorebird nesting areas, strategies that work with nature can make Massachusetts communities safer and allow people and wildlife to adapt to coastal hazards.

- **Balancing Priorities:** The state is tackling a lot of big challenges at once and these policy priorities can sometimes seem like they are pulling in different directions. However, a well-coordinated approach across state government can help ensure progress is made across the board. Planning for these challenges together, rather than in isolation, will create stronger, more connected, and more resilient communities for all Massachusetts residents.

It is important that these efforts avoid exacerbating existing systemic inequities as communities face increasingly severe and widespread coastal hazards. Vulnerable communities, tribal nations, and other priority populations must be centered and included throughout the processes of coastal resilience planning, projects, and decision making. While these principles are already at the forefront of the state's resilience planning, ongoing coordination and integration of statewide initiatives to increase language accessibility and ensure equitable distribution of resources is essential.

While Massachusetts strives to adapt our coastline to the impacts of coastal hazards, there will ultimately be hard conversations about where and when to move people and infrastructure out of harm's way. These conversations can be made easier with state leadership, ongoing partnership with coastal communities, and a framework for understanding where communities are most vulnerable and where risk reduction can have the greatest collective impact.

State-led Strategies for Coastal Resilience

In addition to partnering with and continuing to support local and regional implementation efforts, the state can take steps to achieve coastwide resilience by embedding the ResilientCoasts framework across state government through its research, planning, policies, regulations and investments.

To achieve the state's vision for coastal resilience, the following ten state-led strategies have been identified:

1 – Identify and invest in district- and regional-scale projects and partnerships, tailored where necessary to region-specific needs and circumstances.

The state proposes **7** actions under this strategy (see page 238)

2 – Increase the resilience of new and re-development by integrating best available data on current and future coastal hazards.

The state proposes **10** actions under this strategy (see page 240)

3 – Require state investments to be informed by future climate conditions and avoid increasing unnecessary physical and financial exposure to coastal hazards.

The state proposes **7** actions under this strategy (see page 242)

4 – Acknowledge the fiscal realities of addressing coastal hazards by prioritizing resilience actions that have the highest impact and maximize long-term risk reduction.

The state proposes **4** actions under this strategy (see page 244)

5 – Support communities in identifying and reducing or eliminating physical and financial risks to people, buildings, and infrastructure and educate residents and property owners about risks.

The state proposes **10** actions under this strategy (see page 246)

6 – Build the science and evidence base for effective coastal resilience projects and techniques and facilitate use of best practices.

The state proposes **8** actions under this strategy (see page 248)

7 – Invest in protection, restoration, enhancement, and/or management of natural and cultural resources and public access to the shoreline.

The state proposes **6** actions under this strategy (see page 250)

8 – Invest in emergency preparedness and response based on current and future coastal hazards and ensure new and existing critical infrastructure can withstand coastal impacts to provide safe and reliable services to residents before, during, and/or after storms.

The state proposes **5** actions under this strategy (see page 252)

9 – Support and incentivize voluntary relocation of people, infrastructure, and other assets in areas that are currently or projected to be subject to repetitive flooding, inundation, erosion, and/or shoreline migration.

The state proposes **7** actions under this strategy (see page 254)

10 – Support a thriving coastal economy by facilitating and investing in the resilience of water-dependent industries, businesses, and recreational resources where appropriate.

The state proposes **7** actions under this strategy (see page 256)

The following pages outline proposed state agency actions to take place over the next several years to support the implementation of these state-led strategies. Actions are marked either [**COASTWIDE**] or [**STATEWIDE**] to indicate the scale of implementation. Some actions, especially those involving state statutes or regulatory programs, necessitate statewide implementation. However, even where actions are proposed to be implemented statewide, they are identified here because they are critical to coastal resilience.

STRATEGY 01

Identify and invest in district- and regional-scale projects and partnerships, tailored where necessary to region-specific needs and circumstances.

The scale of need coupled with limited resources necessitates prioritizing state investments in coastal resilience projects that are high-impact and cost-effective. District- or regional-scale projects are those that leverage the collective capacity and resources of neighborhoods and communities to address shared coastal vulnerabilities often across municipal boundaries. Designing, permitting, and constructing projects at this scale can stretch limited dollars further for greater impact and help avoid the redundancy and/or inconsistency that often results from a piecemeal approach along shared shorelines. Coastal Resilience Districts are one such scale for project implementation.

Massachusetts is already encouraging regional projects through existing climate resilience grant programs. A centralized "one stop" grant portal with a streamlined application process for climate, conservation, and biodiversity grants at EEA is slated to be launched. The state has also undertaken the ResilientMass Finance and Investment Study to identify new ways to grow funding and financing opportunities for resilience projects. However, more can be done to support and incentivize communities to work collaboratively at the district- and regional-scale, identify priorities, and finance projects that protect people, infrastructure, and coastal ecosystems.

The state can build on existing efforts by prioritizing district- and regional-scale projects in existing grant programs; creating new and multi-year funding opportunities specifically for these projects; offering technical assistance to coordinate among communities and with state agencies; creating streamlined funding application processes for high priority projects; coordinating with the private sector; and identifying local options for district-scale assessment and revenue sources.

Proposed State Actions

NEAR-TERM (1-2 years)

1.1 – Support and incentivize collaboration within and between Coastal Resilience Districts, including community efforts to jointly identify, prioritize, and implement capital and infrastructure projects for resilience, through technical assistance and funding for regional capacity building. [**COASTWIDE**]

1.2 – Identify and support the implementation of several large-scale priority pilot projects through multi-year funding opportunities, technical assistance, and cross-agency coordination on permitting. [**COASTWIDE**]

1.3 – Establish a priority project designation within the Environment and Climate One Stop (ECO One Stop) portal to fast-track high-impact regional projects that meet certain criteria. [**STATEWIDE**]

1.4 – Work with coastal communities to pilot district-level financing options identified in the ResilientMass Finance and Investment study. [**STATEWIDE**]

1.5 – Coordinate with the private sector on their role in participating in and funding district-scale and regional-scale projects through public-private partnerships. [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

1.6 – Increase funding and technical support for developing and implementing regional sediment management plans, which guide coordination and prioritization for sediment placement. Cost-effective and resource-protective sediment management can help sustain recreation and tourism; enhance public safety; and restore coastal sandy habitats. [**COASTWIDE**]

1.7 – Update state statutes that give municipalities the authority to establish local funding streams through district improvement financing and special tax assessments to ensure that funding can be used for coastal resilience projects. [**STATEWIDE**]

STRATEGY 02

Increase the resilience of new and re-development by integrating best available data on current and future coastal hazards.

Integrating the best available data on coastal hazards into decisions about where and how communities develop will help avoid increasing physical and financial exposure of people, businesses, and infrastructure along the coast. It is also critical for safeguarding investments in new housing intended to meet state demand. The state can implement this strategy by both providing technical resources and guidance for local efforts and by setting a resilient statewide regulatory baseline.

The Massachusetts State Building Code is an important tool for ensuring all new development on the coast is resilient. A recent state study estimates that 2024 updates to the code that increased freeboard requirements by one foot for construction in flood-prone areas may result in $1.5 to $2.3 billion in avoided losses.[105] The same study estimates that expanding requirements for flood-prone construction to the 500-year floodplain (the code currently only applies to the 100-year floodplain), could result in an additional $1.1 to $1.3 billion in avoided losses. The state recently established a Resilience Technical Subcommittee to inform updates to the next edition of the code.

The state is developing numerous municipal resources including a Local Action Guide for Promoting Flood-Smart Development and, in partnership with the Metropolitan Area Planning Council (MAPC) and the Pioneer Valley Planning Council (PVPC), a Resilience Playbook to provide guidance on local resilience policies and actions (beyond just coastal). The playbook contains a searchable list of over 100 actions that cities and towns can take to build climate resilience. It also provides more detailed implementation blueprints for a subset of actions.[106] In addition, the state is revising its Massachusetts Environmental Policy Act (MEPA) Protocol on Climate Change Adaptation and Resiliency, which will help ensure robust consideration of climate change in state environmental review processes.

The state can build on these existing efforts by providing additional resources for communities, including providing training materials for members of boards and commissions who are often making important local development decisions. The state can also continue to embed coastal resilience into its laws and regulations, including updates to the state building code, wetlands regulations, MEPA review processes, and municipal master plan requirements.

Proposed State Actions

NEAR-TERM (1-2 years)

2.1 – Make the newly established Resilience Technical Subcommittee a standing committee to inform updates to the state building code. [**STATEWIDE**]

2.2 – Embed resilience into administrative and other processes for Board of Building Regulations and Standards by establishing board seats for resilience experts and adding resilience to the board's core objectives. [**STATEWIDE**]

2.3 – Develop training materials for members of local conservation commissions, planning boards, and zoning boards of appeals on considering climate change in development. [**STATEWIDE**]

2.4 – Develop guidance for state environmental review processes on the appropriate use of short- and long-term resilience measures. [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

2.5 – Update regulations for state environmental review to ensure it effectively captures proposed new construction and redevelopment in high-hazard coastal areas. [**STATEWIDE**]

2.6 – Incorporate resilience amendments into the 11th edition of the Massachusetts State Building Code. [**STATEWIDE**]

2.7 – Integrate the ResilientCoasts framework into the MA Office of Coastal Zone Management's (CZM) coastal policy guide for federal consistency review. [**COASTWIDE**]

LONG-TERM (5+ years)

2.8 – Make training mandatory for members of local conservation commissions, planning boards, and zoning boards of appeals on considering climate change in development. [**STATEWIDE**]

2.9 – Investigate establishing performance standards for the future floodplain in the state wetlands regulations. [**STATEWIDE**]

2.10 – Integrate climate resilience into state requirements for municipal master plans (M.G.L. c. 41, §81D). [**STATEWIDE**]

STRATEGY 03

Require state investments to be informed by future climate conditions and avoid increasing unnecessary physical and financial exposure to coastal hazards.

The state must make prudent, cost-saving investments in communities and coastal ecosystems to reduce exposure to coastal hazards. Every $1 invested in resilience and disaster preparedness can yield up to $13 in cost savings. Integrating criteria for coastal resilience into decisions and investments from the beginning can help the state avoid significant losses and costs later.

Several statewide projects are already underway to integrate climate into decisions and investments, including the development of standards for integrating climate projections into infrastructure design. These standards will be developed for key public infrastructure like wastewater treatment plants and culverts and could be required in the future for projects funded by state grants or state disaster relief funds.

In addition, the Division of Capital Asset Management and Maintenance (DCAMM) uses its Capital Asset Management System Resilience Survey, a web-based form, to gather both qualitative and quantitative resilience information at the start of projects involving land and buildings owned or leased by the state, to inform the study and design process.

The Massachusetts Department of Transportation is currently undertaking several studies that will help set the stage for resilient investment including a flood risk assessment of transportation assets and a criticality assessment that will help identify evacuation routes statewide. The state has also integrated resilience evaluation in the annual Capital Investment Plan process and is working to incorporate resilience across state grantmaking through the Climate in Grantmaking Initiative.

The state can take additional steps to ensure that decisions about state assets, including real estate and critical infrastructure, integrate climate risks. State funding and tax credit allocations should prioritize resilience in all projects, especially investments in affordable housing.

Proposed State Actions

NEAR-TERM (1-2 years)

3.1 – Adopt a set of resilience standards to ensure that infrastructure replaced or rebuilt with money from the state's recently created Disaster Recovery and Resilience Fund can better withstand future climate conditions. [**STATEWIDE**]

3.2 – Incorporate Near-Term Adaptation Areas identified in ResilientCoasts, as appropriate, into the existing DCAMM Resilience Survey and assessment process to inform and assist agencies with care and control in identifying priorities for coastal resilience investment and action. [**COASTWIDE**]

MEDIUM-TERM (3-5 years)

3.3 – Integrate climate resilience criteria and incentives into Massachusetts Qualified Allocation Plan (QAP) for Low-Income Housing Tax Credits. The QAP influences affordable housing construction and reflects the state's housing needs and priorities. [**STATEWIDE**]

3.4 – Assess the cost-benefit of relocation versus retrofit when investing maintenance or capital dollars in state-owned structures located in coastal high-hazard areas. [**COASTWIDE**]

3.5 – Incorporate resilience into the Commonwealth Leasing and Real Estate Activity Administrative Bulletin, which establishes policy principles and requirements for Commonwealth leasing and real estate activity. [**STATEWIDE**]

3.6 – Expand the Climate Ready Housing Program, a state funded program currently focused on deep energy retrofits and decarbonization projects in the affordable housing sector, to include resilience retrofits. [**STATEWIDE**]

LONG-TERM (5+ years)

3.7 – Improve coordination and screening criteria used in state real estate transactions (acquisition or disposal of properties) to capture opportunities for resilience and/or avoid coastal risks and exposure. [**COASTWIDE**]

STRATEGY 04

Acknowledge the fiscal realities of addressing coastal hazards by prioritizing resilience actions that have the highest impact and maximize long-term risk reduction.

The investments needed to adapt to coastal hazards far outstrip current resources. It is therefore in the public interest to prioritize and target resources to where they can have the greatest benefit for the most people, balancing for equity and fairness. To advance toward coastal resilience in the most cost-efficient and effective manner, the state must coordinate investments strategically across regions.

Several state and federal projects are underway to help inform strategic investments in coastal resilience. Currently, two U.S. Army Corps of Engineers (USACE) projects are undertaking assessments on the coast to evaluate flood vulnerability and identify potential projects to manage risk. One study focuses on the City of Boston while the other focuses on the Boston Harbor region (extending from Winthrop to Hull).

The Massachusetts Office of Coastal Zone Management is also studying the characteristics of five potential offshore sand resource areas in Massachusetts waters, including identifying cultural resources and evaluating dredgeability for use as potential borrow sites for nourishment of nearby beaches. Limited availability of sediment can be a constraint to beach nourishment projects for coastal resilience.

The state can build on these existing efforts by strategically investing in coastal resilience projects that will help reduce near- and long-term coastal flood risk, either identified by the USACE or other plans and studies. Near-Term Adaptation Areas identified in ResilientCoasts can help identify and prioritize areas with high concentrations of people and housing, infrastructure, and economic resources at near-term risk of coastal flooding. The state should also undertake more detailed benefit-cost analyses to inform policies on offshore sediment sourcing and state-funded beach nourishment projects and emergency sand placement.

Proposed State Actions

NEAR-TERM (1-2 years)

4.1 – Prioritize coastal resilience projects in Near-Term Adaptation Areas through the MA Office of Coastal Zone Management's Coastal Resilience Grant Program. [**COASTWIDE**]

MEDIUM-TERM (3-5 years)

4.2 – Develop state policies on the use of offshore sources of sediment, develop benefit-cost analysis of sand placement (cost, duration, risk reduction), and identify priority areas for state-funded beach nourishment. [**COASTWIDE**]

4.3 – Identify and invest in district-scale flood protection in strategic locations, prioritizing large population and economic centers and areas with high concentrations of critical infrastructure, especially where they coincide with vulnerable communities and priority populations. [**COASTWIDE**]

LONG-TERM (5+ years)

4.4 – Develop criteria to inform limitations on state-supported emergency sand placement. [**COASTWIDE**]

STRATEGY 05

Support communities in identifying and reducing physical and financial risks to people, buildings, and infrastructure and educate residents and property owners about risks.

Coastal communities in Massachusetts are on the frontlines of climate change. More than three million people across 98 cities and towns are expected to experience coastal flooding over the next 50 years. The state can take steps to support these communities in reducing risks to people and infrastructure and help educate residents and property owners about risks.

The state is already supporting local efforts through numerous technical assistance and grant programs, including the Municipal Vulnerability Preparedness and Coastal Resilience Grant Programs. The common application for EEA climate resilience grants will serve as a centralized hub of state climate funding with a streamlined application process.

The state has also identified expedited permitting as a priority for supporting resilience. An evaluation of existing permitting processes is currently underway that will help identify next steps for ensuring these processes can help accelerate, rather than be a barrier to, climate resilience projects.

Efforts are also underway to engage with and educate residents, including through the state's Climate Action Campaign, which is a statewide media campaign to raise awareness about climate change and promote ways individuals can take action. To ensure that homeowners understand their flood risks, the Division of Insurance (DOI) is developing and will issue a Filing Guidance Notice that will require home insurance carriers in the state to uniformly and consistently disclose that the property/ dwelling policy does not cover flood risks.

DOI also partners with other states to require insurers with a certain dollar amount of premiums to respond to a survey regarding their preparedness to address climate risks. Information collected through this survey allows the state to better understand how insurers in Massachusetts are considering and addressing climate change and climate risk in their business operations, underwriting and reserves.

The state can do more to help reduce community risks, including supporting the use of local tools like zoning and Transfer of Development rights that can help encourage strategic, resilient development. Statewide standards for flood risk disclosure and hazardous site clean up; streamlined permitting processes for resilience projects; and funding opportunities for individual and public resilience projects like home elevation and municipal infrastructure can also support local efforts to reduce risk.

Proposed State Actions

NEAR-TERM (1-2 years)

5.1 – Establish state flood risk disclosure requirements for the rental and sale of residential properties. This would require landlords and sellers of residential properties to make disclosures concerning known and potential flood risks. [**STATEWIDE**]

5.2 – Support municipal use of Transfer of Development Rights (TDR) by promulgating regulations for a state TDR program and capitalizing a state TDR bank to help facilitate local transactions. TDR is a market strategy that allows development rights to be bought and sold. [**STATEWIDE**]

5.3 – Establish a state revolving loan fund for local and regional climate resilience projects. [**STATEWIDE**]

5.4 – Through the state's Climate Action Campaign, undertake language accessible education opportunities to inform residents about flood risks and encourage eligible property owners to obtain and maintain flood insurance policies. [**STATEWIDE**]

5.5 – Launch annual or biennial municipal survey to collect information from cities and towns on coastal resilience risks, policies, activities, budgets, and capacity to inform prioritization of state resources and technical assistance. [**COASTWIDE**]

5.6 – Expedite permitting for resilience projects. [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

5.7 – Prepare industry-wide guidance incenting all Massachusetts homeowner's insurance companies to offer premium credits, reduced premiums, deductible credits or deductible waivers when homeowners take specific climate risk and resilience loss mitigation efforts. [**STATEWIDE**]

5.8 – Establish a statewide home elevation grant and/or loan program to assist low-income property owners with elevating residential structures in high-hazard areas. [**STATEWIDE**]

5.9 – Incentivize communities to adopt resilient zoning that prioritizes high density development in upland areas and minimizes new construction in high-hazard areas. [**STATEWIDE**]

LONG-TERM (5+ years)

5.10 – Develop guidance on resilience standards for site cleanup and remedy selection under the Massachusetts Contingency Plan (MCP), which outlines procedures for hazardous site assessment, remediation, and compliance with environmental standards. [**STATEWIDE**]

STRATEGY 06

Build the science and evidence base for effective coastal resilience projects and techniques and facilitate use of best practices.

Understanding the breadth of resilience projects and techniques and where they work best is essential for effectively addressing coastal hazards. From tried-and-true measures to more innovative, emerging approaches, a solid science and evidence base can help state, local, and private decision makers select appropriate measures in different locations across the coast. Local observations of coastal hazards as well as updates in climate science and modeling, can help inform our evolving understanding of current and future risks.

Massachusetts is a national leader with some of the most sophisticated state and local climate science and modeling being used to inform our planning and decision making. The state is doubling down on this leadership with its newly established Office of Climate Science, which will continue to increase state agency, municipal, and public access and understanding of statewide climate change projections and trends and provide technical assistance and guidance.

Several ongoing studies will continue to support the state's data-driven approach to resilience. The Massachusetts Office of Coastal Zone Management is developing design guidance for the redesign and retrofit of seawalls as well as technical recommendations for conducting flow path analyses which help inform the resilience of new and redevelopment projects.

More work is needed to update and improve datasets that help inform coastal resilience actions, including the state's Massachusetts Coast Flood Risk Model (MC-FRM) and the coastal structures inventory. New modeling and studies can help expand our current understanding of risk, including evaluating compound flood risks, which are the flood risks resulting from multiple sources (sea level rise, storm surge, stormwater, riverine, and groundwater). Resources are also needed to support monitoring of ecological processes and evaluation of restoration outcomes as well as networks for monitoring existing flood risks.

Proposed State Actions

NEAR-TERM (1-2 years)

6.1 – Update modeled coastal flood data products to include projected mean high water for 2030, 2050, and 2070 and make data available for all communities. [**COASTWIDE**]

6.2 – Provide resources for monitoring ecological and landform processes and evaluating restoration outcomes. [**STATEWIDE**]

6.3 – Provide technical assistance and educate communities about suitable and effective coastal resilience measures including fact sheets on how property owners can reduce risk. [**COASTWIDE**]

6.4 – Establish a flood monitoring network that tracks and documents multiple sources of flooding (stormwater, coastal, riverine flooding and groundwater rise). [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

6.5 – Update the Massachusetts Coast Flood Risk Model (MC-FRM) to incorporate landform change, culvert information, and other critical processes and data and review the need to update MC-FRM on a five-year basis as part of the Climate Science Report. [**COASTWIDE**]

6.6 – Update and improve the statewide coastal structures inventory, which includes both publicly and privately owned seawalls, revetments, groins, jetties, and other coastal structures on the shoreline, to assess the functionality and vulnerability of existing coastal structures. [**COASTWIDE**]

6.7 – Assess exposure of underground resources and infrastructure to sea level rise (including saltwater intrusion) and erosion. [**COASTWIDE**]

LONG-TERM (5+ years)

6.8 – Undertake modeling of the combined impacts of multiple sources of flooding including coastal, riverine, stormwater flooding and groundwater rise and incorporate into Coastal Resilience Districts. [**STATEWIDE**]

STRATEGY 07

Invest in protection, restoration, enhancement, and/or management of natural and cultural resources and public access to the shoreline.

Natural and cultural resources are a precious and important part of the Massachusetts coastline. Coastal ecosystems like salt marshes and beaches provide significant environmental and ecosystem service value and are often more cost-effective than alternatives. For example, salt marshes help reduce wave energy, capture and store carbon, provide flood storage, and protect life and property from coastal hazards. Coastal wetlands from Maine to North Carolina are estimated to have reduced flood heights and saved $625 million in direct flood damages during Hurricane Sandy.[107] Various factors affect wetland capacity for damage reduction including storm exposure, expanse of salt marshes, and elevation of development. Salt marshes in the Northeast also store carbon equivalent to approximately 10 million cars in the top meter of peat soil.[108] Natural and cultural resources also support local economies through outdoor recreation and tourism and sustainable fisheries.

Massachusetts understands the value and importance of its natural and cultural resources and the importance of public access to these resources and the shoreline. The state has developed nation-leading biodiversity conservation goals; undertaken an assessment of the vulnerability of coastal cultural resources to hazards like sea level rise; and is developing tidal crossing standards to help protect wildlife, fish, and biodiversity resources. The Massachusetts Office of Coastal Zone Management and partners have also secured $9 million in federal funds from the National Oceanic and Atmospheric Administration (NOAA) to undertake coastal habitat restoration across the state.

The Massachusetts Department of Environmental Protection is protecting wetlands and waterways, including public access to the shoreline, with forthcoming regulatory updates that incorporate resilience and streamline ecological restoration. The ResilientLands Initiative and its Coastal Working Group are also guiding actions to conserve, restore, and care for the land to benefit both nature and people.

The state can do more to protect, restore, and enhance coastal ecosystems; manage coastal cultural resources; and protect and enhance public access to the shoreline. Building off ongoing efforts to update wetlands and waterways regulations, the state can further streamline or create regulatory pathways for restoration and resilience projects. A project currently underway is assessing opportunities for streamlined permitting and will inform next steps.

Additional stakeholder engagement is needed to build consensus for methods of prioritizing state resources for coastal ecosystem restoration, particularly salt marshes. Following the completion of the state's coastal cultural resource vulnerability assessment, the state can also support communities in addressing the vulnerability of cultural resources through adaptive management strategies.

Proposed State Actions

NEAR-TERM (1-2 years)

7.1 – Streamline and/or create regulatory pathways for existing restoration techniques like removing barriers to tidal flow (culverts, dams, etc.) as well as new restoration strategies where they have no or minimal adverse impacts to the resource areas and adjacent properties. [**STATEWIDE**]

7.2 – Form a stakeholder working group to evaluate and develop a methodology for prioritizing salt marshes for state-funded acquisitions and restoration actions based on risks and resilience and identify marsh migration zones coastwide. [**COASTWIDE**]

7.3 – Form a stakeholder working group to evaluate nearshore subtidal natural and cultural resources to create recommendations for protection, restoration, and/or management. [**COASTWIDE**]

7.4 – Expand public access easement requirements as a condition of state funding for shoreline projects (e.g., beach nourishment, seawalls and revetments). [**COASTWIDE**]

MEDIUM-TERM (3-5 years)

7.5 – Assist municipalities and tribal nations in identifying and implementing adaptive management strategies for cultural resources threatened by coastal hazards (e.g., inventorying, monitoring, documenting, and/or removing and relocating resources). [**COASTWIDE**]

7.6 – Update existing wetland resource area delineations to reflect current conditions and inform updates to ResilentCoasts typologies and Coastal Resilience Districts. [**STATEWIDE**]

STRATEGY 08

Invest in emergency preparedness and response based on current and future coastal hazards and ensure critical infrastructure can withstand coastal impacts to provide safe and reliable services to residents before, during, and/or after storms.

While adapting and reducing exposure to coastal hazards remains critical, the state must also prepare for inevitable climate events and ensure that systems are in place to help people and businesses remain safe and recover from impacts. Critical infrastructure systems that provide vital services like transportation, electricity, water, and other utilities are increasingly exposed to flooding and erosion, compromising access and reliability for thousands of residents. Coastal storms, which are expected to increase in frequency and severity, have the potential to cause injuries, health issues, and even death.

The ResilientMass Initiative, including the most recent ResilientMass Plan (2023), sets the stage for effective and proactive emergency preparedness statewide. In addition, several state studies are laying the groundwork for more resilient critical infrastructure. The Massachusetts Department of Transportation is undertaking a criticality assessment of assets that will help inform the identification of evacuation routes statewide. The state can build off this effort by evaluating flood risks to evacuation routes and prioritizing resources for resilience.

The Massachusetts Department of Energy Resources is undertaking an expanded vulnerability and risk assessment for critical energy infrastructure that will be incorporated into the State Energy Security Plan. At the same time, the Massachusetts Legislature recently passed a bill requiring electric companies to develop Climate Vulnerability and Resilience plans to assess potential impacts of climate change on planning, operations, and physical assets.

The state can do more to ensure that Massachusetts residents can safely evacuate or shelter in place during storm events and recover quickly. Assessing and investing in resilient critical infrastructure is essential – from utility and transportation infrastructure to community facilities. Where the state does not own and operate infrastructure or facilities directly, it can support resilience through updated regulatory standards and guidance and investment of state resources.

Proposed State Actions

NEAR-TERM (1-2 years)

8.1 – Use findings from the State Energy Security Plan vulnerability and risk assessment to inform electric companies' development of state-mandated Climate Vulnerability and Resilience Plans. [**STATEWIDE**]

8.2 – Host a technical session with electric companies to establish resilience and storm fund metrics to inform the development of state-mandated Climate Vulnerability and Resilience Plans and ensure alignment with ResilientMass and ResilientCoasts. [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

8.3 – Undertake a coastwide evacuation pilot study to assess vulnerability and prioritize resources to increase the resilience of critical public roadways and public transit routes and stations before and/or during emergency events. [**COASTWIDE**]

8.4 – Identify opportunities to use state investments in community-serving facilities to promote Resilience Hubs (e.g., facilities that can provide shelter, back-up power, coordinate communication, and distribute resources before, during, and/or after emergency events), especially in vulnerable communities and isolated communities that face evacuation challenges. [**STATEWIDE**]

LONG-TERM (5+ years)

8.5 – Review storm cost recovery strategies, including the use of storm reserve funds, to ensure cost-effective resilient investments and alignment with climate-driven weather patterns. [**STATEWIDE**]

STRATEGY 09

Support and incentivize voluntary relocation of people, infrastructure, and other assets in areas that are currently or projected to be subject to repetitive flooding, inundation, erosion, and/or shoreline migration.

While coastal vulnerability in Massachusetts is widespread, not all areas face equal risks. Some areas of our coast will experience more frequent and severe inundation and erosion, and these places may be beyond our collective capacity to protect long-term. Addressing long-term risk requires making smart, and often hard, decisions to ensure a more sustainable and prosperous community and coast for tomorrow and future generations.

As communities in Massachusetts increasingly evaluate the role of managed retreat in local resilience efforts, the state can provide support through technical resources, data, and funding. It is important to have processes in place that allow communities to make strategic decisions about when and where to relocate housing, infrastructure and other assets. For example, stakeholders have consistently expressed support for a state-funded buyout program to help acquire high-risk properties from voluntary sellers.

State grant programs like the Municipal Vulnerability Preparedness program and the Coastal Resilience Grant Program have already provided funding for municipal projects that include the relocation of infrastructure and assets. The state is developing data and resources to further support this work.

The state can do more to support local efforts on relocation, including investigating the options, logistics, and funding needs of establishing a statewide voluntary buyout program for high-risk properties. It can also facilitate education and citizen science efforts to document and expand awareness of flood risks and work with communities to proactively identify priority areas for relocation of municipal coastal infrastructure and properties.

Proposed State Actions

NEAR-TERM (1-2 years)

9.1 – Undertake a statewide voluntary buyout study to understand the options, logistics, and funding needs of administering this type of program at the state level. [**STATEWIDE**]

9.2 – Conduct education and outreach with communities on planning for areas currently experiencing or expected to experience frequent inundation and/or erosion, including areas expected to face daily high tide flooding. [**COASTWIDE**]

9.3 – Expand the network of residents monitoring chronic flooding in vulnerable neighborhoods to increase awareness and documentation and to help inform prioritization of relocation resources. [**STATEWIDE**]

MEDIUM-TERM (3-5 years)

9.4 – Assist communities with accessing data on repetitive loss properties (e.g., properties that have submitted multiple flood damage claims to FEMA) and provide information and resources to help the state and communities better understand and plan for these high-risk locations. [**COASTWIDE**]

9.5 – Investigate and issue guidance on the impact of landform and mean high water changes on existing regulatory programs/requirements. [**STATEWIDE**]

9.6 – Establish and capitalize a statewide voluntary buyout program for at-risk residential properties. [**STATEWIDE**]

9.7 – Work with municipalities to identify priority areas for relocation of municipal coastal infrastructure and assets. [**COASTWIDE**]

STRATEGY 10

Secure a thriving coastal economy by facilitating and investing in resilience of water-dependent industries, businesses, and recreational resources.

The state's seaports and water-dependent businesses are a critically important part of the coast. The Massachusetts marine economy, including tourism and recreation, is currently estimated to contribute $8.3 billion to the state's gross domestic product (GDP) and $4.1 billion in wages across nearly 6,000 businesses with over 86,000 employees. The fishing industry alone generates more than $600 million annually and supports nearly 6,000 jobs.[109]

Unlike other infrastructure and assets, vulnerable port infrastructure and water-dependent businesses cannot relocate to safer areas – they rely on their proximity to the ocean. They also face unique challenges in adapting to coastal hazards because of the importance of maintaining a land-water connection to facilitate docking and handling, storage and transfer of cargo, and other essential port functions. As we strive to protect and increase the resilience of existing marine industries, there are also opportunities for Massachusetts to become a leader in emerging industries.

The state recently invested $2 million to create BlueTech OCEAN (Open Collaborative Experimentation and Acceleration Network), a two-year project that will boost the state's global leadership in ocean science, marine robotics, clean energy, and other game-changing marine industries. Maintaining the state's competitiveness in existing and new marine industries necessitates coastal resilience. The Massachusetts Office of Coastal Zone Management and Department of Environmental Protection are conducting an assessment of Designated Port Areas in the state to understand the strengths of the program and the ongoing and emerging challenges, including climate change and resilience.

Recreational resources on the coast that support state and local economies are similarly under threat. Better understanding where and how to address coastal hazards to these resources, as well as the potential impact on municipal budgets, will help communities prepare for changing conditions. The state should support identifying and undertaking strategies, where appropriate, to preserve and enhance access to the coastline and outdoor recreational resources that serve as the foundation for travel and tourism in many regions.

Proposed State Actions

NEAR-TERM (1-2 years)

10.1 – Support efforts to protect ports and working waterfronts from coastal hazards including through direct assistance. [**COASTWIDE**]

10.2 – Begin implementation of actions identified in the DPA assessment. [**COASTWIDE**]

10.3 – Leverage the Seaport Economic Council to educate coastal communities about existing grant opportunities, technical resources, and state initiatives. [**COASTWIDE**]

MEDIUM-TERM (3-5 years)

10.4 – Explore development of maintenance and resilience standards for Designated Port Areas while ensuring that shoreline access is maintained for water-dependent industries. [**COASTWIDE**]

10.5 – Undertake a study to better assess the economic impacts of coastal hazards on local government revenue and coastal economies including projected revenue loss and tax implications and options for revenue replacement. [**COASTWIDE**]

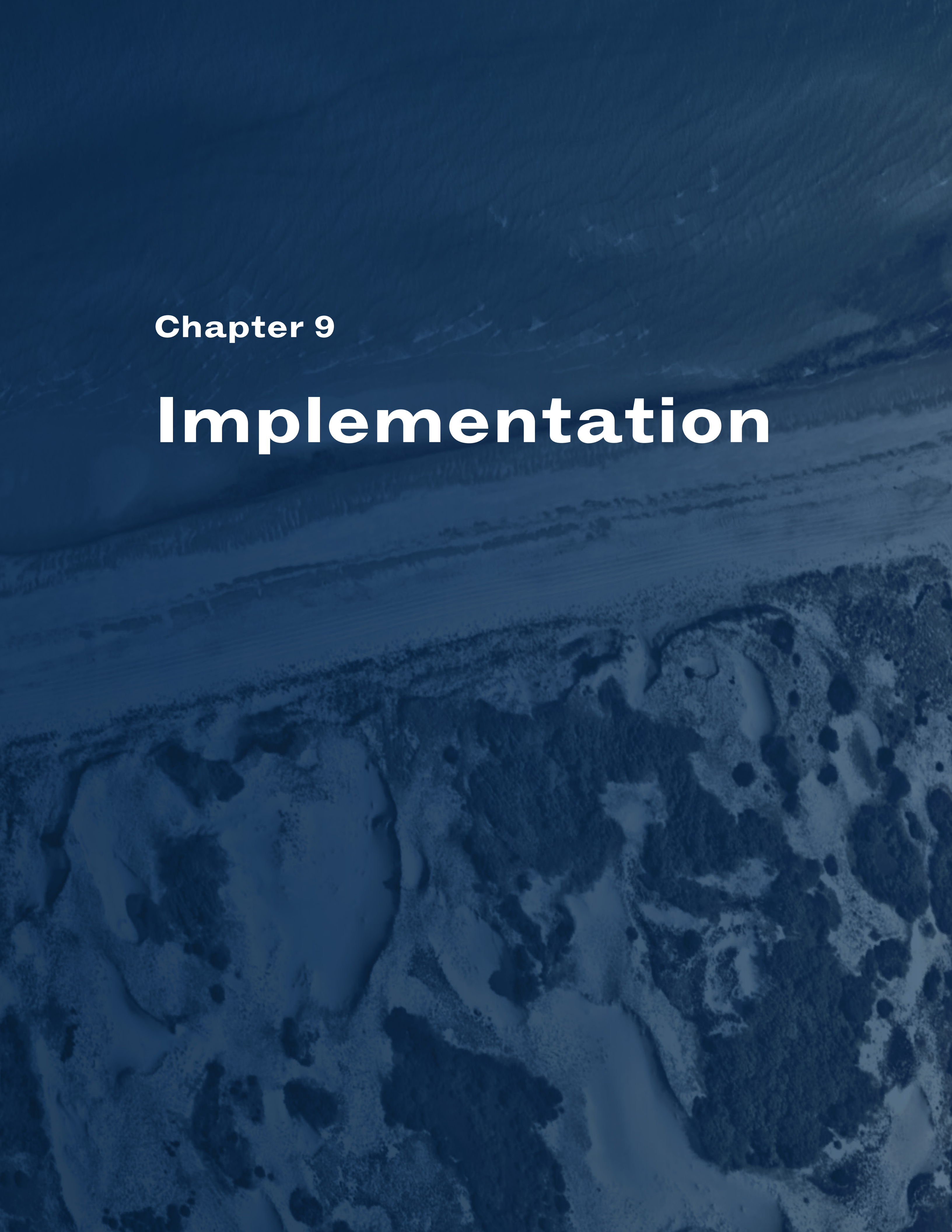
10.6 – Support communities in developing strategies to preserve and enhance access to the coastline and outdoor recreational resources that serve as the foundation for travel and tourism in many regions. [**COASTWIDE**]

LONG-TERM (5+ years)

10.7 – Provide local businesses, financial institutions, chambers of commerce, educational institutions, and Indigenous communities on the coast with business resilience and skills development, including financial tools and entrepreneurship training, to support development of the marine economy. [**COASTWIDE**]

Chapter 9

Implementation



Roadmap to Implementation

Successful implementation of ResilientCoasts will require a whole-of-government approach as well as coordination and collaboration of numerous partners across public and private sectors.

This Plan

Addressing coastal resilience in Massachusetts will be an ongoing effort requiring coordination across a wide range of partners, including state and local governments, tribal nations, residents, businesses, nonprofits and community-based organizations, private property owners, and others.

Through this initial planning process, the ResilientCoasts Initiative collected and synthesized feedback from a variety of coastal communities and partners on resilience priorities and other on-the-ground knowledge, including where state leadership is most needed. This plan, guided by both internal and external feedback, aims to:

- Propose a clear, consistent, equitable, and comprehensive framework for coastal resilience statewide including an overall vision, guiding principles, supporting goals, and associated indicators and metrics for tracking success.
- Provide a baseline for identifying and evaluating challenges and opportunities for coastal resilience both statewide and for distinct coastal regions.
- Develop an initial data-driven approach to identifying areas for regional collaboration on coastal resilience (Coastal Resilience Districts), as well as areas with near-term concentrations of coastal flood risk to people and housing, infrastructure, and economic resources (Near-Term Adaptation Areas).
- Provide place-based best practice guidance for key coastal typologies and coastal resilience measures.
- Identify state-led strategies to achieve coastal resilience including actions that can help support and accelerate local coastal resilience efforts while ensuring that the state leads by example.
- Chart a course for implementation of the ResilientCoasts Initiative and identify existing gaps in technical resources and data, capacity, and funding that will need to be addressed to achieve success.

The ResilientCoasts Plan lays the foundation for the next 50-years of coastal resilience in Massachusetts. However, coastal resilience requires decision making in the face of ongoing variability and uncertainty. The severity and scale of coastal hazards will depend, in part, on rates of sea level rise, which are influenced by changing economic, social, environmental and climatic conditions.

Because of the dynamic nature of the problem, the state will need to be nimble in implementing ResilientCoasts to address coastal hazards. Forthcoming updates to the Massachusetts Coast Flood Risk Model, the Massachusetts Climate Change Assessment, and the ResilientMass Plan will help inform any adjustments to the implementation strategy or priorities. The state will also continue to evaluate potential updates to coastal typologies to acknowledge contexts that influence the selection of resilience projects including urbanized waterfronts.

Massachusetts is committed to continuing to build on this Plan by sustaining public outreach and engagement, working directly with coastal communities and local partners, expanding our engagement with tribal nations, and deploying state resources to support the needs and priorities outlined in the Plan.

Monitoring Progress

The ResilientCoasts Initiative is a component of the broader statewide approach to resilience. It is part of ResilientMass, which serves as the state's umbrella initiative for climate adaptation and resilience programs, policies, and initiatives. ResilientCoasts can benefit from existing processes and mechanisms designed to track and implement ResilientMass, including the ResilientMass Plan Action Tracker,[110] ResilientMass Metrics,[111] and ongoing intergovernmental coordination facilitated by the ResilientMass Action Team (RMAT).[112]

ResilientCoasts will leverage these systems to monitor implementation of the Plan including progress on goals, indicators, and metrics outlined in Chapter 3 (see page 32) and state-led actions outlined in Chapter 8 (see page 232). Materials and data from the Plan will also be embedded within existing ResilientMass map and data centers as well as on the ResilientCoasts webpage.

ResilientCoasts is a whole-of-government approach to coastal resilience. As such, implementation will not be limited to any single agency within state government. It will require cross-agency coordination and buy-in, consistency in adhering to the framework laid out in the Plan, and active participation in undertaking and tracking progress on the proposed state-led strategies and actions. Additionally, close coordination between state and local government and other partners will help ensure that any state-supported coastal resilience efforts are consistent with the coastwide framework as well.

Ongoing coordination with coastal communities will be critical and help to ensure that local needs and priorities are reflected in state efforts to develop technical resources, update policy and regulatory frameworks, and prioritize and allocate resources for coastal resilience across the state. Within state government, coordination will be facilitated through existing forums including RMAT. An interagency coordination committee will also periodically continue to convene with members that have the most significant role to play in achieving coastal resilience through stewardship of state-owned properties and infrastructure, regulation of development and resource areas, preparation for and recovery from natural disasters, and investment of state funds.

Additionally, the Executive Office of Energy and Environmental Affairs (EEA) prepares an annual Massachusetts Climate Report Card to assess progress over the previous 12 months, provide transparency to the public, and identify interventions needed to achieve net zero greenhouse gas emissions and build resilience to climate impacts.[113] ResilientCoasts will be included beginning with the 2025 report card.

Next Steps

Future phases of ResilientCoasts will focus on implementation efforts, including support for design, permitting, and construction of coastal resilience projects and carrying out state-led strategies and actions, including regulatory, policy, and funding mechanisms.

Community Outreach and Engagement

Ongoing community outreach and engagement will be critical to the success of ResilientCoasts. These engagement efforts must be inclusive and accessible (including language access) for all. Continued and iterative public engagement will help build the necessary support for implementation efforts in current and future phases and will include:

- Meaningful public involvement, particularly from vulnerable and priority populations, ensuring the views and perspectives of all coastal stakeholders help shape priority setting and decision making.
- Routine engagement with coastal communities both at the municipal level and through regional collaboration within Coastal Resilience Districts.
- A maintained online presence through the ResilientMass and ResilientCoasts webpages and social media channels to provide updates, information, and accessible interactive tools and technical resources as described in more detail below.

Capacity-Building and Regional Collaboration

Stakeholder engagement for the ResilientCoasts Plan, as well as many years of coastal resilience planning and implementation, make clear that coastal communities require increased capacity to more effectively address coastal hazards and build resilience at the local and regional level. Implementation efforts will support ongoing municipal-scale coastal resilience efforts and identify ways to facilitate and incentivize district-scale collaboration across and between CRDs:

- Collecting and cataloging information on local capacity, projects and priorities, and unmet need directly from coastal communities via a periodic survey.
- Partnering with coastal communities to identify and address challenges/barriers to district-scale collaboration, including those related to capacity and governance, and outline processes and resources for undertaking district-scale planning, prioritization, and implementation.
- Convening and operationalizing Coastal Resilience Districts, including district-scale funding mechanisms, which can be piloted based on recommendations from the forthcoming ResilientMass Funding and Financing Strategy.

Development of a Coastal Communities Survey is identified as a near-term action in Chapter 8 (see page 232) and aims to collect local information on priorities, needs, costs, policy and planning initiative, etc. to help the state monitor progress and help inform resource allocation.

Technical Resources and Data

Additional technical resources and data are needed to support coastal resilience at the local, regional, and state level. In addition to expanding research and analyses in line with the proposed actions in Chapter 8 of this Plan, the state will continue to develop and maintain technical resources and tools for stakeholders to use in coastal resilience efforts, including:

- Continuing to maintain an up-to-date sea level rise and coastal flooding viewer and integrating new modeling and data into the viewer (e.g., compound flood risk) as it is developed.
- Hosting webinars and workshops to provide technical resources for common resilience topics and challenges encountered by coastal stakeholders.
- Developing and maintaining a database of proposed and planned coastal resilience projects and using this information to update risk profiles for Coastal Resilience Districts as projects successfully eliminate or reduce local and regional vulnerability.
- Launching a Web Viewer to host information from the ResilientCoasts Plan, including mapped locations of Coastal Resilience Districts, Near-Term Adaptation Areas, and key coastal typologies, as well as other data layers that help inform coastal resilience efforts (shoreline condition, demographics, etc.). These data will also be integrated into existing state platforms including MassGIS and the ResilientMass Climate Resilience Design Standards tool.[114]

Partner on High-Impact Projects

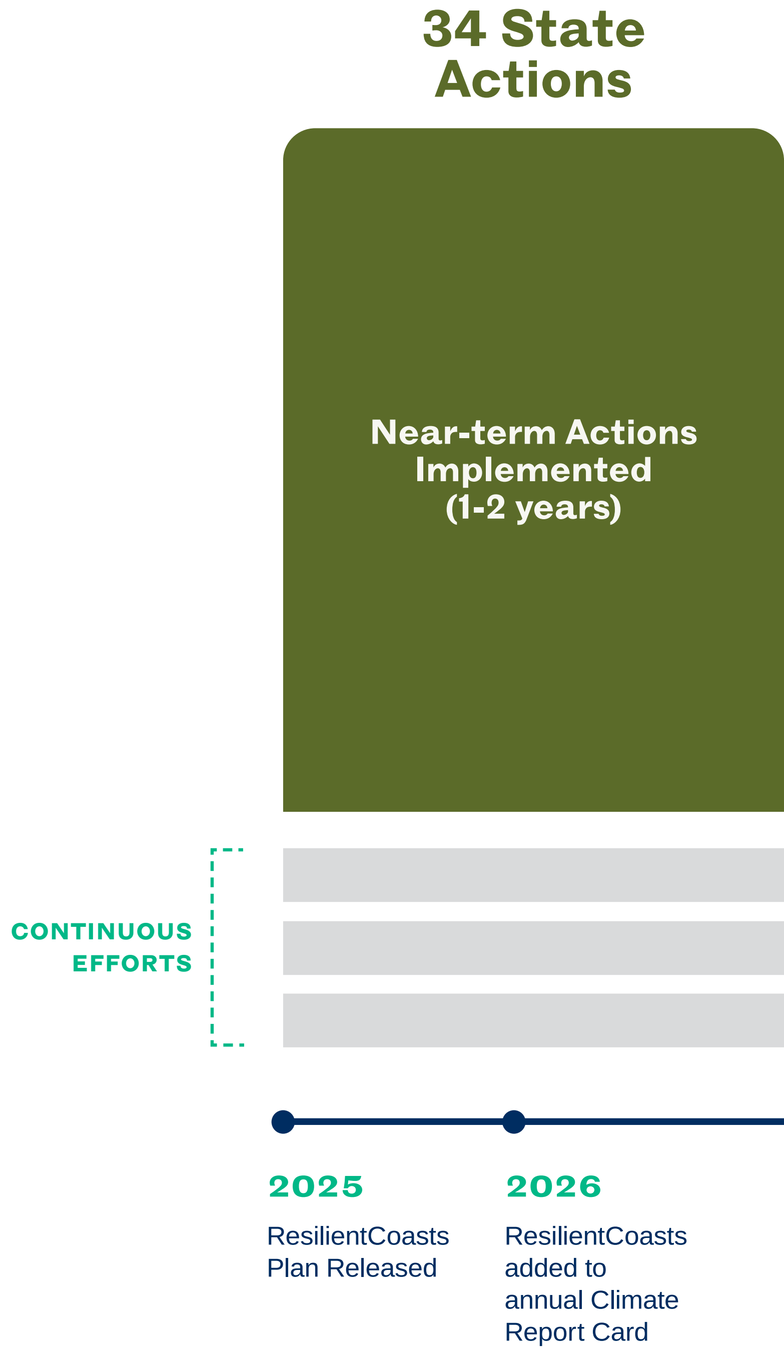
In partnership with coastal communities across the 15 CRDs, the next phase of ResilientCoasts will aim to identify and move forward high-priority and high-impact coastal resilience projects that reduce damage from coastal hazards in the most at-risk areas of the coast. This effort will dovetail with the ongoing U.S. Army Corps of Engineers studies in the City of Boston and the Boston Metropolitan Area as well as other local and regional implementation planning efforts to identify potential project areas coastwide.

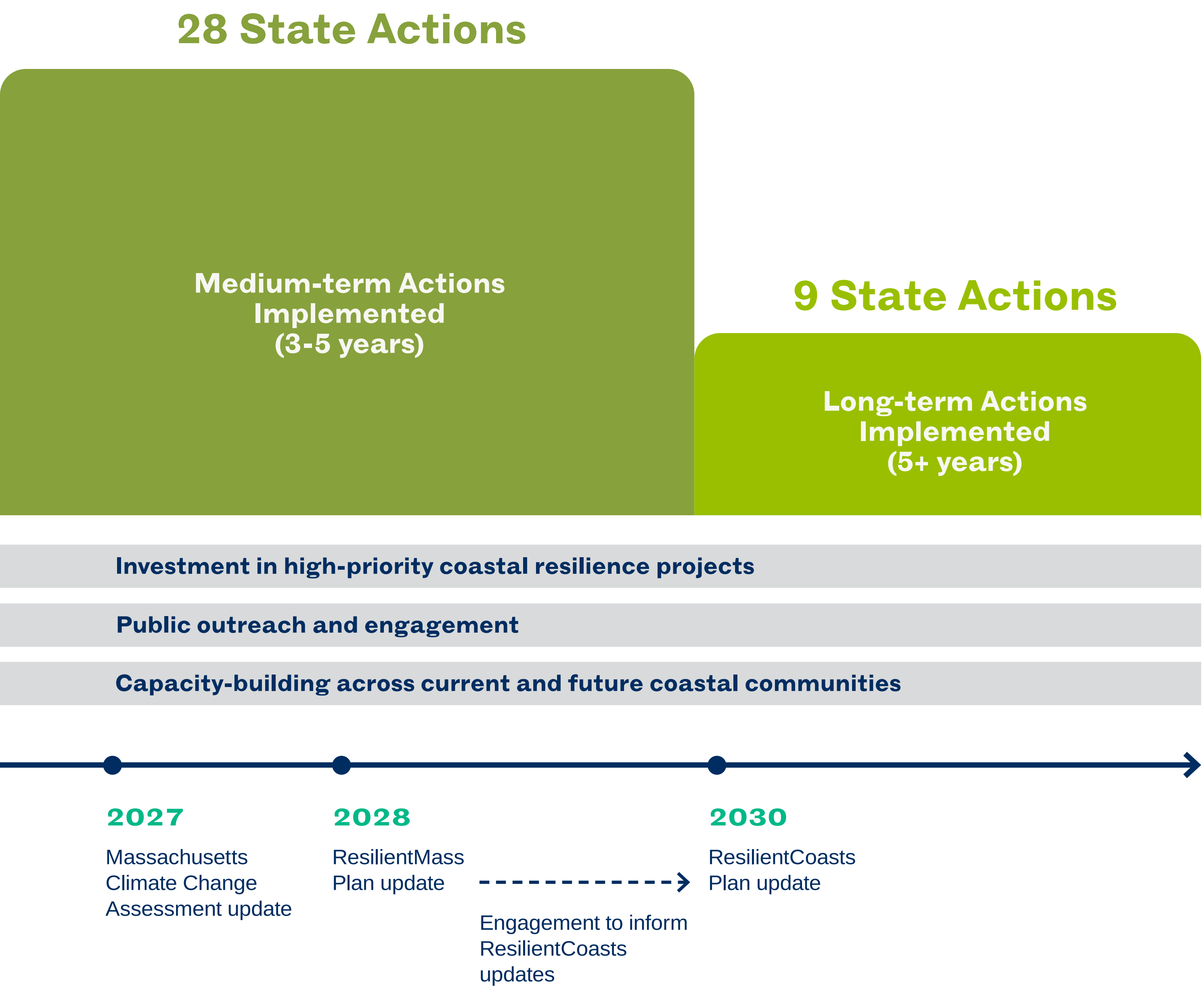
The Road Ahead

The ResilientCoasts Plan provides a first-of-its-kind framework for accelerating coastal resilience efforts across Massachusetts and includes data, information, and priorities that will be critical for identifying and implementing high-impact projects to reduce local and regional coastal hazard risk.

Implementation will combine ongoing efforts—such as maintaining data and technical resources, engaging with local leaders and the public, and building capacity within Coastal Resilience Districts—with the 10 state-led strategies and 71 near-, medium-, and long-term actions outlined in Chapter 8. Many of these actions are designed to identify and advance priority projects across Coastal Resilience Districts in partnership with local and regional entities.

The Massachusetts Office of Coastal Zone Management will continue to oversee the initiative, coordinating state-led actions implemented by various agencies across state government. This collaborative approach ensures coastal resilience is fully integrated into state investments and decision making, while also aligning with the broader ResilientMass initiative to strengthen statewide capacity for climate adaptation and resilience.




28 State Actions
Medium-term Actions Implemented (3-5 years)
9 State Actions
Long-term Actions Implemented (5+ years)
Investment in high-priority coastal resilience projects
Public outreach and engagement
Capacity-building across current and future coastal communities
2027
Massachusetts Climate Change Assessment update
2028
ResilientMass Plan update
Engagement to inform ResilientCoasts updates
2030
ResilientCoasts Plan update

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A special thanks to the following individuals and teams who contributed to the Plan in addition to others who may not be listed.

Project Management Team

ResilientCoasts was managed by the Office of Coastal Zone Management's (CZM) Chief Coastal Resilience Officer in collaboration with a project management team of representatives from CZM and the Executive Office of Energy and Environmental Affairs (EEA) Climate Team.

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EEA Climate Team
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Internal Working Group

Representatives from key State agencies participated in the Internal Working Group (IWG) for ResilientCoasts. Considering the whole-of-government approach to ResilientCoasts, the IWG provided critical cross-agency input and guidance in the development of all aspects of the Plan, both refining principles and strategies and thinking through and addressing potential implications for other State initiatives.

Executive Office for Administration and Finance (A&F)
Division of Capital Asset Management and Maintenance (DCAMM)

Executive Office of Economic Development (EOED)

Executive Office of Energy and Environmental Affairs (EEA)
Department of Conservation and Recreation (DCR)
Department of Fish and Game (DFG)
Division of Ecological Restoration (DER)
Division of Fisheries and Wildlife (MassWildlife)
Division of Marine Fisheries (DMF)
Massachusetts Department of Environmental Protection (MassDEP)
Massachusetts Environmental Policy Act Office (MEPA)
Massachusetts Office of Coastal Zone Management (CZM)
Municipal Vulnerability Preparedness Program (MVP)
Office of Climate Science (OCS)
Office of Environmental Justice and Equity (OEJE)

Executive Office of Health and Human Services (EOHHS)
Department of Public Health (DPH)

Executive Office of Housing and Livable Communities (HLC)

Executive Office of Labor and Workforce Development (LWD)

Executive Office of Public Safety and Security

Massachusetts Emergency Management Agency (MEMA)

Executive Office of Transportation

Massachusetts Department of Transportation (MassDOT)
Massachusetts Bay Transit Authority (MBTA)

Massachusetts Water Resources Authority (MWRA)

External Task Force

The State formed a task force of external stakeholders from different sectors. The External Task Force (ETF) provided a range of crucial community, stakeholder group, and subject matter expert perspectives to guide and ground truth potential approaches throughout the development of the Plan.

Northeast Center for Coastal Resilience
Northeast Climate Adaptation Science Center at UMass Amherst
Stone Living Lab at UMass Boston
A Better City
Boston Green Ribbon Commission
South Shore Chamber of Commerce
Atlantic Resiliency Innovation Institute
Boston Harbor Now
Conservation Law Foundation
Mass Audubon
Mystic River Watershed Association
New England Aquarium
The Nature Conservancy
The Trustees of Reservations
GreenRoots
Groundwork Southcoast
FM Global
Coastal Caucus (Massachusetts State Senator Julian Cyr)
Massachusetts Municipal Association
Barr Foundation
Essex County Community Foundation
Greater Boston Real Estate Board
NAIOP Massachusetts
Martha's Vineyard Commission
Metropolitan Area Planning Council
U.S. Army Corps of Engineers

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Consensus Building Institute

Elizabeth Cooper, Senior Mediator

* no longer affiliated with the organization

Key Concepts and Terms

Climate adaptation: Actions taken at the individual, local, regional, and national levels to reduce risks from changed climate conditions and prepare for impacts from additional changes projected for the future.

Climate change: A statistically significant variation in climate data or patterns over a given period of time, due to either natural climate variability or human activity.

Coastal hazards: As used in the ResilientCoasts Plan, this term refers to sea level rise, storm surge, wave action, and coastal erosion.

Coastal resilience: The capacity of coastal systems and communities to anticipate, prepare for, respond to, and recover from environmental challenges, particularly those related to climate change and natural disasters.

Critical infrastructure: Physical or virtual systems and assets so vital that their incapacity or destruction may have a debilitating impact on the security, economy, public health, safety, and environment of any local, state, tribal, or federal jurisdiction.

Compound flooding: Flooding that results from multiple drivers like stormwater and groundwater in addition to tidal flooding and storm surge. Compound flooding is not currently captured by MC-FRM and therefore not analyzed in this plan.

Cultural resources: Aspects of a cultural system that are valued by or significantly representative of a culture or that contain significant information about a culture. A cultural resource may be a tangible entity or a cultural practice. Tangible cultural resources may include districts, sites, buildings, structures, and objects, as well as archaeological resources, cultural landscapes, museum objects, and ethnographic resources.

District-scale: Subdivisions within a larger region or community. May be within a single community or span multiple communities. Is typically smaller than a full region. ResilientCoasts primarily uses this term to refer to the proposed Coastal Resilience Districts in Chapter 5.

Hardening: A catch-all term for a wide range of physical improvements and techniques used to make infrastructure more resistant to damage from storms and flooding, including undergrounding utility wires, using stronger waterproof materials, updating design standards for things like wires and poles, adding system redundancy, and using the latest technology for things like meters, monitoring equipment, and switches.

Hard infrastructure: Tangible, physical, engineered infrastructure, assets, and facilities that support daily life, such as electrical grids, roads, bridges, tunnels, ports, and seawalls.

Long-term coastal flooding: The ResilientCoasts Plan relies on projections from the Massachusetts Coast Flood Risk Model (MC-FRM) for the 0.1% annual chance flood event for the 2070s, based on a sea level rise scenario of 4.3 feet above the 2008 baseline.

Nature-based Solutions: Sustainable planning, design, environmental management, and engineering practices that incorporate or mimic natural features or processes into the built environment to promote climate adaptation and resilience. In coastal settings, nature-based solutions incorporate ecological principles into shore protection strategies to support multiple benefits, including, hazard adaptation and mitigation, natural resource resilience and enhancement, and recreation and scenic resource preservation. These may include living shoreline projects like beach and dune nourishment, salt marsh restoration, cobble berms, and bank stabilization, as well as floodable parks and open spaces and other projects.

Near-term coastal flooding: The ResilientCoasts Plan relies on projections from the Massachusetts Coast Flood Risk Model (MC-FRM) for the 1% annual chance flood event for the 2030s, based on a sea level rise scenario of 1.3 feet above the 2008 baseline.

Overwash: Process by which beach sediment is carried landward across the barrier by elevated water levels and waves.

Regional-scale: Encompasses broader areas, defined by geographical, cultural, or administrative criteria. These areas are generally larger than districts. Example: Boston Harbor Region includes the area from Winthrop to Hull, spanning multiple Coastal Resilience Districts.

Risk: The potential for an unwanted outcome resulting from an event or occurrence, as determined by its likelihood and the associated consequences. Risk may degrade or hinder the performance of essential functions and affect critical assets associated with continuity operations.

Vulnerability: The likelihood of hazards that have occurred in Massachusetts in the past and are likely to occur there in the future. The ResilientCoasts Plan evaluated the vulnerability of people, infrastructure, and economic resources based on projections from the Massachusetts Coast Flood Risk Model (MC-FRM).

Wave overtopping: Conveyance of coastal waters over a seawall, bulkhead or revetment that occurs when wave runup exceeds the crest elevation of the structure.

Wave runup: The uprush of water above the stillwater level caused by wave action.

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