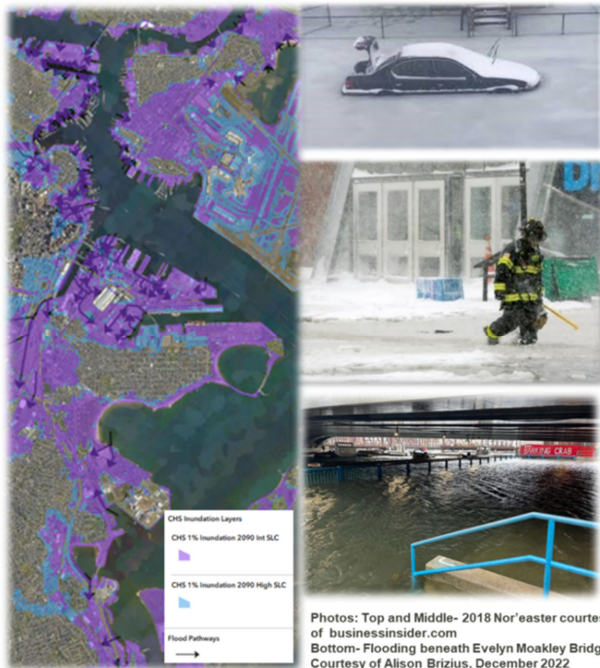


Boston Coastal Storm Risk Management Study

Draft Economics Appendix



City of Boston

US Army
Corps of
Engineers

New England
District



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1 INTRODUCTION

Coastal Storms and coastal storm-related inundation effects of climate change threaten the coastline of the City of Boston, endangering its communities, businesses, and critical infrastructure. Increased risk of inundation to property and other adverse impacts threaten community resilience and public safety and warrant Federal interest in investigating alternatives to reduce the risks stemming from coastal storms in the study area. The study area for this effort is the 47-mile water-land interface that forms the perimeter of five Boston neighborhoods - East Boston, Charlestown, Downtown/North End, South Boston, and Dorchester. These areas have experienced increased flooding over the last 25 years, with over 21 Federal and State disaster declarations and four of the top five surge events in the historical record. Three of those top five surge events occurred since 2018, with the deadly Hurricane Sandy missing Boston's high tide by five hours. The city was most recently impacted by a nor'easter in October 2025, which caused significant street flooding and power outages throughout the Boston area. Climate change is anticipated to magnify storm-related damages through the 50-year period of analysis, which runs from 2040 to 2090. The five neighborhoods that comprise the study area are presented in Figure 1, below.





Figure 1. Study Area Neighborhoods

1.1 Study Authority and Purpose

The City of Boston contacted USACE New England District on March 11, 2020, with a letter requesting assistance to investigate the current and increasing vulnerability to



coastal flooding and storm damage risks within the City of Boston and along its approximate 47 miles of coastline.

This study is being conducted under the authority of a Senate Committee on Public Works Resolution dated September 12, 1969, which reads:

RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be, and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining water resource improvements for flood control, navigation and related purposes in Southeastern New England for those wetlands, streams and estuaries which drain into the Atlantic Ocean and its bays and sounds in the reach of the coastline of Massachusetts, Rhode Island and Connecticut southerly of, and not including, the Merrimac River in Massachusetts, to, and including the Pawcatuck River in Rhode Island and Connecticut, with due consideration of enhancing economic growth and quality of the environment.

Figure 2, below, shows the flood extent anticipated under the high and intermediate sea level change (SLC) curves in 2090. While USACE does not explicitly formulate for SLC beyond the additional damage higher water levels would cause in coastal storms, the figure shows that anticipated increased water levels have the potential to increase quantity of damages caused by future coastal storm events given that inundation will extend to a larger floodplain.

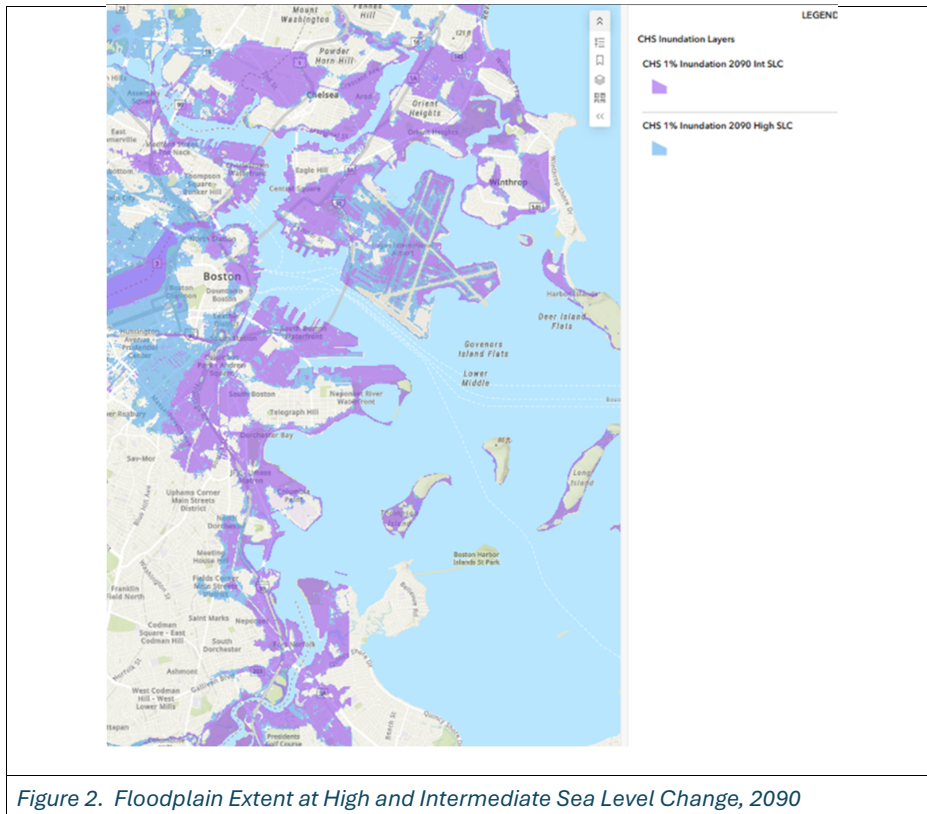


Figure 2. Floodplain Extent at High and Intermediate Sea Level Change, 2090

1.2 Economic Analysis Paradigm: Four Accounts and Public Benefits Analysis

USACE economic analysis requires accounting for four classes of benefits that would be derived over a 50-year period of analysis if USACE provided a remedy to the water resource problem. Those benefit types are:

- **National Economic Development (NED) Benefits:** The NED account documents the economic value of the national output of goods and services produced by the proposed investment. In the case of benefits to a coastal storm risk intervention,

these are the costs that would be incurred as the result of a storm event and are generally comprised of damages to assets in the study area, labor market losses and business disruptions stemming from utility outages and transit delay, and value of land loss. NED benefits are often difficult to quantify: for example, USACE will not put a value on a human life. While the loss of life will cause a decrease in the national output of goods and services, benefit categories such as life loss are generally accounted for in the Other Social Effects (OSE) account, described below. In this document, NED benefits for which a numerical value was derived are included in the NED calculation and benefits for which a numerical value was not calculated are catalogued as OSE. This classification is not based upon the relative importance of the benefit but rather the fact of unripe quantification methods.

- *Regional Economic Development (RED) Benefits:* The RED account is composed of economic value added in the local area and is considered a transfer rather than a true benefit to the nation. For example, the construction of a USACE project in Boston may cause a temporary increase in the number of construction workers purchasing lunch in Boston. That cost of lunch would be a benefit to the lunch purveyor, but the construction worker is going to eat lunch whether he is working on the Boston job or at a job site somewhere else. The benefit is both temporary and a transfer from somewhere else and not a gain to the national economy as a whole. In general, RED benefits are calculated as a multiplier of NED costs and are material/local employment dependent. While they are important to the non-Federal interest, they are not used in plan selection unless a sponsor is selecting a Locally Preferred Plan (LPP).
- *Environmental Quality (EQ) Benefits:* EQ benefits are derived from improvements to the habitat of humans or other species stemming from the USACE intervention. For example, planting oyster beds to dissipate wave effects on an eroding shoreline would also have the EQ benefit of improving water quality. Clearer water can prevent harmful algae blooms and allow light to reach submerged aquatic vegetation, both of which improve environmental quality.
- *Other Social Effects (OSE) -* OSE benefits refer both to NED benefits that defy quantification and to benefits that do not clearly fit into the other categories of benefits but which are important enough to consider as part of the decision-making process. Beyond life loss, this effort also considers reduction historic preservation as OSE benefits that would be attributable to specific interventions being considered to reduce coastal storm damage in Boston.

These four benefit categories have formed the basis of USACE benefit calculation since the promulgation of the *Principles & Standards* (P&S) by the Water Resources Council (WRC) in 1973. The P&S established the NED, RED, EQ, and OSE, which were then known as “social well-being” accounts. NED, RED, EQ, and OSE were incorporated into the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G) which replaced the P&S in 1983. Under the P&G, the vast majority of planning decisions were based on NED benefits until the passage of the Water Resources Development Act (WRDA) of 2007 (P.L. 110-14). WRDA 2007 encouraged the use of a broader set of “public” benefits to make planning decisions (see ER 1105-2-103, §1-15(a)(6)) and the Council on Environmental Quality (CEQ) led an interagency effort to modernize the P&G that concluded in 2013 and 2014, when the WRC issued the *Principles and Requirements for Federal Investments in Water Resources* in 2013 and the *Interagency Guidelines* in 2014 (together the PR&G). The PR&G specified that public benefits referred to economic, environmental, and social benefits; however, while the PR&G led to the preparation of *Agency Specific Procedures* (ASPs) for other Federal agencies, Congress prohibited USACE from generating its own ASPs that would allow for use of the standards of the PR&G. USACE was ultimately directed to develop ASPs by WRDA 2020 (P.L. 116-260, Division AA) and those ASPs became effective on 18 January 2025. The ASPs guide the plan formulation and economic evaluation required of all USACE Civil Works efforts and while the planning emphasis has changed over time, the four benefit categories still apply. For each category, the benefits to an intervention come from the difference between the future without-project condition and future with-project condition, where the future with-project condition has the project in place over the 50-year period of economic analysis.

This document applies this paradigm to a suite of proposed interventions to reduce the risk from coastal storms in Boston.

1.3 Description of the Study Area

Boston is the largest city in New England and the 25th largest city, by population, in the United States. With a land area of only 48 square miles and a population of approximately 650,000, Boston is one of the densest cities in the country, sitting behind only New York City and San Francisco. Because Boston is highly urbanized, rooftops and pavements cover much of its surface area. Nonetheless, the city also has a revered network of well-utilized parks and open spaces, which include not only Frederick Law Olmsted’s 1,100-acre Emerald Necklace but also the Harborwalk which is a nearly 40-mile contiguous linear path along its waterfront. Boston is highly transit



dependent, with over 25% of commuters reliant upon public transportation (ACS, 2024), which comes in the form of rail, light rail, buses, and ferries.

1.3.1 Geography

The City of Boston is located within the Northeast Coastal Zone which extends from northeastern New Jersey to the southern coast of Maine. The city itself is located within the Boston Basin subregion, which extends along the coast of Massachusetts from Cohasset to north of Beverly and as far inland as the Framingham area. The Boston Basin is ringed by low hills to the south and an extensive escarpment to the west and north. The topography within the basin consists of low, rolling glacial landforms and till-covered bedrock hills. The Charles and Mystic Rivers converge just north of downtown to flow into the Boston Main Channel, which provides access to Boston Harbor and the Atlantic Ocean. The Neponset River runs to the south of the city. Much of Boston was formed by landfill, as evidenced by the grid pattern in many of the neighborhoods. Boston Harbor is protected from winds coming from the south by the Cape Cod peninsula, which makes the nor'easter the most common and damaging type of storm in the area. Nor'easters are characterized by coastal flooding including storm surge, high winds, heavy rain or snow, and beach erosion.

Figure 3, below, shows Boston's 1630 shoreline transposed onto the current (1999) shoreline. Its purpose is to illustrate how much of the city sits on landfill. In each of the neighborhood sections, the descriptions of local geography reference to areas of landfill. This information is important in and of itself, but the extent of landfill within the study area is best captured by looking at the city as a whole.



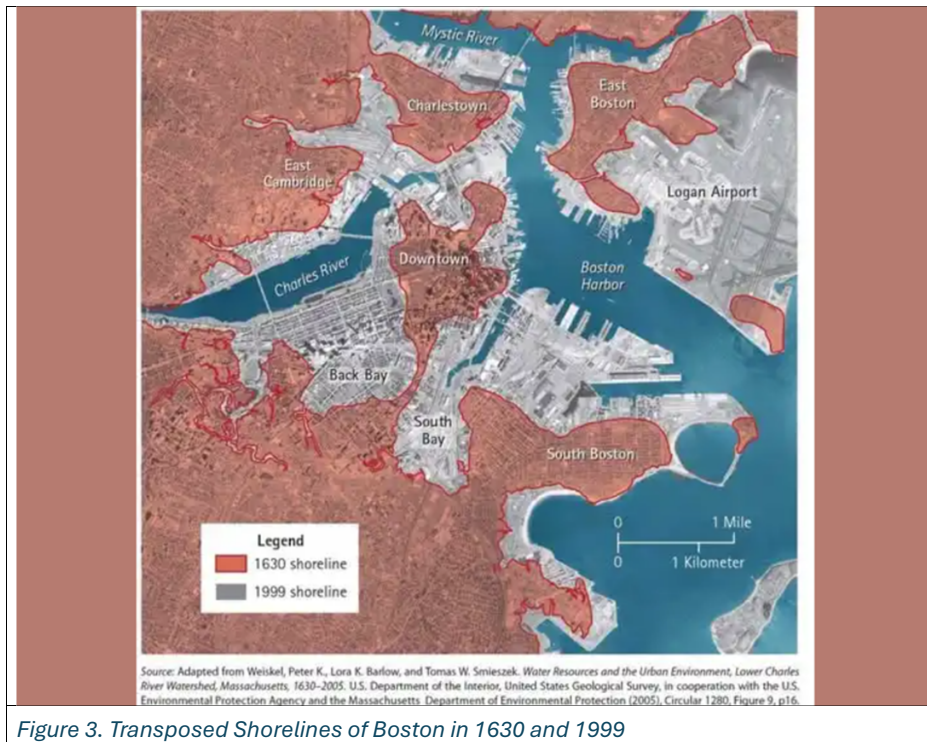


Figure 3. Transposed Shorelines of Boston in 1630 and 1999

1.3.2 Land Use

Land use varies throughout the study area and differs so much between neighborhoods that multiple chapters in this appendix will discuss local land use. In basic summary:

- **East Boston (EB)** is home to Logan International Airport, which takes up more than 3 square miles of the neighborhood's 5 square mile land area. Still, East Boston is one of the City's most populous neighborhoods, with 43,006 people (US Census, 2020) living in standard Boston "triple deckers", row houses, and a growing number of waterfront apartments, all of which sit in relatively close proximity to business, including tank farms, that actively serve the airport.
- **Charlestown (CH)** has similar housing stock to East Boston, but the residential heart of the neighborhood is surrounded by factories and other larger businesses, elevated highways, the Boston Autoport, and the decommissioned

Charlestown Navy Yard, which is now comprised of small businesses and luxury condominiums.

- The *North End* is one of Boston's smallest neighborhoods, accommodating more than 10,000 residents in .36 square miles. Much of the North End is a historic area with a building height limit of 60 to 70 feet, so most of its residents live in four- to five- story attached apartment buildings with ground-floor retail along winding and narrow streets.
- *Downtown* Boston is one of the few areas in the city where taller buildings have been allowed. While much of Boston's downtown area is a mix of commercial buildings, tourist businesses, and urban plazas, the movement of population back to urban centers that took place in the late 20th and early 21st centuries has given rise to a number of large, high-rise waterfront apartment buildings. Nonetheless, with 13,451 residents counted in the 2020 US Census, Downtown is the least residential both by number of residents and by proportion of residences of any neighborhood considered in this study. The Boston CSRM study considers the North End and Downtown areas together (DT/NE) as they are not hydrologically separable, but they are two distinct neighborhoods.
- While not hydrologically separable, until relatively recently, *South Boston* (SB) had two distinct parts. The area closest to Downtown was highly industrial, with numerous port related businesses, factories, logistics hubs, and with the move away from breakbulk shipping toward containers in the 1960s and the population shift away from northeast cities in the 1970s and 1980s, parking. In the 1990s, the City of Boston undertook a large and successful master-planning effort aimed at revitalizing the industrial area of South Boston and the *Seaport District* was the result. While the modern Seaport District still includes a relatively large amount of ground-level parking, the area is becoming a high-density, mixed-use neighborhood with both sparkling glass towers and adaptively- reused six- to ten-story buildings. Historic South Boston, which sits to the south and west of the Seaport is a mix of row houses, wooden triple-deckers, and single-family homes. Five to six-story apartment buildings with ground-floor retail line the wider avenues. The Seaport District and historic South Boston are referred to as SB in the Boston CSRM Study.
- *Dorchester* has row houses, triple-deckers, large Victorian homes, and modern transit-oriented apartment buildings. It is mostly residential, with much of the commercial stock comprised of one-story storefront businesses. Shopping plazas abut Route 93, which moves traffic between Cape Cod and the South Shore and Downtown, or Morrissey Boulevard. Between Route 93 and the waterfront is a mixture of parkland, townhomes, and the campuses of the

University of Massachusetts at Boston and Boston College High School. Of all the neighborhoods considered in the Boston CSRM Study, Dorchester has the largest proportion of single-family homes.



Figure 4. Typical Boston Triple-Decker Homes

More details on neighborhood land use are included in the next chapter.

1.3.3 Socioeconomic Conditions

As with land use, the socioeconomic conditions of the Boston CSRM Study Area vary by neighborhood; however, there are a number of important characteristics that differentiate the neighborhoods from the rest of the nation and from one another. A summary of those characteristics is presented here to provide a preview of critical socioeconomic dynamics faced by the population at risk (PAR) in each neighborhood.

There were four socioeconomic characteristics that the economic analysis identified to differentiate Boston from other areas of the nation and establish the differences between the five neighborhoods. These are:

- *Renter-Occupied v. Owner-Occupied Housing*

As with many major cities, most Boston Residents (65.1%) are renters (ACS, 2022). This is the exact opposite of the national average. The ACS five-year average from 2020 to 2024 shows that across the nation, 65.1% of residents own the unit where they live. Boston's flipped result stems from a number of factors, including the high cost of housing in the city and the fact that Boston has a large population of students who reside there temporarily. Among the five neighborhoods, Charlestown has significantly fewer renters than the other neighborhoods, but far beyond the national average.

MAGroup	Owner Occupied	Renter Occupied	Total
Charlestown	49.21%	50.79%	100.00%
Dorchester	37.57%	62.43%	100.00%
Downtown	23.39%	76.61%	100.00%
East Boston	28.45%	71.55%	100.00%
South Boston	36.40%	63.60%	100.00%

Ownership statistics matter because they affect rebuild assumptions used in the economic modeling. Units that are not owner-occupied are assumed to have lower rebuild rates because the owner who would be organizing and paying for the rebuild has somewhere else to live. Estimating NED benefits requires a modeler to estimate rebuild behavior in the study area and a high proportion of renters would indicate that a damaged structure would be rebuilt fewer times during the study period than if that structure was owner-occupied.

- *Age of Residents*

Life loss is a function of the number of elderly people who reside in the study area. *Age of population matters because* longitudinal research following Hurricanes Sandy (*Frontiers in Public Health*, 5 August 2025) and Harvey (*Journal of the American Geriatrics Society*, 16 December 2025) have shown that elderly residents exposed to coastal storms are not only more likely than the general population to die during a storm event, but they are also more likely to have negative health outcomes in the five years following a storm event than elderly residents who do not experience the coastal storm event.

The Boston CSRM study made the assumption that because of the long duration storms that are most common to the study area, commercial businesses would



be closed and people would be in their homes. It was also assumed, based on discussion with the City of Boston's Office of Emergency Management, that it would be reasonable to assume that in spite of the availability of shelters, people are likely to stay in their homes rather than evacuate. The basic assumption of the modeling was that people of all ages would stay in their homes in the face of a storm. For this reason, the PAR was limited to residential structures and split into under 65 and 65+ categories.

- *Proportion of Residents for whom English is Not a First Language*
In the United States, people who for whom English is not their first spoken language can be more vulnerable in a storm. There are multiple reasons for this. First, local evacuation policies may not be translated into English and newer or more isolated arrivals may not receive orders in a language that they fully comprehend. Second, some communities of non-native English speakers may be relatively socially isolated and may not have social networks that support evacuation. For example, no family members or friends who live outside of the flooded area with whom they could stay in an evacuation event. This was a phenomenon seen in Hurricane Sandy. Third, in the US, limited English proficiency is correlated with lower earnings and that population may not have the resources to evacuate. Fourth, in some communities, non-native English speakers are more likely to live in larger, multigenerational households and evacuation of an elderly family member may be difficult.

The proportion of non-native English speakers in a study area matters in life loss analysis because non-native English proficiency is an element of social vulnerability and socially vulnerable populations face higher risks of death in a storm event (*Science Advances*, 16 August 2023). This study did not adjust life loss modeling to specifically account for non-native English speakers because the City of Boston is highly conscientious about ensuring official messaging occurs in the languages of its communities and because the city's high population of international students makes it difficult to determine whether a person is socially vulnerable or a graduate student from abroad with limited financial resources. Nonetheless, given the size of the communities with limited English proficiencies in both East Boston and Dorchester, it may be that model estimates of life loss from storm events in those areas slightly underestimate the life safety risk in those areas. Given the scales of the interventions considered in those areas, it is unlikely that slightly undercounting life loss between the future

with-and without-project conditions would change the recommended projects in those neighborhoods.

- *High Reliance on Public Transportation/Limited Access to Personally Operated Vehicles*

Boston is a historic, four-season city with narrow streets and limited parking which makes car-ownership extremely expensive. Boston residents are highly reliant on a dependable network of heavy and light rail trains, buses, and ferries that are operated by the Massachusetts Bay Transportation Authority. All of the study neighborhoods have subway access within walking distance. The reliability of the transit system and the fact that residents have limited needs that require car ownership is one of the reasons that many people enjoy living there.

Unfortunately, limited access to personally operated vehicles also makes it more difficult to evacuate in the event of a coastal storm so *car ownership matters* in establishing evacuation rates used in life loss modeling as well as accounting for damages to automobiles in the future with- and without-project conditions. In the case of the Boston CSRM study, car ownership was not considered because evacuation rates were already determined using City of Boston statistics and damages from structures and contents was already sufficiently high to not require the consideration of automobile damages which can be difficult to defend given that cars can be moved out of harm's way relatively easily. Furthermore, anecdotal evidence showed rates of car ownership would be sufficiently low enough to assume that they would not make a difference in formulation or project justification. That said, the bias on modeling results of omitting this factor, if any, would be to slightly underestimate benefits of an intervention.

1.3.4 Coastal Hydrology

Coastal Flooding occurs when water levels rise above the shoreline along the waterfront, overtopping the shoreline and temporarily flooding inland areas. Most of the developed areas along the shoreline are built on fill, are generally low-lying and flat, and are only a few inches to a few feet above the Harbor's existing highest annual tides (City of Boston, 2016). Because of this, the extent of flooding and the potential damage and disruption that can occur are sensitive to small changes in water level elevation (e.g., ± 6 inches) once the shoreline is overtopped. Coastal flooding already occurs along the lowest spots of the shoreline, such as near Long Wharf in the Downtown



neighborhood, where Harbor water levels and waves overtop the shoreline and cause disruption of pedestrian and vehicle traffic along with business disruptions.

The existing risk of coastal storm damages are not isolated to low-lying areas along the waterfront. Over the past five years extratropical storms have set record water levels inundating the community and public transportation tunnels. Water surface reached record highs at nearly 9.6 feet North American Vertical Datum of 1988 (NAVD88) where land elevations are generally between +8 and +12 feet NAVD88.

Coastal Inundation refers to the permanent inundation of land by high tides, such as areas that are below mean higher high water. Under existing conditions, only the wetland areas, including Wood Island Marsh, Belle Island Marsh, Neponset Creek, and along the Neponset River are susceptible to permanent inundation. However, as sea levels change, the area permanently inundated during tide cycles will increase. An example of this is Long Wharf which is nearly inundated in the existing condition at an astronomical or king tide condition. Boston Harbor tide range is 10 feet, exposing much of the coastline at low tide and posing an inundation threat at high tide. Wave or surge on top of tide increases the risk.

Waves in the Harbor include both longer period ocean-driven swell propagating through the Harbor, and locally generated, wind-driven waves. Ocean-driven swell waves propagate in the Outer Harbor; however, these waves are broken up by the Boston Harbor Islands and the Winthrop and Hull peninsulas. The long reach from the outer harbor to the inner harbor and coastline is variable, meaning the effects of waves throughout the Harbor communities vary based on their fetch.

Understanding waves and local wave conditions is a crucial part of coastal flood risk management along the shoreline, both with respect to infrastructure design (including coastal defense structures) and understanding residual risk. Waves are essentially energy passing through a fluid (in this case, water). They can be measured and experienced as wave runup, as splashing and overtopping, as a dynamic force on piers, wharves, and other coastal structures, and as waves that propagate inland once a shoreline is inundated.

- **Wave Runup** is the culmination of the wave breaking process as waves approach sloped or vertical shorelines. Wave runup includes both wave setup (the mean increase in water level as waves get slower and increase in height near the shoreline) and swash (the decelerating water that surges up the shoreline during and after the wave breaks). The slope and roughness (e.g., smooth, cobbled rock, vegetated) of the natural shoreline or engineered structures are key parameters in defining how high the



waves can runup the shoreline. Smooth vertical walls have the highest potential wave runup elevations, whereas a sloped shoreline with riprap armoring will dissipate wave energy and reduce the wave runup potential.

- **Wave Overtopping** occurs when the wave runup elevation exceeds the height of the shoreline (*e.g.*, the top of a naturalized or embankment shoreline or floodwall) potentially flooding inland areas. Overtopping can range from a spray to a splash to a stream of water, depending on shoreline, tidally influenced water levels, and wave characteristics. Waves overtop low spots along the shoreline under existing conditions.
- **Overland Wave Propagation** occurs along natural, gently sloped shorelines when water levels are high enough to allow waves to travel inland across the shoreline as opposed to breaking and running up the face of a more sloped or vertical structure. Under existing conditions, overland wave propagation only occurs in small areas where the shoreline is not hardened, for example, along the Belle Isle Marsh in East Boston. As waves propagate inland over wetlands and vegetated areas, they generally decrease in height due to wave energy dissipation. However, waves that propagate over inundated areas with sufficient water depth and limited obstructions (*e.g.*, parking lots) may increase in height.
- **Waves** are also a powerful and *dynamic force* that can cause significant structural damage. Along the shoreline, waves crash into the piers and wharves causing them to shake and vibrate. This contributes to wear and tear on the structures. Waves can cause damage gradually over time, and they can cause abrupt damage during an extreme storm event. The degree of damage depends on the storm conditions, the direction of the waves, and a structure's condition.

Coastal Erosion occurs when currents and waves wear down and carry away earthen or engineered materials along the shoreline. In areas with a natural or naturalized shoreline, like the interior of Belle Isle Marsh, erosion can lead to inland migration of the shoreline. For engineered coastal defenses (*e.g.*, a floodwall or seawall), scour is of particular concern at the toe of the structure, because this erosion can weaken the foundation of the structure and increase the risk of failure. Specific coastal hydraulic conditions are discussed in individual neighborhood chapters in the Main Report.

1.4 Organization of Economics Appendix

Boston is a city of neighborhoods with an extensive system of roads, bridges, and underground automobile and subway tunnels connecting them both to one another and to the rest of the metropolitan area, including the abutting cities of Cambridge (121,186 residents), Somerville (82,149 residents), Quincy (101,636), Chelsea (40,245 residents), and the town of Brookline (63,266 residents, all figures from US Census 2024). A decision was made early in the study not to develop a planning alternative that focused specifically on floodproofing the subway tunnel system as 1) the Massachusetts Bay Transportation Authority was planning and undertaking its own series of improvements to reduce coastal storm risk, and 2) because such a remedy would be cost prohibitive and limit the other types of interventions that could be applied in the city that could be of immediate benefit to the City and its residents. This decision was not made lightly given that the disruption caused by a subway system outage would impact a population far larger than the population of City residents. It was also determined early in the study that any work required to upgrade any municipal water infrastructure would be undertaken as a separate, local effort and that repairs and upgrades to that system would be undertaken as necessary. A similar decision was also made early in the study not to entertain the idea of a barrier or a gate across Boston Harbor. After omitting these two types of measures, establishing the hydrologic separability of the neighborhoods, and considering the requirement to reach 35% design for immediate recommendations, it became evident that the best planning strategy would be to focus on Boston's neighborhoods to develop a series of interventions that could be implemented over time as the peril the city faces from coastal storm risk increases.

The organization of this document attempts to explain the overarching principles of USACE planning and apply the framework of USACE economic analysis to five very different types of neighborhoods.

- Chapter 2 applies the USACE system of using estimated damages over time without the potential USACE intervention as the baseline of its economic analysis. Because of the importance of the relative differences between the neighborhoods, this chapter will present details of the future without-project condition by neighborhood.
- Chapter 3 describes the model used to estimate damages in the future with- and without-project conditions and ultimately determine which coastal storm risk management interventions alternatives would move forward. It concludes with a presentation of model outputs of the future without-project condition in the five neighborhoods.



- Chapter 4 catalogues the alternative plans derived in the Plan Formulation process (see Main Report) and explains the reasoning behind the exclusion of some of those plans from economic modeling.
- Chapter 5 presents the economic modeling results by neighborhood.
- Chapter 6 establishes the suite of alternatives to be moved forward for consideration and explains the rationale for continuing to consider a number of alternatives that are, as of yet, not justified based on NED benefits.

2 Existing and Future Without Project Conditions

USACE economic analysis requires a comparison between the condition that would exist if no Federal action was undertaken (FWOP) and the condition that would exist if a Federal intervention to remedy the water resource problem was constructed (FWP). The first step to establish both the FWOP and the FWP conditions is taking inventory of the study area in its current form. This is the existing condition. The FWOP is established using existing condition and projecting any changes that are anticipated to occur over the period of analysis. Foreseeable changes include anything that might change the number, classification, or distribution of assets, population, and environmental conditions in the study area. For the Boston CSRM analysis, it was assumed that changes to the existing condition over the study duration would be limited to storm-related changes to the shoreline and structure inventory. Repairs to the multiple tunnel systems (subway, roadway, and water/sewer) required to return them to operation after storm events would occur, but local dependence on having these systems operating continuously would limit any significant upgrades, leaving them still subject to risk from coastal storms. The FWOP assumes that any new land use projects will be designed to be resilient and will not add to the damage pool.

The rest of this chapter walks through the existing and FWOP conditions of each neighborhood.

2.1 East Boston



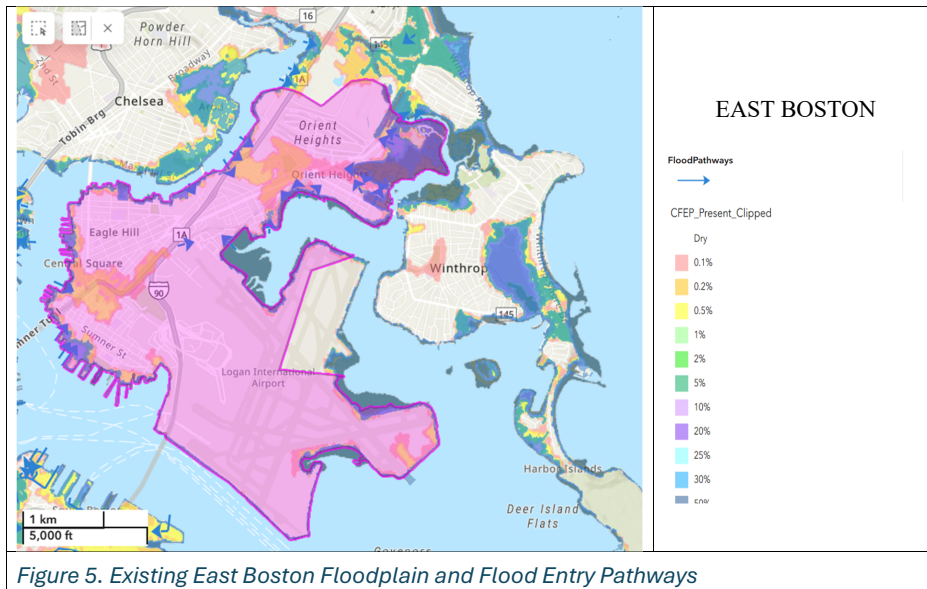


Figure 5. Existing East Boston Floodplain and Flood Entry Pathways

2.1.1 Geography

Other than a half-mile wide, low-elevation spit of land between Chelsea Creek and Constitution Beach at its northern end, East Boston (EB) is surrounded by water. The north side of East Boston also contains two urban salt marshes. The Wood Island Marsh sits at the northwest corner of Logan International Airport and Belle Isle Marsh sits at East Boston's northeast boundary and is shared with the neighboring cities of Winthrop and Revere. These marshes serve as flood entry pathways in both the existing and FWOP conditions, with East Boston being cut off from the Massachusetts mainland from flooding through Belle Isle Marsh in a 0.1% Annual Exceedance Probability (AEP) flood event. The western boundary of East Boston is Chelsea Creek, an active navigation channel used for the transit of home heating oil, aviation fuel, and recreational vessels. Water also enters East Boston from low points along the connecting spit on the western edge of the neighborhood from which it inundates the most densely-populated and commercial part of the neighborhood, Central-Maverick Square. The City of Chelsea sits on the other side of Chelsea Creek. The south and eastern shorelines of East Boston are dominated by the runways of Logan Airport which form the northern border of Boston Harbor and which are not included in the scope of this study. Other than Eagle Hill and Orient Heights, much of the area is low-lying, as

East Boston was once five distinct islands that are now connected by landfill. The Boston Harborwalk, a 43-mile linear park along Boston's waterfront, is currently discontinuous in the East Boston neighborhood, with stops and starts beyond the necessary break at Logan Airport. Any changes to the East Boston shoreline in the FWOP are anticipated to be related to climate change and would likely be worse in areas near the marshes and Constitution Beach as those areas do not have hardened shorelines.

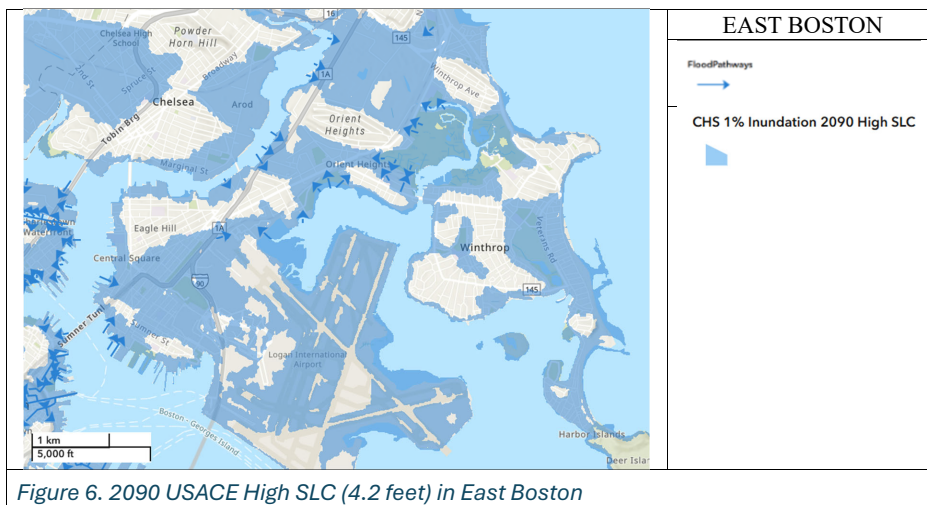


Figure 6. 2090 USACE High SLC (4.2 feet) in East Boston

2.1.2 Land Use in East Boston

Calculated by land area, more than three fifths of the land in the East Boston neighborhood is part of Logan International Airport. The remainder of the area is characterized by densely packed multistory, multifamily homes. At this time, development in East Boston is mostly limited to more efficient use of airport property and the development of high-rise residential buildings on west and east facing properties. The analysis presented here accounts for buildings that have been permitted; that said, those properties are assumed to be constructed in such a way that their damages are not added as §308 of WRDA 1990 (P.L. 101-640) limits what can be considered in the NED benefit-cost analysis associated with structures in the regulatory floodplain.

2.1.3 Critical Infrastructure

By land area, Logan International Airport is the largest landholder in East Boston. It is operated by Massport and served more than 43,000,000 passengers in 2025 (*Airport Statistics*, Massport), making it the 16th busiest airport in the nation and a massive source of employment in the Commonwealth. The airport's coastal runways and terminals are excluded from the study area. FWOP modeling indicates coastal runways are outside the floodplain at a 1% AEP event with 46" of relative sea level rise considered. Massport will address coastal resilience for its airport properties outside this study.

There are four major transportation tunnels in and out of East Boston. The Sumner and Callahan Tunnels connect East Boston and Downtown beneath Boston's inner harbor. These two tunnels are considered as one in this analysis as they are parallel and complementary, with traffic flowing in opposite directions. These tunnels are used for movement both to and from the airport as well as movement to and from downtown and points beyond by communities north of the airport. The Ted Williams Tunnel begins on Logan Airport property and leads to South Boston on a more easterly route than the Sumner and Callahan, providing direct access to the Massachusetts Turnpike and points west. Like the Sumner and Callahan system, the MBTA's Blue Line subway tunnel connects East Boston and Downtown beneath the inner harbor. The MBTA's Silver Line Bus Rapid Transit Tunnel takes a similar easterly route as the Ted Williams Tunnel between Logan Airport property and South Boston where it connects to other subway lines at South Station. The subways are used by travelers but also by airport employees and other commuters to and from East Boston and other points north of Downtown. In the FWOP, all four of these tunnels are subject to inundation from high frequency events and face increased risk from relative sea level change.

East Boston is also home to the Orient Heights Rail Yard which is used for storage and maintenance of Blue Line subway trains. The Orient Heights Rail Yard lies on a small peninsula to the south of Belle Isle Marsh and is susceptible to inundation from both sides in conditions of intermediate and high sea level change given its low elevation of 11' NAVD88. There is no plan to relocate the maintenance yard because of the limited available space that can be accessed via tracks and the demand on the Blue Line with its available routes.

In addition to its massive system of transportation infrastructure, East Boston has its own water and utility tunnel systems. The Boston Water Sewer Commission (BWSC) is responsible for most stormwater and wastewater in the city and existing BWSC infrastructure is at risk of inundation within the project area. The current system is



designed for, on average, a 10% AEP event, with the primary means of intervention being conveyance through a subsurface system of pipes and outfalls throughout the city. Much of this inundation risk is generated through stormwater not being able to gravity flow through existing systems, although there may be some risk in the FWOP of those pipes being exposed to backflow where backflow structures are missing. There are no existing BWSC pump stations in East Boston. Remedies to limit risk to those systems are not explicitly considered in this analysis as BWSC is conducting a parallel analysis, outside this study authority, to identify stormwater and wastewater infrastructure improvement needs. As of this writing, there is no evidence that the FWOP would be different from the existing condition.

East Boston has three City-run fire stations and one fire station run by Massport. It has one municipal police station and two state-run police facilities that serve the airport and other Massport properties. East Boston has one hospital, which is not a major medical center. The neighborhood hosts seven public schools including five elementary schools, one middle school, and one high school. The Boston Center for Youth and Families (BCYF) Pino Center, Paris Street Community Center and Umana Barnes School serve as neighborhood emergency shelters.

2.1.4 Social Characteristics of East Boston

The City of Boston's Planning Department prepared worksheets for each neighborhood which present the most relevant social characteristics of those neighborhoods. These statistics show that East Boston is a growing neighborhood, with 42,985 residents counted in the adjusted 2020 census. They also show that East Boston has the highest share of residents who are non-citizens of all of the five neighborhoods, with 23% of residents considered linguistically isolated, which potentially adds risk in understanding and responding to evacuation orders. Over 75% of households live in rental housing, compared with 65% citywide, and 43% of households are considered rent burdened (spending more than 30% of income in rent). Approximately 46% of the East Boston community is dependent on public transportation for daily commuting, the highest of the five neighborhoods. 35% of the population reports no access to a vehicle, making evacuation difficult. These characteristics of the population at risk (PAR) are not anticipated to change between the existing condition and the FWOP.



EAST BOSTON POPULATION INFORMATION		Comparison Area(s)	Data Source
	East Boston Total	City of Boston	
Population Trends			
2000 Census	38,413	588,501	2000 Census
2010 Census	40,508	617,059	2010 Census
2020 Census plus Group Quarters Challenge Adjustment	42,985	681,937	Adjusted 2020 Census
2030 Projection		740,685	BPDA Research Projections
2040 Projection		769,362	BPDA Research Projections
2050 Projection		800,178	BPDA Research Projections
Average Household Size	2.68	2.30	2017-2021 ACS
Age Distribution			
17 and Under	8,226	101,811	adjusted 2020 Census
18-24*	5,001	119,953	
25-64	25,823	376,260	
65+	3,935	83,913	
Language Data			
Share of Households in Linguistic Isolation**	23%	12%	2017-2021 ACS
Number of Languages Meeting Language Access Threshold***	1	11	2017-2021 ACS
Citizenship Data			
Share of Residents who are Non-Citizens	33%	14%	2017-2021 ACS
Medical Data			
Share of Population with a Disability	10%	12%	2017-2021 ACS
Neighborhood Employment			
Number of Payroll Jobs in the Study Area	9,282	651,206	2020 LODES
Patterns of Wealth and Poverty			
Share of Children Living in Poverty	23%	24%	2017-2021 ACS
Share of Residents who are SNAP Recipients	19%	19%	2017-2021 ACS
Neighborhood Housing			
Share of Households Living in Rental Housing	75%	65%	2017-2021 ACS
Share of Renter Households that are Housing Cost	43%	47%	2017-2021 ACS
Neighborhood Transportation Conditions			
Share of Resident Workers Commuting by Public Transportation	46%	28%	2017-2021 ACS
Share of Households Without a Vehicle	35%	34%	2017-2021 ACS

*Adjusted to reflect Boston's successful group quarters challenge, assumes group quarters population is aged 18-24

**Homes in which no one in the house over age 14 speaks English very well

***Boston Language Access

****Renter-occupied units that pay more than 30% of income in rent

Figure 7. Social Characteristics of East Boston

Figure 7. Social Characteristics of East Boston

2.1.5 FWOP Model Inputs for East Boston

Because a neighborhood's geographic boundaries do not necessarily align with the floodplain, assets to be damaged and PAR are a subset of the assets and population of the neighborhood as a whole. Plan formulation and evaluation is based upon that subset of assets and population at risk. The figure below presents the "model areas" established for the economic modeling for the East Boston neighborhood.



Figure 8. East Boston Model Areas

The figure below presents a summary of the assets at risk in East Boston. This is the sum of the assets at risk in each model area.

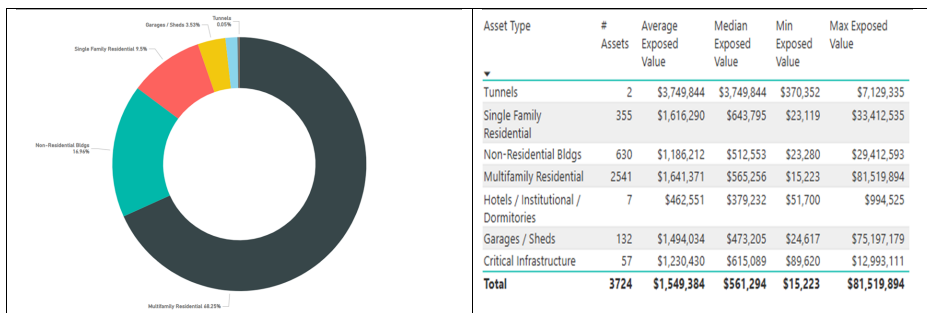


Figure 9. Asset Inventory Profile by Number and Value of Assets at Risk in East Boston.

Similarly, the PAR statistics used in the economic modeling are limited to the characteristics of the population living in the model area. The table below presents the population statistics that informed the economic modeling for East Boston. As explained in Chapter 1, the statistics used to specify the model are the age of the population, which is used to determine life risk, and rental versus ownership rates, which informs rebuild assumptions. The study team also recognizes that facility with English and reliance on public transportation may inform evacuation rates; however, without more specific data on evacuation in the Boston CSRM study area, the study team could not establish to what degree those population characteristics would inform life loss. To that end, any bias would be to slightly underestimate life loss results in East Boston.

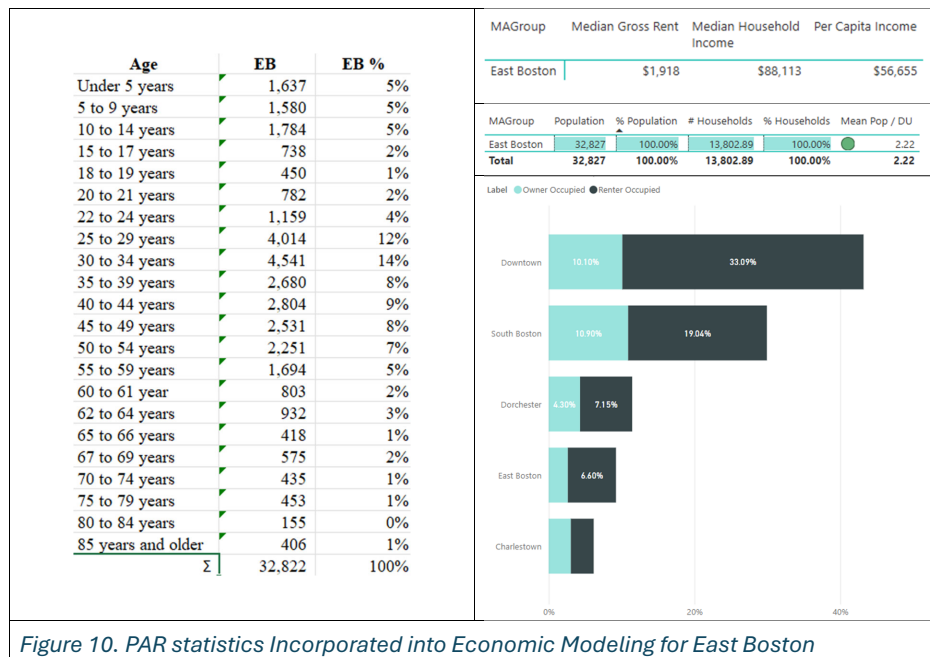


Figure 10. PAR statistics Incorporated into Economic Modeling for East Boston

FWOP life loss from coastal storms in East Boston is anticipated to be concentrated in Orient Heights. The estimated life loss in East Boston over the 50-year period of analysis is 78.16 people.

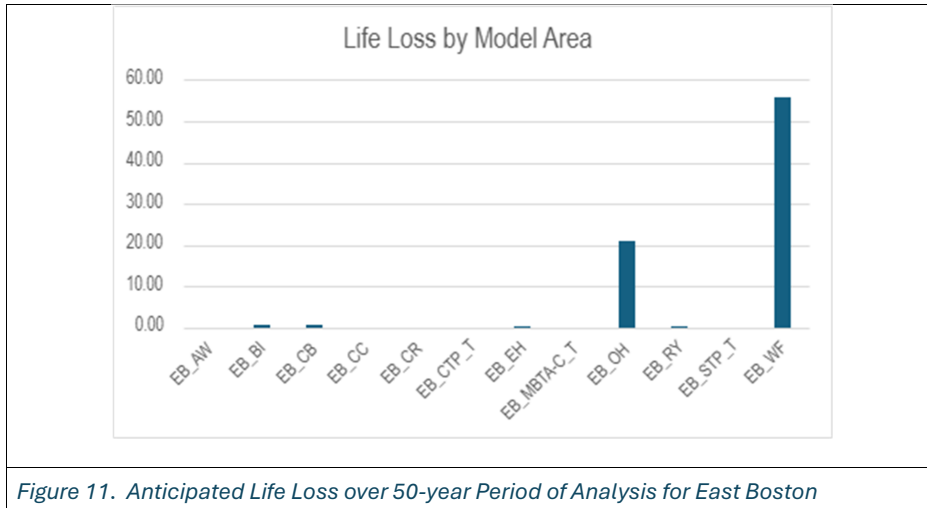
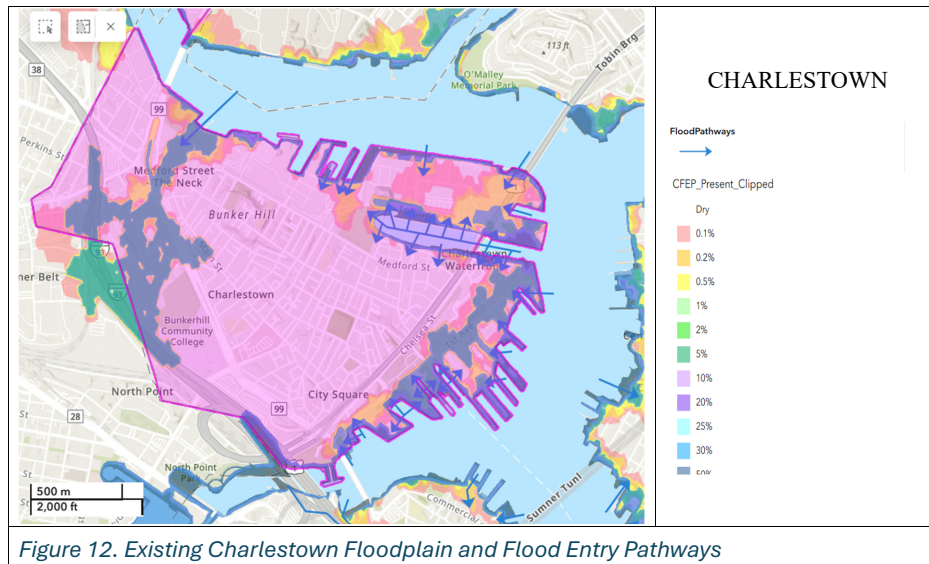


Figure 11. Anticipated Life Loss over 50-year Period of Analysis for East Boston

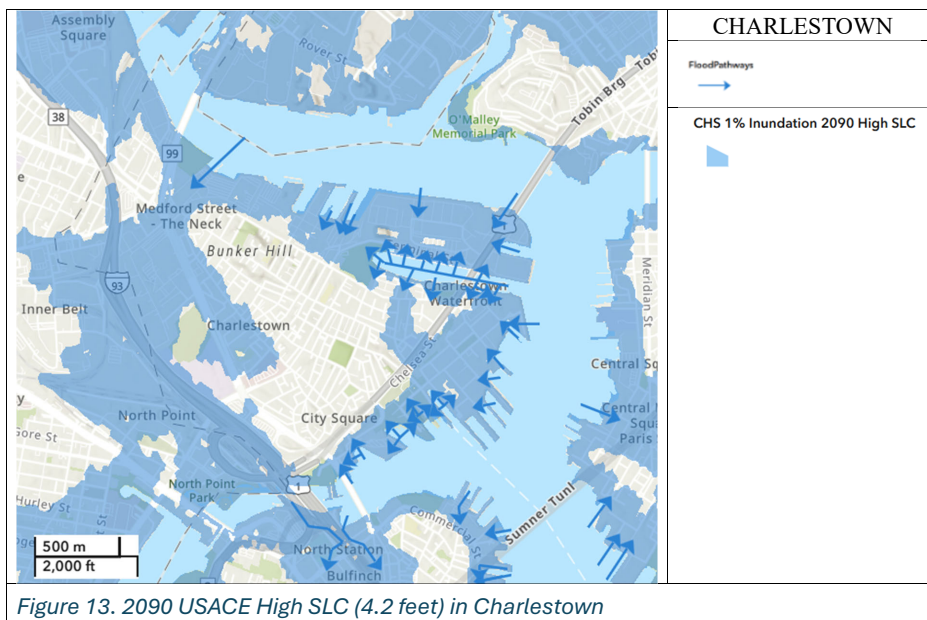
2.2 Charlestown



2.2.1 Geography

Charlestown could appropriately be called “North Boston,” as it sits directly north of the Downtown area. It is shaped like a triangle and surrounded on two sides by water. Maritime uses are an important element of its waterfront land use. The northeast-facing waterfront abuts the Mystic River Channel which leads from Boston Harbor to the Mystic River. The eastern corner is surrounded by water on three sides, forming its own small peninsula. South of that peninsula on the eastern waterfront lies the Little Mystic Channel. The southeast-facing shoreline overlooks the western shoreline of East Boston, with slightly over 1,000 feet of channel separating the finger quays in the water between them. The southeast-facing shoreline was a Naval facility from the year 1800 until it was decommissioned in 1974. It has been adapted into a land reuse project with housing, businesses (some maritime dependent), and a National Park. The entirety neighborhood lies north of the Charles River Dam, which creates an impoundment that separates Boston and Cambridge. The western side of Charlestown connects to the cities of Cambridge and Somerville. Charlestown is connected to Boston at grade level by the Washington Street Bridge. Even after using some hilly areas to create landfill, Charlestown is still relatively more hilly than other parts of the study area, with Bunker Hill, Breed’s Hill (which is approximately 65-70 feet above sea level, and the actual site

of the Battle of Bunker Hill and the Bunker Hill monument), and other slightly rolling terrain. The Boston Harborwalk, a 43-mile linear park along Boston's waterfront, is currently discontinuous in the Charlestown neighborhood; however, the entire shoreline is hardened. Water currently enters the neighborhood across its entire perimeter, with a major entry point at Alford and Medford Streets ("The Neck") as well as broadly over the Charlestown Navy Yard. Any changes to the Charlestown shoreline in the FWOP are anticipated to be related to climate change and could potentially isolate the neighborhood from the rest of the city given the flow of water through the low point at Medford Street through North Point in Cambridge.



2.2.2 Land Use

Much of the waterfront land in Charlestown is dedicated to maritime use. Those maritime uses include the 81-acre Boston Autoport and other working waterfront uses at the northern boundary of the neighborhood. The Autoport is a shipping and storage facility that handles 90,000 vehicles annually. Much of the southeast flank of the site is

devoted to the former Charlestown Navy Yard which has been adapted into midrise apartment buildings, commercial properties, parkland, and a National Park. The flagship facility of Spaulding Rehabilitation Hospital, an internationally recognized recovery medical center, sits at the northern end of the Navy Yard. The wharves in this area support recreation and historic preservation with Constitution Wharf serving as the home base for the U.S.S. Constitution, a Revolutionary War ship. Boston's Historic Freedom Trail winds through the neighborhood and includes the Bunker Hill Monument and the U.S.S. Constitution and its museum. The Navy Yard area is essentially separated from the rest of Charlestown by the Chelsea Street approach to the Tobin Bridge, which rises 135 feet above the Mystic River and serves as a barrier. To the south of the Autoport and north of Chelsea Street lies the vast majority of the residential area of Charlestown. That area is characterized by multistory, multifamily homes, the tallest of which is six-stories. Rutherford Avenue delineates the western parts of Charlestown, which include Bunker Hill Community College and its above ground MBTA stop as well as multiple industrial properties. For the purposes of this document, prospective development in Charlestown is assumed to comply with §308 of WRDA 1990 (P.L.101-640), which limits the number of structures in the regulatory floodplain that can be considered in the NED benefit-cost analysis.

2.2.3 Critical Infrastructure

Charlestown is surrounded by transportation infrastructure. Beyond the MBTA Orange Line and commuter rails and their associated rights of way, the neighborhood is bordered by Interstate 93, which rises high as it passes Charlestown. The Chelsea Street/Tobin Bridge approach has pedestrian-scale crossings in Charlestown closer to Downtown and the North End but it becomes a wall with areas of under-bridge scaffolding as it moves northeast, separating the Navy Yard from the rest of the neighborhood. The Mystic River Channel forms the north border of the neighborhood. Ferries operate between the Charlestown Navy Yard and Downtown.

In addition to its massive system of land and water transportation infrastructure, Charlestown has its own water and utility tunnel systems. Like in East Boston, BWSC is responsible for most stormwater and wastewater in the city. The existing system is designed for, on average, a 10% AEP event. Remedies to limit risk to those systems are not explicitly considered in this analysis as BWSC is conducting a parallel analysis, outside this study authority, to identify stormwater and wastewater infrastructure improvement needs. As of this writing, there is no evidence that the FWOP would be different from the existing condition.



Charlestown has two fire stations and one police station. Charlestown has one hospital, Spaulding Rehabilitation, discussed above. In addition to Bunker Hill Community College, Charlestown hosts one public elementary school, one public school serving kindergarten through eighth grade, and one public high school. The BCYF Charlestown Community Center and Kent Community Center serve as emergency shelters.

2.2.4 Social Characteristics of Charlestown

The City of Boston's Planning Department prepared worksheets for each neighborhood, which present the most relevant social characteristics of those neighborhoods. These statistics show that Charlestown is a growing neighborhood, with 19,120 residents counted in the adjusted 2020 census. Charlestown is a relatively wealthy neighborhood. Compared to the citywide average of 65%, Charlestown has a lower rate of renters, and, among renters, a lower rate of housing cost burden. These characteristics of the population at risk (PAR) are not anticipated to change between the existing condition and the FWOP.



CHARLESTOWN POPULATION INFORMATION	Charlestown Total	Comparison Area(s) City of Boston	Data Source
Population Trends			
2000 Census	15,195	588,501	2000 Census
2010 Census	16,439	617,059	2010 Census
2020 Census plus Group Quarters Challenge Adjustment	19,120	681,937	Adjusted 2020 Census
2030 Projection		740,685	BPDA Research Projections
2040 Projection		769,362	BPDA Research Projections
2050 Projection		800,178	BPDA Research Projections
Average Household Size	2.19	2.30	2017-2021 ACS
Age Distribution			
17 and Under	3,459	101,811	Adjusted 2020 Census
18-24*	1,112	119,953	
25-64	12,215	376,260	
65+	2,334	83,913	
Language Data			
Share of Households in Linguistic Isolation**	5%	12%	2017-2021 ACS
Number of Languages Meeting Language Access Threshold***	1	11	2017-2021 ACS
Citizenship Data			
Share of Residents who are Non-Citizens	7%	14%	2017-2021 ACS
Medical Data			
Share of Population with a Disability	8%	12%	2017-2021 ACS
Neighborhood Employment			
Number of Payroll Jobs in the Study Area	12,505	651,206	2020 LODES
Patterns of Wealth and Poverty			
Share of Children Living in Poverty	16%	24%	2017-2021 ACS
Share of Residents who are SNAP Recipients	13%	19%	2017-2021 ACS
Neighborhood Housing			
Share of Households Living in Rental Housing	51%	65%	2017-2021 ACS
Share of Renter Households that are Housing Cost Burdened****	35%	47%	2017-2021 ACS
Neighborhood Transportation Conditions			
Share of Resident Workers Commuting by Public Transportation	24%	28%	2017-2021 ACS
Share of Households Without a Vehicle	19%	34%	2017-2021 ACS
*Adjusted to reflect Boston's successful group quarters challenge, assumes group quarters population is aged 18-24			
**Homes in which no one in the house over age 14 speaks English very well			
***Boston Language Access			
****Renter-occupied units that pay more than 30% of income in rent			

Figure 14. Social Characteristics of Charlestown

Figure 14. Social Characteristics of Charlestown

2.2.5 FWOP Model Inputs for Charlestown

Because a neighborhood's geographic boundaries do not necessarily align with the floodplain, assets to be damaged and PAR are a subset of the assets and population of the neighborhood as a whole. Plan formulation and evaluation is based upon that subset of assets and population at risk. The figure below presents the "model areas" established for the economic modeling for the Charlestown neighborhood.

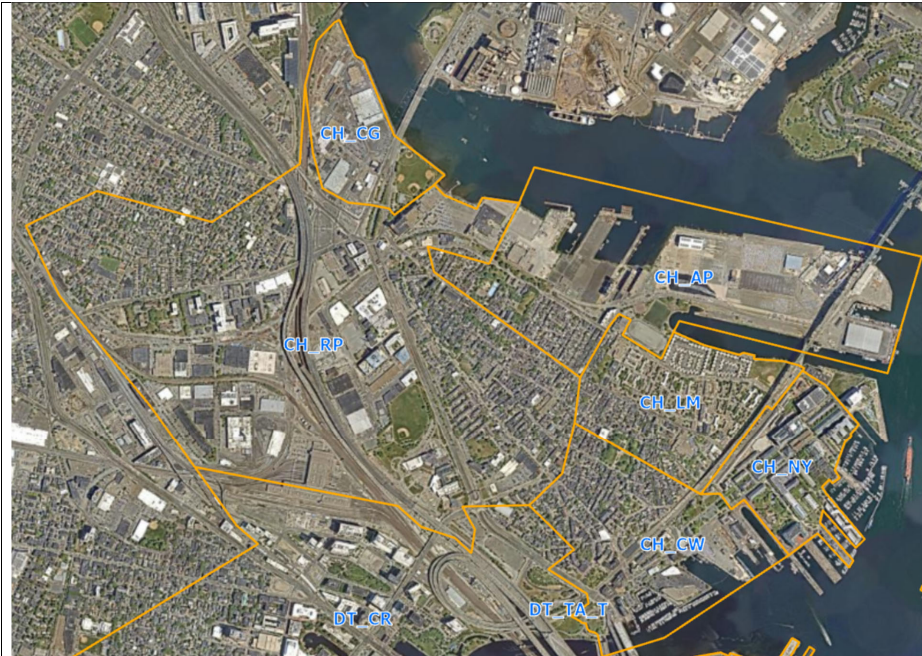


Figure 15. Charlestown Model Areas

The figure below presents a summary of the assets at risk in Charlestown. This is the sum of the assets at risk in each model area.

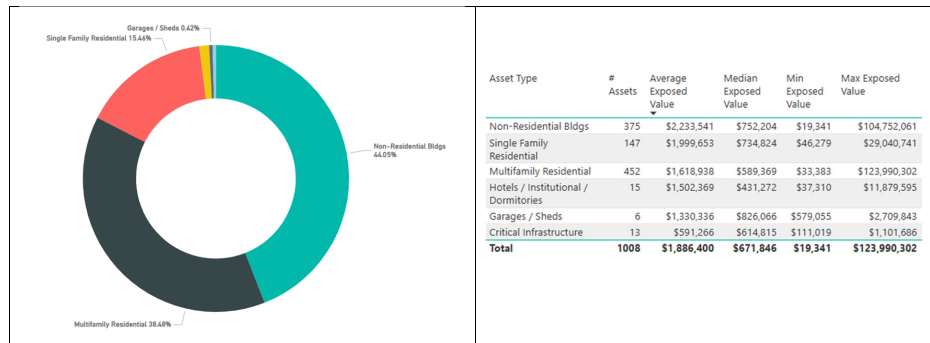
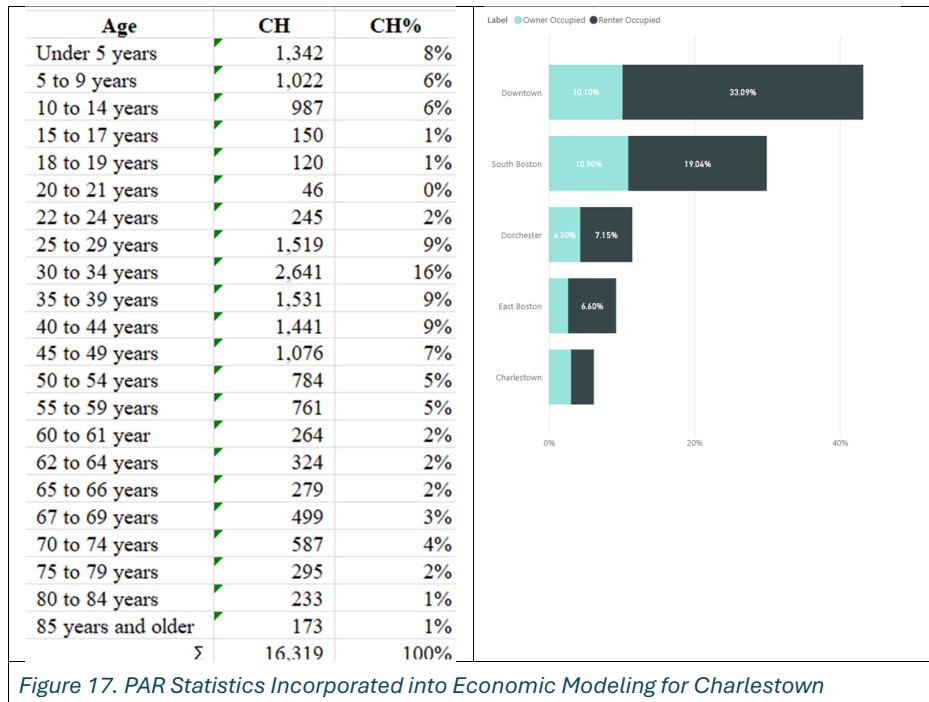


Figure 16. Asset Inventory Profile by Number and Value of Assets for Charlestown

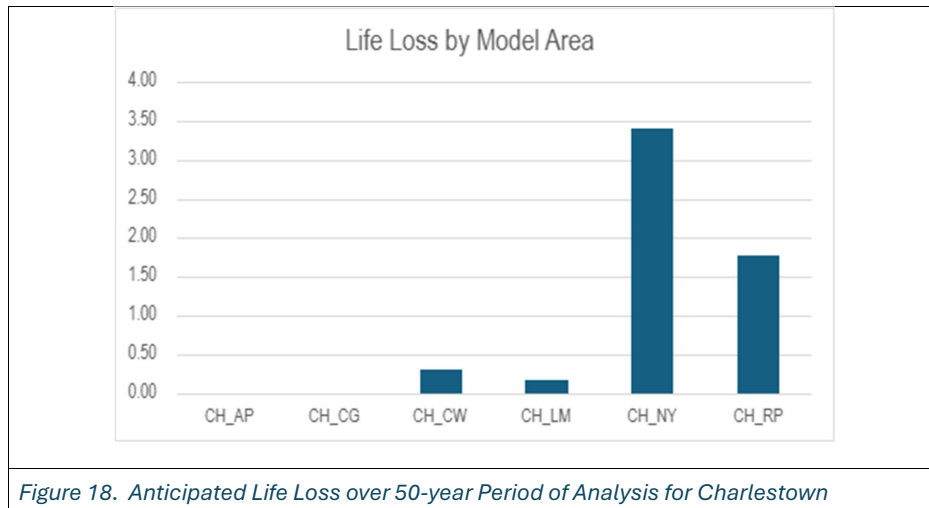
Similarly, the PAR statistics used in the economic modeling are limited to the characteristics of the population living in the model area. The table below presents the population statistics that informed the economic modeling for Charlestown. As explained in Chapter 1, the statistics used to specify the model are the age of the population, which is used to determine life risk, and rental versus ownership rates, which informs rebuild assumptions.

MAGroup	Median Gross Rent	Median Household Income	Per Capita Income
Charlestown	\$2,242	\$142,462	\$95,872

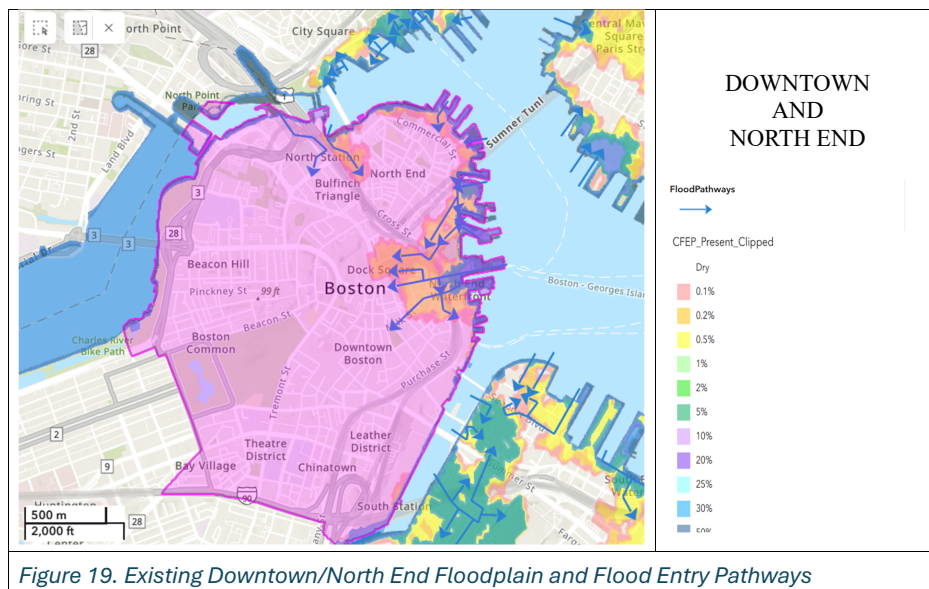
MAGroup	Population	% Population	# Households	% Households	Mean Pop / DU
Charlestown	16,322	100.00%	8,048.26	100.00%	1.98
Total	16,322	100.00%	8,048.26	100.00%	1.98



FWOP life loss from coastal storms in Charlestown is anticipated to be concentrated in the areas of the Navy Yard and Ryan Playground. The estimated life loss in Charlestown over the 50-year period of analysis is 5.68 people.



2.3 Downtown/North End

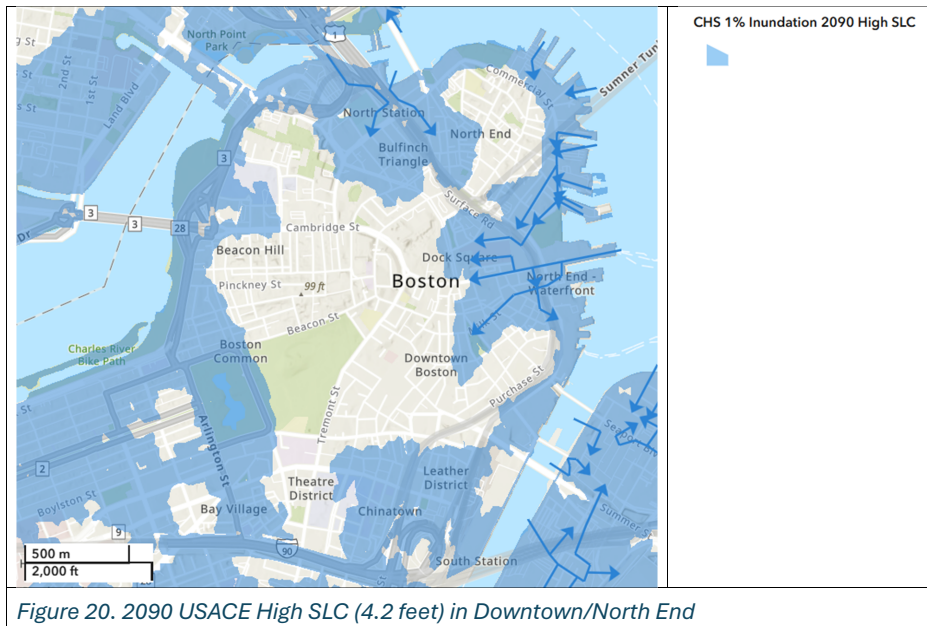


2.3.1 Geography

Downtown and the North End are the two neighborhoods in the study area that are not hydrologically separable. The North End forms the eastern border of the northeast corner of the downtown peninsula. These neighborhoods are considered together in the evaluation.

Surrounded by the Charles River, Boston's inner harbor, and the Fort Point Channel, Boston is truly the proverbial "City on a Hill." Beacon Hill currently rises 98 feet above sea level. The Back Bay and South End neighborhoods, which supplemented the original Boston Neck and now connect Downtown and the North End to the mainland at its southwest edge were formed from the original Beacon Hill, which rose 138 feet. The Charles River and its system of dams frame the northwest quadrant of the city. The new Charles River Dam (USACE, 1978) physically delineates the shoreside boundary of the North End neighborhood. The North End has slightly rolling terrain leading to an entirely hardened shoreline, much of which is lined with the Harborwalk. The North End and its piers comprise the northeast quadrant. The southeast boundary of the North End is Christopher Columbus Park, which sits on the Boston Harbor waterfront. The Downtown waterfront continues south with more piers until it reaches through the Fort Point Channel across the Leather District and the bridges into South Boston.

	DOWNTOWN & NORTH END
	FloodPathways →



2.3.2 Land Use

Land use in Downtown/North End is a mixed. Downtown includes high rise commercial and residential structures, extensive greenspaces in the form of Boston Common, the Boston Public Garden, the Charles River Esplanade, and four- to five-story townhouses of Beacon Hill. City Hall Plaza, Faneuil Hall Marketplace, the Washington Street shopping corridor, and the Rose Kennedy Greenway, which comprises the southern border of the North End, are active open spaces used by the local community and tourists. Massachusetts General Hospital, Massachusetts Eye and Ear Hospital, and Shriners Children's Hospital constitute a cluster of medical centers along the Charles River north of the Longfellow Bridge to Cambridge. T.D. Garden, the home of the Celtics and the Bruins, sits at the Downtown side of USACE's Charles River Dam. Government Center forms a large hub of City, State, and Federal offices. The Leather District is known for its large industrial lofts, many of which have been converted to commercial and residential uses. Chinatown and the Theater District are mostly comprised of ten- to 15-story commercial, residential, municipal, and medical center buildings, with a few surviving three- to five-story multifamily residential buildings

interspersed. Other than in Bay Village and the residential area of Beacon Hill, the first floors of most downtown buildings include shops and cafes.

The North End has a proportionally large residential community living in four and five story multifamily buildings and waterfront warehouse loft conversions. It is one of the oldest residential communities in the city and part of Boston's Freedom Trail network., which stops at Old North Church, Copps Hill Burying Ground, and Paul Revere's House. There is a community of townhouses at the end of Union Pier and a large coast guard station operating out of Battery Wharf. Waterfront land is generally accessible to the public via the Harborwalk, with Puopolo Athletic Field, Langone Field, Prince Street Park, and multiple urban squares contributing to publicly accessible open space. Many cafes, restaurants, and small shops occupy the first floors of the neighborhood's streets.

2.3.3 Critical Infrastructure

Downtown Boston has extensive public infrastructure both at grade and underground. The area is bookended by North Station and South Station, the termini of the commuter rail and connections to the rest of the MBTA system. The MBTA's four major subway/light rail lines meet between Park Street, Downtown Crossing, Government Center, and State Street. Storrow Drive connects the city to the metropolitan suburbs to the west. The Central Artery/Tunnel Project moved much of the downtown highway network underground, replacing a major set of above ground highway infrastructure with underground roadways and interchanges and creating the Rose Kennedy Greenway at grade.

In addition to its massive system of land and water transportation infrastructure, Downtown has its own water and utility tunnel systems. Like the other neighborhoods, BWSC is responsible for most stormwater and wastewater in the city, and the existing system is designed for, on average, a 10% AEP event. Remedies to limit risk to those systems are not explicitly considered in this analysis as BWSC is conducting a parallel analysis, outside this study authority, to identify stormwater and wastewater infrastructure improvement needs. As of this writing, there is no evidence that the FWOP would be different from the existing condition; however, the operation of a potential USACE storm surge barrier at the Fort Point Channel (see South Boston Alternatives in Chapter 4) at the southeastern edge of the neighborhood may be integral to future BWSC interventions.

Multiple major hospitals operate in the Downtown area including Massachusetts General Hospital and Tufts Medical Center. Shriners Children's Hospital and the



Massachusetts Eye and Ear Hospital are internationally recognized specialty medical centers. There are three fire stations: one on Hanover Street in the North End, and two serving Downtown (one near South Station and one at the border of Government Center and Beacon Hill). The North End/Downtown area hosts two police stations, one for City officers and one for State Troopers. BCYF Nazzaro Community Center is the emergency shelter for the North End. There is one public school in the North End, the Elliot School, which serves kindergarten through eighth grade. The Josiah Quincy School, which serves kindergarten through fifth grade, is the only public school in Downtown. The BCYF Blackstone Community Center, Josiah Quincy School, and McKinley Elementary School serve as emergency shelters for Downtown.

2.3.4 Social Characteristics of Downtown/North End

The City of Boston's Planning Department prepared worksheets for each neighborhood which present the most relevant social characteristics of those neighborhoods. These statistics show that like the other neighborhoods of Boston, Downtown and the North End are growing neighborhoods, with 32,738 residents counted in the adjusted 2020 census. They are both relatively wealthy neighborhoods; however, they both have a high rate of renters, surpassing Boston's average. These characteristics of the population at risk (PAR) are not anticipated to change between the existing condition and the FWOP.



DOWNTOWN/NORTH END POPULATION INFORMATION	Downtown / North End Total	Comparison Area(s) City of Boston	Data Source
Population Trends			
2000 Census	21,129	588,501	2000 Census
2010 Census	25,959	617,059	2010 Census
2020 Census plus Group Quarters Challenge Adjustment	32,738	681,937	Adjusted 2020 Census
2030 Projection		740,685	BPDA Research Projections
2040 Projection		769,362	BPDA Research Projections
2050 Projection		800,178	BPDA Research Projections
Average Household Size	1.71	2.3	2017-2021 ACS
Age Distribution			
17 and Under	1,969	101,811	Adjusted 2020 Census
18-24*	7,207	119,953	
25-64	18,606	376,260	
65+	4,956	83,913	
Language Data			
Share of Households in Linguistic Isolation**	10%	12%	2017-2021 ACS
Number of Languages Meeting Language Access Threshold***	1	11	2017-2021 ACS
Citizenship Data			
Share of Residents who are Non-Citizens	11%	14%	2017-2021 ACS
Medical Data			
Share of Population with a Disability	10%	12%	2017-2021 ACS
Neighborhood Employment			
Number of Payroll Jobs in the Study Area	215,037	536	2020 LODS
Patterns of Wealth and Poverty			
Share of Children Living in Poverty			
Share of Residents who are SNAP Recipients	8%	24%	2017-2021 ACS
	10%	19%	2017-2021 ACS
Neighborhood Housing			
Share of Households Living in Rental Housing			
Share of Renter Households that are Housing Cost Burdened****	72%	65%	2017-2021 ACS
	40%	47%	2017-2021 ACS
Neighborhood Transportation Conditions			
Share of Resident Workers Commuting by Public Transportation			
Share of Households Without a Vehicle	19%	28%	2017-2021 ACS
Share of households without a vehicle	54%	34%	2017-2021 ACS
*Adjusted to reflect Boston's successful group quarters challenge, assumes group quarters population is aged 18-24			
**Homes in which no one in the house over age 14 speaks English very well			
***Boston Language Access			
****Renter-occupied units that pay more than 30% of income in rent			

Figure 21. Social Characteristics of Downtown/North End

2.3.5 FWOP Model Inputs for Downtown/North End

Because a neighborhood's geographic boundaries do not necessarily align with the floodplain, assets to be damaged and PAR are a subset of the assets and population of the neighborhood as a whole. Plan formulation and evaluation is based upon that subset of assets and population at risk. The figure below presents the "model areas" established for the economic modeling for the Boston CSRM study.



Figure 22. Downtown/North End Model Areas

The figure below presents a summary of the assets at risk in Downtown/North End. This is the sum of the assets at risk in each model area.

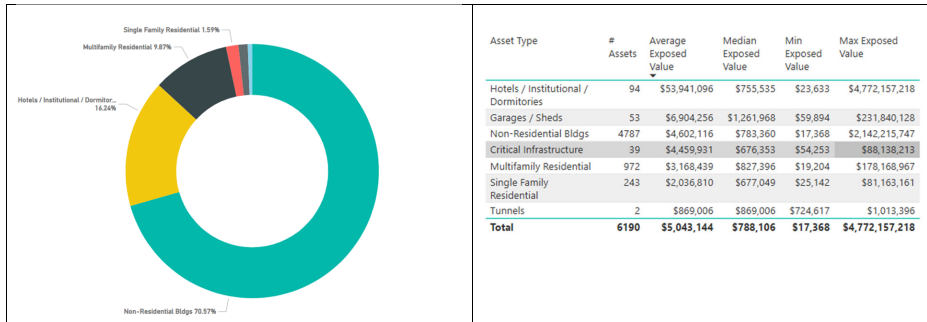


Figure 23. Asset Inventory Profile by Number and Value of Assets for Downtown/North End

Similarly, the PAR statistics used in the economic modeling are limited to the characteristics of the population living in the model area. The table below presents the population statistics that informed the economic modeling for the Downtown and North End Neighborhoods. As explained in Chapter 1, the statistics used to specify the model are the age of the population, which is used to determine life risk, and rental versus ownership rates, which informs rebuild assumptions.

MAGroup	Median Gross Rent	Median Household Income	Per Capita Income
Downtown	\$2,683	\$142,695	\$115,513

MAGroup	Population	% Population	# Households	% Households	Mean Pop / DU
Downtown	112,993	100.00%	59,279.19	100.00%	1.62
Total	112,993	100.00%	59,279.19	100.00%	1.62

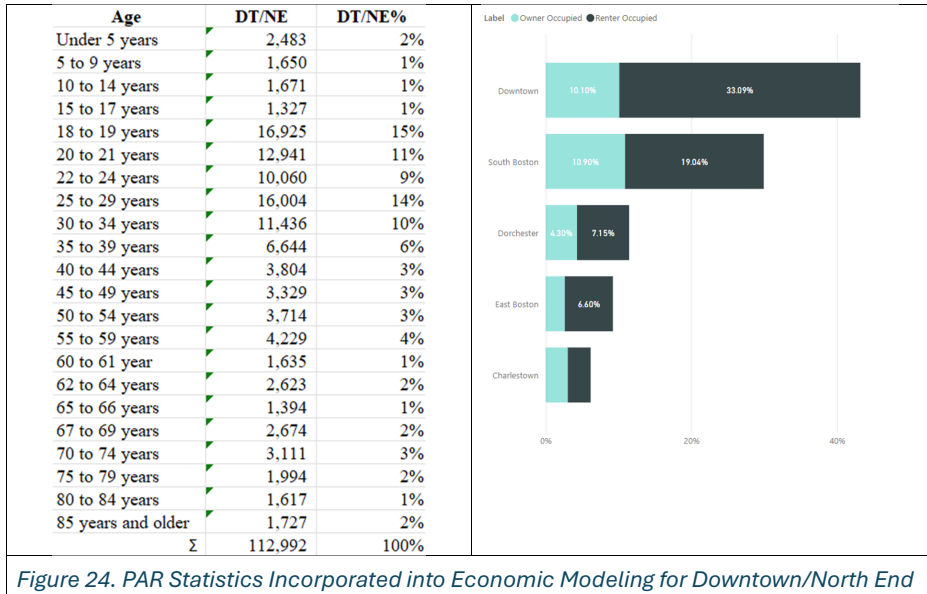


Figure 24. PAR Statistics Incorporated into Economic Modeling for Downtown/North End

FWOP life loss from coastal storms in Downtown/North End is anticipated to be very low with an estimate of 2.44 people lost to the effects of those storms over the 50-year period of analysis.

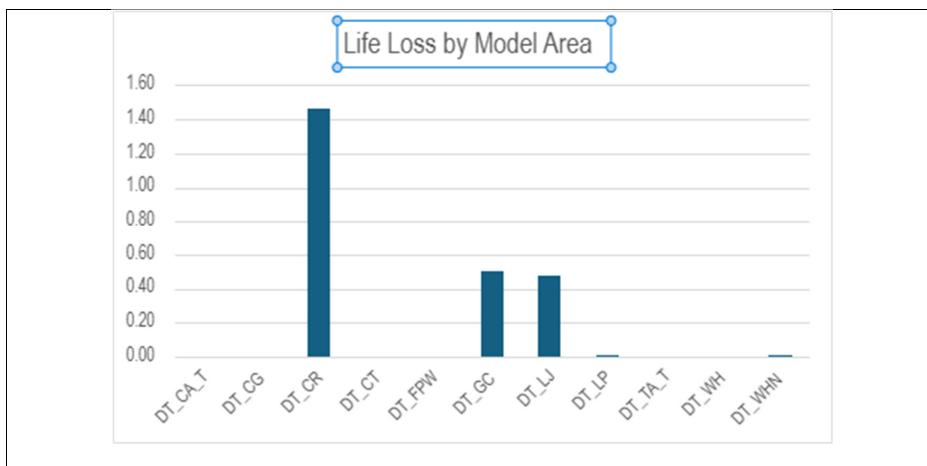
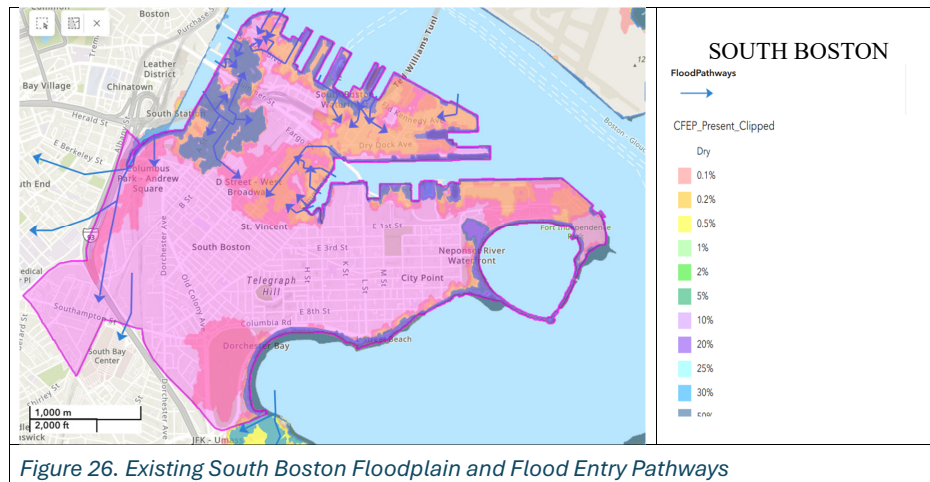


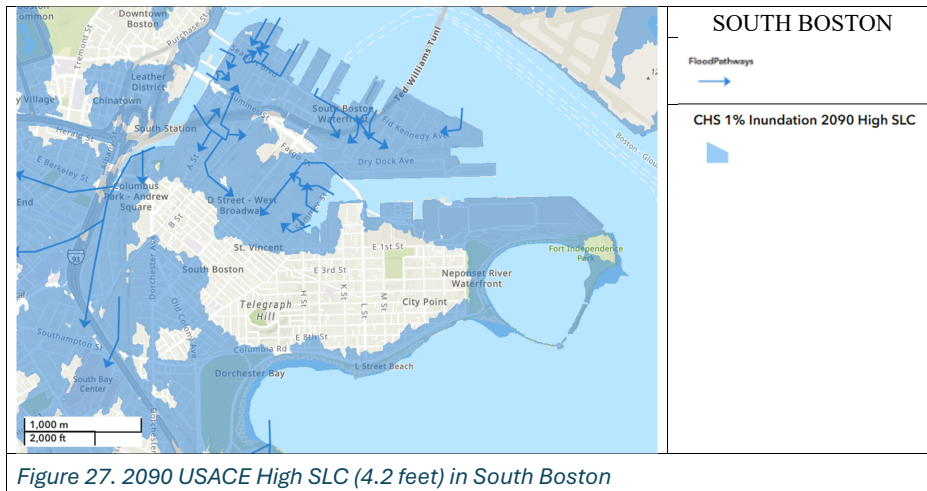
Figure 25. Anticipated Life Loss over 50-year Period of Analysis for Downtown/North End

2.4 South Boston



2.4.1 Geography

South Boston is a diamond-shaped neighborhood that is surrounded by water on three sides. It is separated from Downtown Boston by the Fort Point Channel. The northern part was once highly industrial as evidenced by the wharves created by the Boston Wharf Company in the mid-1800s that protrude into the Boston Main Channel. The Reserved Channel moves east to west forming a large inlet into the neighborhood. On the southern shore of the Reserved Channel is Fort Independence Park, which ties back into South Boston through a man-made circular park around Pleasure Bay that is operated by the Massachusetts Department of Conservation and Recreation. The southeast facing shoreline between Pleasure Bay and the Dorchester neighborhood is sandy beachfront facing Dorchester Bay. The connection to the mainland is through Dorchester along the southwest side of the community. This connection is historic as Boston and South Boston were originally large spits of land in Boston Harbor.



2.4.2 Land Use

Land use in South Boston is a mixture of commercial, industrial, residential, and recreational. The near triangle formed by the Fort Point Channel, Boston Main Channel, and Reserved Channel is a mix of new high-rise construction and adaptive reuse of waterfront warehouse properties. The area's redevelopment was anchored by the construction of the John Joseph Moakley Federal Courthouse, Boston's Institute for Contemporary Art, and the Thomas M. Menino Convention and Exhibition Center. A large fish processing district remains in this area. Many of the industrial loft buildings along the Fort Point Channel have been adaptively reused and currently serve both commercial and residential purposes. The land directly to the south of the Reserved Channel is a working container port, Massport's Conley Terminal.

Directly south of the Convention Center and the port lies the residential district of South Boston. That area is lined with multifamily residential properties with many blocks of typical Boston triple-deckers. The east- and south- facing waterfront is comprised of beaches with waterfront homes along Day Boulevard linking Pleasure Bay and Moakley Park/Carson Beach.

2.4.3 Critical Infrastructure

Boston's container port, Conley Terminal, is in South Boston. USACE completed deepening the channels to Conley Terminal to 47 feet and is about to begin a study to consider further channel improvements. Conley Terminal serves destinations throughout New England. South Boston is served by both the MBTA's Red Line subway and Silver Line Bus Rapid Transit system, which travels in underground tunnels through South Boston between Logan Airport and South Station. The Ted Williams Tunnel, which services Logan Airport and points north of Boston, terminates in South Boston.

Like the other neighborhoods, BWSC is responsible for most stormwater and wastewater in the city, and the existing system is designed for, on average, a 10% AEP event. Remedies to limit risk to those systems are not explicitly considered in this analysis as BWSC is conducting a parallel analysis, outside this study authority, to identify stormwater and wastewater infrastructure improvement needs. As of this writing, there is no evidence that the FWOP would be different from the existing condition; however, the operation of a potential USACE storm surge barrier at the Fort Point Channel at the northwestern edge of the neighborhood may be integral to future BWSC interventions.

South Boston does not have its own full-service hospital. There are two fire stations, one serving the side of South Boston closer to downtown and one serving the highly residential areas closer to the beaches. There is one police station in South Boston. There are eight public schools, including two high schools, two middle schools, and two elementary schools. The BCYF's Condon Community Center, Curley Community Center, and Tynan Community Center serve as emergency shelters for Downtown.

2.4.4 Social Characteristics of South Boston

The City of Boston's Planning Department prepared worksheets for each neighborhood which present the most relevant social characteristics of those neighborhoods. These statistics show that South Boston is growing, like the other neighborhoods, with 43,512 residents counted in the adjusted 2020 census. Compared to the citywide average of 65%, South Boston has a lower rate of renters, and, among renters, a lower rate of housing cost burden. These characteristics of the population at risk (PAR) are not anticipated to change between the existing condition and the FWOP.



SOUTH BOSTON POPULATION INFORMATION	Comparison Area(s)		Data Source
	South Boston Total	City of Boston	
Population Trends			
2000 Census	29,938	588,501	2000 Census
2010 Census	33,674	617,059	2010 Census
2020 Census plus Group Quarters Challenge Adjustment	43,512	681,937	Adjusted 2020 Census
2030 Projection		740,685	BPDA Research projections
2040 Projection		769,362	BPDA Research projections
2050 Projection		800,178	BPDA Research projections
Average Household Size	2	2.3	2017-2021 ACS
Age Distribution			
17 and Under	4,596	101,811	Adjusted 2020 Census
18-24*	4,717	119,953	
25-64	30,181	376,260	
65+	4,018	83,913	
Language Data			
Share of Households in Linguistic Isolation**	5%	12%	2017-2021 ACS
Number of Languages Meeting Language Access Threshold***	1	11	2017-2021 ACS
Citizenship Data			
Share of Residents who are Non-Citizens	5%	14%	2017-2021 ACS
Medical Data			
Share of Population with a Disability	7%	12%	2017-2021 ACS
Neighborhood Employment			
Number of Payroll Jobs in the Study Area	57,403	536	2020 LODES
Patterns of Wealth and Poverty			
Share of Children Living in Poverty	23%	24%	2017-2021 ACS
Share of Residents who are SNAP Recipients	11%	19%	2017-2021 ACS
Neighborhood Housing			
Share of Households Living in Rental Housing	59%	65%	2017-2021 ACS
Share of Renter Households that are Housing Cost Burdened****	32%	47%	2017-2021 ACS
Neighborhood Transportation Conditions			
Share of Resident Workers Commuting by Public Transportation	28%	28%	2017-2021 ACS
Share of Households Without a Vehicle	30%	34%	2017-2021 ACS

*Adjusted to reflect Boston's successful group quarters challenge, assumes group quarters population is aged 18-24

**Homes in which no one in the house over age 14 speaks English very well

***[Boston Language Access](#)

****Renter-occupied units that pay more than 30% of income in rent

Figure 28. Social Characteristics of South Boston

Figure 28. Social Characteristics of South Boston

2.4.5 FWOP Model Inputs for South Boston

Because a neighborhood's geographic boundaries do not necessarily align with the floodplain, assets to be damaged and PAR are a subset of the assets and population of the neighborhood as a whole. This is especially relevant for South Boston and Dorchester as there is no clear geographic demarcation of where one neighborhood ends and the other begins. Plan formulation and evaluation is based upon that subset

of assets and population at risk. The figure below presents the “model areas” established for the economic modeling for the Boston CSRM study.



Figure 29. South Boston Model Areas

The figure below presents a summary of the assets at risk in South Boston. This is the sum of the assets at risk in each model area.

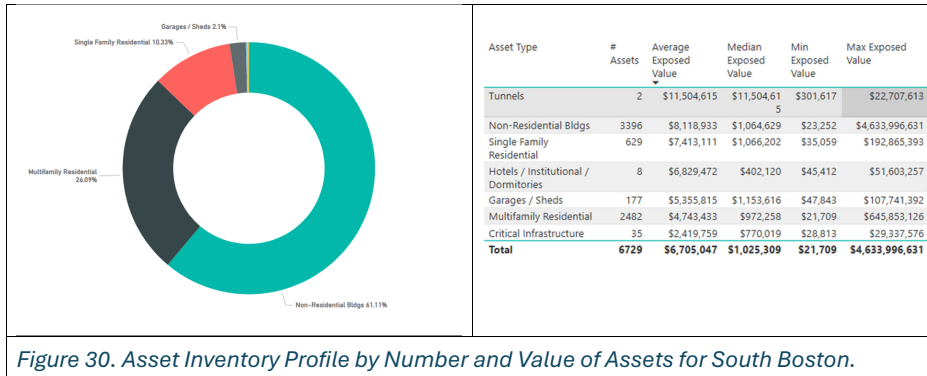


Figure 30. Asset Inventory Profile by Number and Value of Assets for South Boston.

Similarly, the PAR statistics used in the economic modeling are limited to the characteristics of the population living in the model area. The table below presents the population statistics that informed the economic modeling for South Boston. As explained in Chapter 1, the statistics used to specify the model are the age of the population, which is used to determine life risk, and rental versus ownership rates, which informs rebuild assumptions.

MAGroup	Median Gross Rent	Median Household Income	Per Capita Income
South Boston	\$1,876	\$154,138	\$112,607

MAGroup	Population	% Population	# Households	% Households	Mean Pop / DU
South Boston	86,081	100.00%	46,038.93	100.00%	1.60
Total	86,081	100.00%	46,038.93	100.00%	1.60

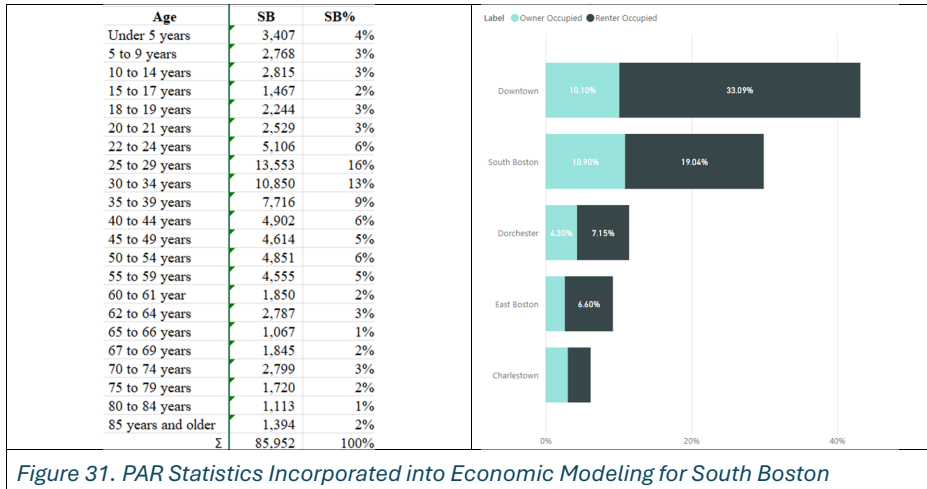


Figure 31. PAR Statistics Incorporated into Economic Modeling for South Boston

FWOP life loss from coastal storms in South Boston is anticipated to be concentrated in the South End model area. The estimated life loss in South over the 50-year period of analysis is 17.29 people.

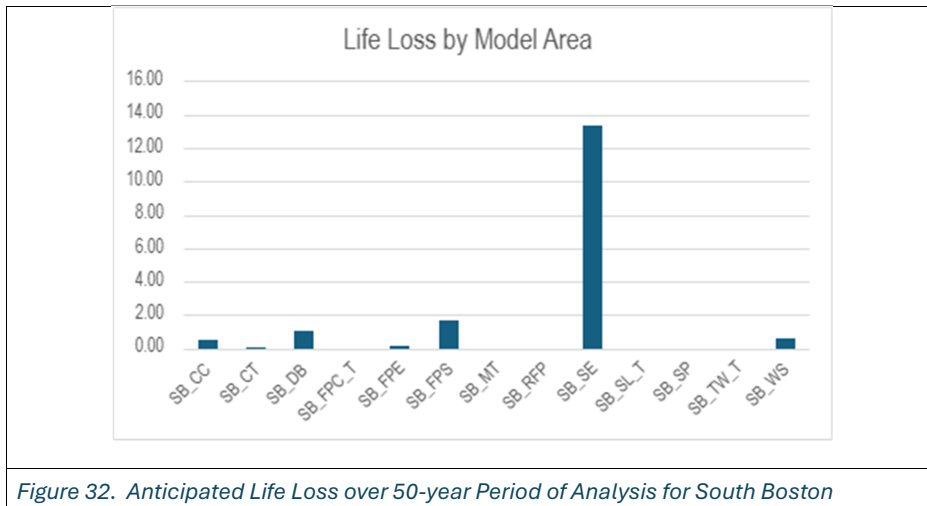
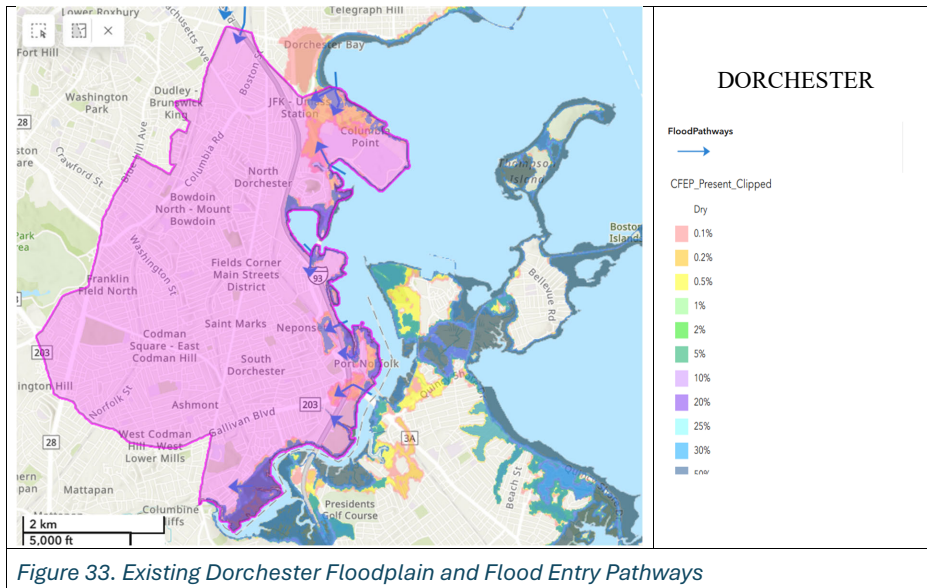


Figure 32. Anticipated Life Loss over 50-year Period of Analysis for South Boston

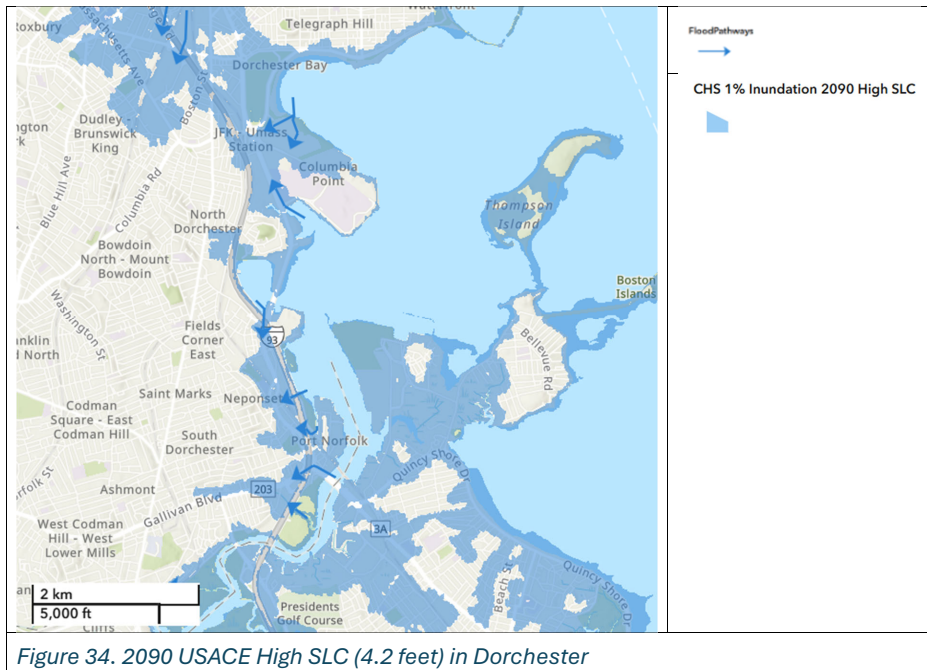
2.5 Dorchester



2.5.1 Geography

Dorchester is Boston's largest neighborhood by acreage. The neighborhood lies on the shoreline of Dorchester Bay, in the lower part of Boston Harbor, and is bordered to the south by the Neponset River. Columbia Point, a landfill-supplemented peninsula forms the northeast edge of the neighborhood. The district of Savin Hill and its beach lie to its south. South of Savin Hill, the southern extension of Interstate 93 hugs the shoreline and connects Dorchester to the City of Quincy and points south, with the National Grid storage tank and solar panel farm as well as the shorefront community of Port Norfolk bulging beyond the highway to the east. The southern tip of Dorchester includes two extensive parks, Pope John Paul Park and Ventura Park, which border the Neponset River. The southern end of Dorchester borders the community of Mattapan. Jamaica Plain and Roxbury form the rest of the neighborhood's western border. Much of the land of Dorchester is rolling terrain, including the shorefront neighborhood of Savin Hill.

DORCHESTER



2.5.2 Land Use

Land use in Dorchester is mostly residential and consists of row houses, triple-deckers, large Victorian homes, and modern transit-oriented apartment buildings. These residential communities are complemented by corridors of one-story storefront businesses. Shopping plazas abut Interstate 93, which moves traffic between Cape Cod and the South Shore and Downtown, or Morrissey Boulevard. Between Route 93 and the waterfront is a mixture of parkland, beaches, townhomes, single-family freestanding houses, industrial facilities, and the campuses of the University of Massachusetts at Boston, Boston College High School, and the John F. Kennedy Presidential Library. Dorchester has the largest proportion of single-family homes of all the neighborhoods considered in the Boston CSRM Study.

2.5.3 Critical Infrastructure

Beyond Interstate 93, Dorchester has significant transportation infrastructure including much of the MBTA's Red Line subway (running at or above grade) and the commuter rail lines to the South Shore. A large liquified natural gas tank with Corita Kent's iconic "Rainbow Swash" remains operational on the shorefront where it sits alongside a solar panel farm. Like the other neighborhoods, plans for stormwater and wastewater infrastructure are under the authority of BWSC and not within the scope of this study. As of this writing, there is no indication that the FWOP would be different from the existing condition.

With the closing of Carney Hospital in 2024, Dorchester no longer has a full-service hospital. Consistent with its large size, Dorchester has seven fire stations and two police stations. The neighborhood has four elementary schools, a middle school, and a high school. Dorchester has numerous emergency shelters, including the McCormick Middle School, King Middle School, New Boston Pilot Middle School, UP Academy Dorchester, Cleveland School, Tech Boston Academy, and Henderson Upper School, as well as BCYF's Grove Hall Community Center, John P. Holland Community Center, Leahy Halloran Community Center, and Perkins Community Center.

2.5.4 Social Characteristics of Dorchester

The City of Boston's Planning Department prepared worksheets for each neighborhood which present the most relevant social characteristics of those neighborhoods. Like the other neighborhoods in this study, Dorchester is growing. Dorchester is, by far, the most populous neighborhood in the study area, with more than double the population of any of the other neighborhoods. It is also a relatively less affluent neighborhood. While there are wealthy areas of Dorchester, there are also areas of poverty. Nearly 30% of residents receive Supplemental Nutrition Assistance (SNAP) benefits. More than half of the renters in Dorchester are cost burdened, which is close to the citywide statistic, but does not account for the fact that Boston has many areas of student-rented apartments. Most Boston college students would be considered rent burdened which would account for such a high proportion of rent burdened population in the city but not be an indicator of poverty. These characteristics of the population at risk (PAR) are not anticipated to change between the existing condition and the FWOP.

DORCHESTER POPULATION INFORMATION	Dorchester Total	Comparison Area(s) City of Boston	Data Source
Population Trends			
2000 Census	118,875	588,501	2000 Census
2010 Census	114,249	617,059	2010 Census
2020 Census plus Group Quarters Challenge Adjustment	123,268	681,937	Adjusted 2020 Census
2030 Projection		740,685	BPDA Research Projections
2040 Projection		769,362	BPDA Research Projections
2050 Projection		800,178	BPDA Research Projections
Average Household Size	2.73	2.30	2017-2021 ACS
Age Distribution			
17 and Under	26,826	101,811	Adjusted 2020 Census
18-24*	14,538	119,953	
25-64	66,744	376,260	
65+	15,160	83,913	
Language Data			
Share of Households in Linguistic Isolation**	13%	12%	2017-2021 ACS
Number of Languages Meeting Language Access Threshold***	4	11	2017-2021 ACS
Citizenship Data			
Share of Residents who are Non-Citizens	14%	14%	2017-2021 ACS
Medical Data			
Share of Population with a Disability	16%	12%	2017-2021 ACS
Neighborhood Employment			
Number of Payroll Jobs in the Study Area	31,562	651,206	2020 LODS
Patterns of Wealth and Poverty			
Share of Children Living in Poverty	29%	24%	2017-2021 ACS
Share of Residents who are SNAP Recipients	29%	19%	2017-2021 ACS
Neighborhood Housing			
Share of Households Living in Rental Housing	63%	65%	2017-2021 ACS
Share of Renter Households that are Housing Cost Burdened****	53%	47%	2017-2021 ACS
Neighborhood Transportation Conditions			
Share of Resident Workers Commuting by Public Transportation	30%	28%	2017-2021 ACS
Share of Households Without a Vehicle	28%	34%	2017-2021 ACS

*Adjusted to reflect Boston's successful group quarters challenge, assumes group quarters population is aged 18-24

**Homes in which no one in the house over age 14 speaks English very well

***[Boston Language Access](#)

****Renter-occupied units that pay more than 30% of income in rent

Figure 35. Social Characteristics of Dorchester

Figure 35. Social Characteristics of Dorchester

2.5.5 FWOP Model Inputs for Dorchester

Because a neighborhood's geographic boundaries do not necessarily align with the floodplain, assets to be damaged and PAR are a subset of the assets and population of the neighborhood as a whole. This is especially relevant for South Boston and Dorchester, as there is no clear geographic demarcation of where one neighborhood ends and the other begins. Plan formulation and evaluation is based upon that subset

of assets and population at risk. The figure below presents the “model areas” established for the economic modeling for the Boston CSRM study.



The figure below presents a summary of the assets at risk in Dorchester. This is the sum of the assets at risk in each model area.

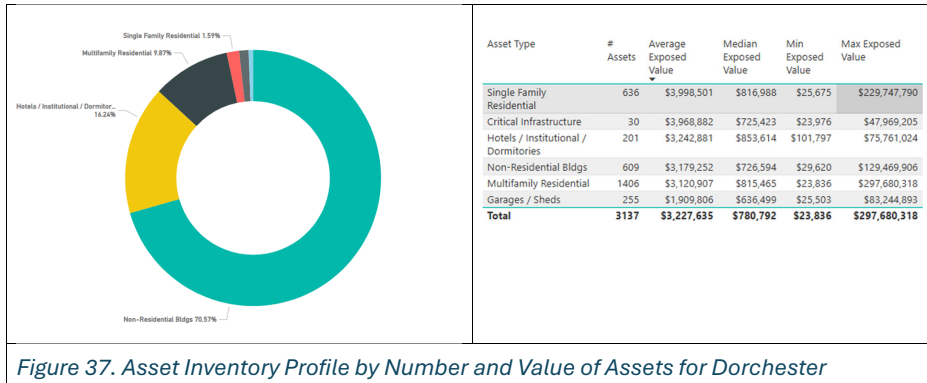


Figure 37. Asset Inventory Profile by Number and Value of Assets for Dorchester

Similarly, the PAR statistics used in the economic modeling are limited to the characteristics of the population living in the model area. The table below presents the population statistics that informed the economic modeling for Dorchester. As explained in Chapter 1, the statistics used to specify the model are the age of the population which is used to determine life risk and rental versus ownership rates, which informs rebuild assumptions. The study team also recognizes that facility with English and reliance on public transportation may inform evacuation rates; however, without more specific data on evacuation in the Boston CSRM study area, the study team could not establish to what degree those population characteristics would inform life loss. To that end, any bias would be to slightly underestimate life loss results as there is a slightly elevated number of people who have limited facility with English residing in Dorchester.

MAGroup	Median Gross Rent	Median Household Income	Per Capita Income
Dorchester	\$2,081	\$95,312	\$57,179

MAGroup	Population	% Population	# Households	% Households	Mean Pop / DU
Dorchester	36,312	100.00%	17,326.63	100.00%	2.07
Total	36,312	100.00%	17,326.63	100.00%	2.07

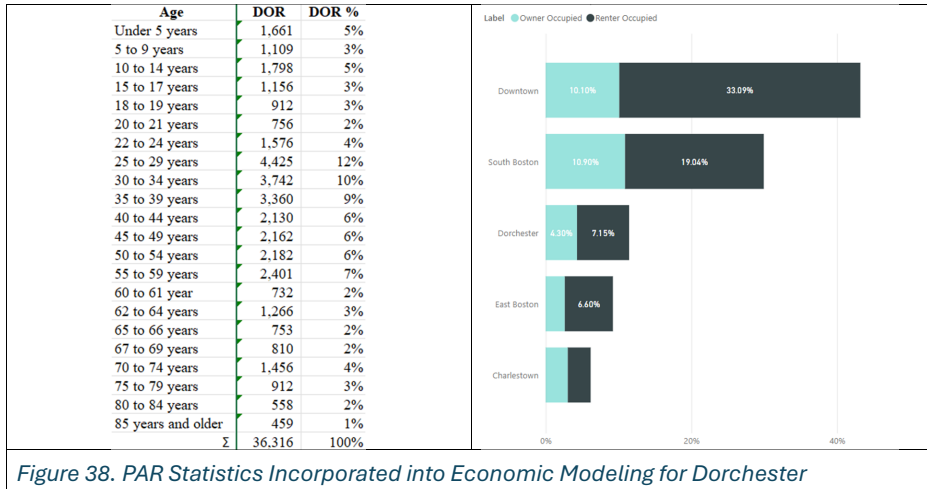


Figure 38. PAR Statistics Incorporated into Economic Modeling for Dorchester

FWOP life loss from coastal storms in Dorchester is anticipated to be concentrated in the northern areas of Moakley Park and Columbia Point as well as in the southern areas of Neponset Circle and Tenean Beach. The estimated life loss in Dorchester over the 50-year period of analysis is 21.97 people.

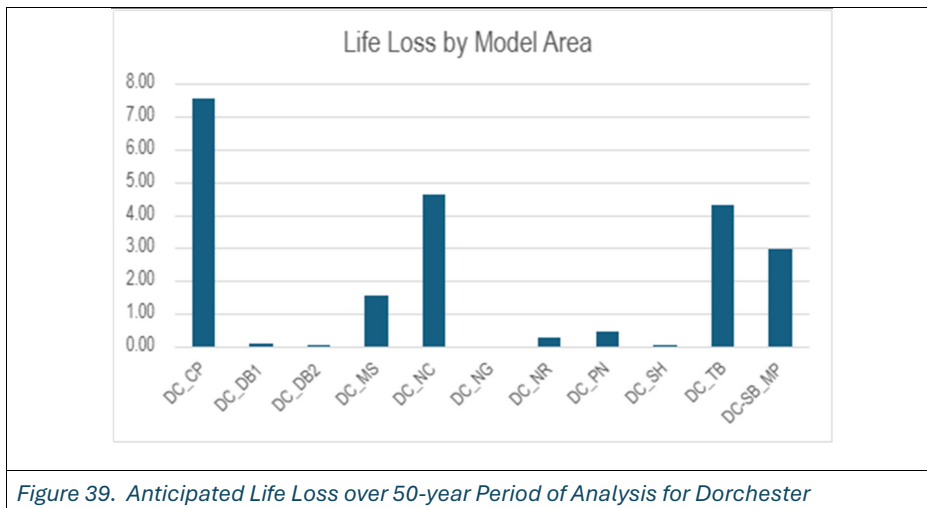
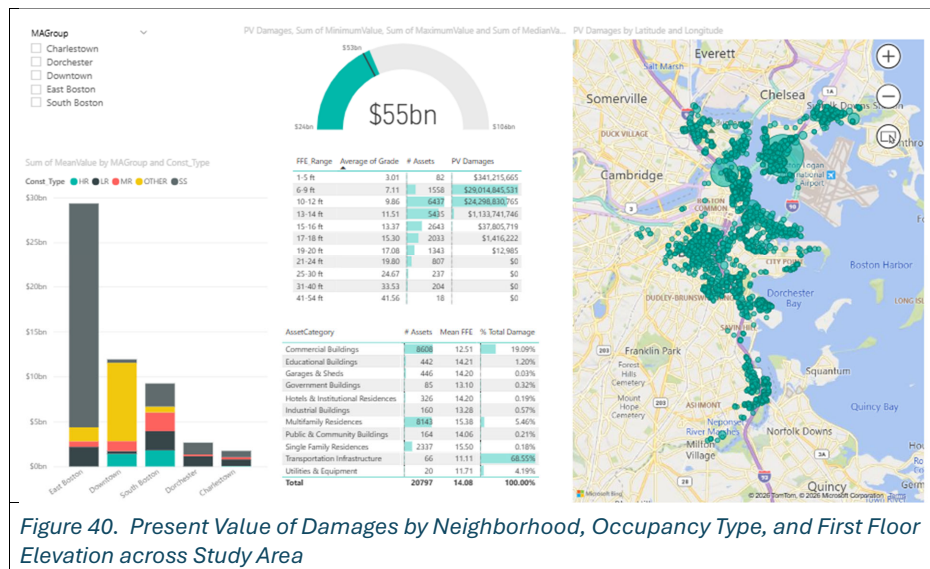


Figure 39. Anticipated Life Loss over 50-year Period of Analysis for Dorchester

2.6 Summary of FWOP

The following tables summarize the physical and social characteristics of the FWOP used in the economic analysis. The physical characteristics feed into the NED analysis and PAR characteristics allow for an estimate of life loss over the duration of the project life, feeding the estimate of Other Social Effects of a USACE intervention. As explained in Chapter 1 of this document, these characteristics do not supply the entire justification of selecting one coastal storm risk management remedy over another, but they will provide important information to decision-makers.



The figure above shows the present value of potential damages across the study area broken down by neighborhood and occupancy type. First floor elevation is included in the economic analysis as this is where damage is assumed to begin. The analysis did not break out the number of people residing in garden or basement level housing as the number of assets at risk is high enough that the exact number would not make a difference in the plans formulated or the results of the analysis. Nonetheless, most of those benefits would occur in the East Boston and South End neighborhoods, both of

which have a high number of basement and garden level apartments. The effect of not including those numbers would be to potentially undercount benefits to potential barrier interventions in East Boston and underestimate the benefits of the Fort Point Storm Surge Barrier in low frequency, high consequence events (see Chapter 4 for Plan Formulation and alternatives considered).

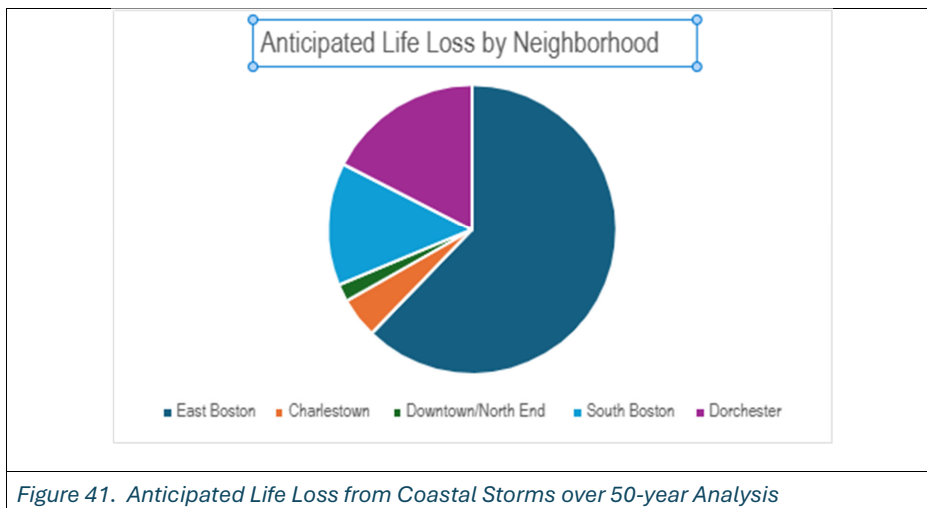


Figure 41. Anticipated Life Loss from Coastal Storms over 50-year Analysis

Estimated life loss over the 50-year analysis period is anticipated to be concentrated in the East Boston neighborhood. This neighborhood is not only low lying and highly populated, but also has a high proportion of population with limited English proficiency. The overall anticipated life loss from the effects of coastal storms in the city of Boston is 125.54 persons.

3 Economic Analysis Paradigm

A Federal project is considered economically justified if the benefits of the project equal or exceed the costs. The economic benefits of a coastal storm damage reduction project are measured by the degree to which the project reduces expected annual storm damages. Damages in the without- and future with-project conditions were calculated using the approved USACE modelling tool, Generation 2 Coastal Risk Model (G2CRM) Version 0.4.564. A summary of the model's key components and the uncertainty surrounding the data elements is provided in the following sections.

3.1 The Basics of G2CRM

G2CRM was used to estimate the inundation damages prevented for project alternatives within the study area. G2CRM is distinguished from other models by virtue of its focus on probabilistic life cycle approaches. This allows for examination of important long-term issues including the impact of climate change and avoidance of repetitive damage. Additionally, G2CRM allows for incorporation of time-dependent and stochastic event-dependent behaviors such as waves, tides, and structure modifications. The model is based upon driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas (model areas) of different types that may interact hydraulically and may be defended by coastal defense elements that serve to shield the areas and the assets they contain from storm damage.

Within the specific terminology of G2CRM, the important modeled components are:

- **Driving Forces:** Storm hydrographs (surge and waves) at locations, as generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE.
- **Modeled Areas (MAs):** Model areas within the five neighborhoods are presented in Chapter 2 of this document. In the cases of Downtown and Dorchester, they are the subareas of the neighborhood with assets that face direct coastal storm risk. In East Boston, Charlestown, and South Boston, they extend over the entire neighborhood because the entire neighborhood is subject to coastal storm risk. The water level in the modeled area is used to determine consequences to the assets contained within the area.

- **Protective System Elements (PSEs):** The infrastructure that defines the coastal boundary be it a coastal defense system that protects the modeled areas from flooding (levees, pumps, closure structures, *etc.*), or a locally developed coastal boundary comprised of bulkheads and/or hardened shoreline.
- **Assets:** Spatially located entities that can be affected by storms. Damage to structure and contents is determined using damage functions. For structures, population data at individual structures allows for characterization of loss of life for storm events and defines the Population at Risk (PAR) used in life loss calculations.

G2CRM models the engineering and economic interactions of these elements as storms occur during the life cycle, areas are inundated, protective systems fail, assets are damaged, and lives are lost. G2CRM is used to calculate the damages to structures and their contents, and life loss across a 50-year economic horizon with (FWP) and without (FWOP) Federal intervention. The interventions under consideration are presented in Chapter 4. The reduction in damages and lives lost between the FWOP and the FWP for each potential intervention are the benefits attributable to that intervention.

G2CRM employs a life-cycle approach to analysis. The possible occurrences of each variable are set by the user and the outcome of each iteration selected using Monte Carlo simulation, which uses randomly selected numbers to simulate the values of the selected variables from within the established ranges and distributions. For each variable, random sampling is employed to select from within the range of possible values. With each sample, or iteration, a new value is selected. At each iteration, different variables are sampled to allow for representations of uncertainty in variables, such as the number of storms in a year. Over many iterations, the overall results should return values representative of the input variability. The number of iterations performed affects both the simulation execution time and the quality and accuracy of the results. This process was conducted simultaneously for each economic and hydrologic variable. The resulting mean value and probability distributions formed a comprehensive picture of possible outcomes depending on the selected sea level rise scenario and their distribution over the economic horizon.

3.2 Assumptions and Run Conditions

G2CRM accuracy is not only dependent upon inputs but also requires consideration of the parameters (i.e., assumptions) under which the model is bound. This section describes key assumptions of the G2CRM model and specific parametric assumptions made for the evaluation for this study.

- **Start Year:** The year in which the simulation begins is 2040. This year determines the starting structure inventory, the mix of assets in the study area, which will evolve through raising and rebuilding efforts throughout the period of analysis.
- **Base Year:** The present value basis and the year in which the benefits of a constructed federal project would be expected to begin accruing is 2040. This is based on the expected signing of the Chief's Report in 2028, four years of funding appropriation and preconstruction engineering/design (PED), and eight years of construction. It may be that different elements of the recommended Action 1 are constructed at different times, with a number of early actionable elements reducing risk to parts of Boston before the base year; however, as there is no authorized project at this time, the economic analysis assumes each alternative to be complete and begin reducing risk in 2040 so that they can be appropriately compared to one another. The implementation strategy is discussed in the Main Integrated Feasibility Report/Environmental Impact Statement (IFR/EIS) document. As components of the recommendation are implemented, modeling will be modified to account for more accurate or past PED and construction durations as well as actualized benefit realization.
- **Basis Year:** G2CRM makes a distinction between base year and basis year. While the base year parameter specifies the temporal reference to any monetary related statistics, the basis year parameter specifies the temporal reference to any sea level calculation within the model. The basis year was selected to be 1992, the midpoint of the utilized National Tidal Datum Epoch (NTDE) (1983-2001).
- **Sea Level Change Rate:** The mean sea level trend of 4.37 mm/year, or 0.014338 feet/year, with 95% confidence rating +/- 0.57 mm/year, as published for Boston, MA, as of 2023, was used as the sea level change rate using the USACE High Curve. Water level elevations at year 2040 are expected to be

between 0.69 and 1.54 feet higher than the current NTDE. Water elevations at year 2090 are expected to be between 1.41 and 4.97 feet higher than the current NTDE.

- **Period of Analysis:** The period of analysis is 50 years, which runs from 2040 to 2089.
- **Iterations:** G2CRM model runs used 100 iterations for the FWOP and the final array of alternatives. The moving average of FWOP damages stabilized by this point and was determined as an adequate threshold. Within this appendix, the term iteration may also be referred to as life cycle.
- **Discount Rate:** The analysis was conducted using the most current discount rate available at the time of the modeling: 3.25% is the federal water resource project evaluation discount rate for fiscal year 2026.
- **Calculated Depreciation:** As discussed, structure values were calculated as depreciated replacement values. Therefore, additional depreciation was not considered as structure upkeep is assumed to offset depreciation.
- **Raise Structure:** Base Flood Elevations (BFE) were identified, according to the preliminary Flood Insurance Rate Map, dated December 31, 2019. The analysis assumed that single family residences are subjected to triggered elevation once the damage threshold reaches 50%.
- **Cumulative Damage Thresholds:** Other than for critical infrastructure which was assumed to be rebuilt indefinitely, the value of damages over time were limited to four times the initial value of the structure. This assumption was not used for critical infrastructure or, specifically, the tunnels. The analysis assumes that infrastructure would be repaired to pre-storm conditions given that these elements of the system are so critical to daily life that putting them out of service for comprehensive upgrades would be too burdensome for the public and too costly to the asset owner.
- **Repetitive Damages:** Repetitive damages were restricted to no more than 4 rebuilds and a cumulative damage threshold of 4x. Critical infrastructure assets have a rebuild of 100 under the assumptions that the municipal resource owner would do just enough to keep the resource functioning for the public. Early runs

which applied limitations on repetitive damage thresholds for critical infrastructure resulted in unrealistic closures of within the transportation system. Data was checked to make sure that only critical infrastructure assets were allowed to take extensive damage.

- **Maximum Number of Rebuilds:** The number of times a property could be rebuilt was limited to four for properties other than high rise and midrise buildings and critical infrastructure. High rise and midrise properties were limited to one rebuild. Critical infrastructure rebuilds were unlimited given the importance of such assets to the day-to-day functioning of the study area.
- **Calculate Assets:** Selecting “yes” directs G2CRM to use the uploaded assets.
- **Use Benefit Bases:** Selecting “no” for this parameter directs G2CRM to assume all structures are in the benefit base. Structures are assumed to comply with the Flood Insurance Rate Map effective at the time of their construction.
- **Cumulative Damage Removal:** Logic may suggest that a structure would be removed or acquired once the cumulative damage exceeds its present value or, at a minimum, brought up to code once exceeded the 50 percent substantial damage (according to 44CFR 59.1); however, there are no current FEMA or USACE guidelines that require the removal or acquisition of a structure once damage has exceeded its present value. Because of the mixture of building types in the study area, this option was not used as there is little evidence that this practice occurs in multistory and multifamily dwellings and urban commercial and industrial properties.
- **Rebuild Time:** Structures were assumed to be rebuilt within 2 years.
- **Life Loss:** This parameter allows the user to toggle life loss calculations on or off. For this study, life loss was calculated. Associated model and parameter assumptions for life loss are also covered in the discussion of the FWOP in Chapter 2.
- **Auto-Generated Waves** - Waves were included in the H5 files imported into each study area; therefore, auto-generated waves were not used.

3.3 Economic Inputs to G2CRM

This section presents the specific economic inputs and their uncertainties used in the modeling Boston CSRM study.

3.3.1 Structure Valuation

The extensive inventory of over 20,000 assets modeled for the Boston CSRM Study was compiled through a multistep process that used multiple sampling efforts to confirm that the data used was representative of the situation on the ground. Because of the size and asset density of the study area, the National Structure Inventory (NSI) served as the backing of the overall structure inventory for the Boston CSRM Study. Square footage, number of floors, and foundation type for structures were obtained from parcel data whenever possible. When square footage was not available, the polygon area of the building footprint was calculated in ArcGIS and multiplied by 0.9 to allow for unusable space such as doors, walls, etc. This area was multiplied by the number of floors with the upper limit placed at the highest number of floors available for that particular function. Once model areas were defined, data was refined and detailed critical infrastructure information added (for example data about tunnels, roadways, schools, hospitals, etc.). At that point, data was generated on a random sample of assets (99) using Google StreetView to confirm that asset characteristics such as occupancy category, material, and age were being properly assigned. RS Means was used to generate depreciated replacement values (DRVs) at 2026 price levels based on asset type, material, presence of a basement or garage, and square footage.

There were multiple checks performed to ensure that first floor elevations, foundation heights, and the presence of inhabited basements was appropriately considered. A randomly selected sample of structure physical characteristics in the Boston CSRM study included ~480 structures which were viewed using GoogleEarth imagery. That sample yielded the distribution of foundation heights by occupancy categories. The first-floor elevation values fused in G2CRM for structures not sampled were calculated at min ground elev + min foundation height, ML ground elev + ML foundation height, and max ground elevation + max foundation height. Minimum, most likely, and maximum foundations heights were inputted into G2CRM.

Inhabited basements/garden level apartments were included in the structure inventory, but were not considered individually. Given the locations and ground elevations where these



types of homes exist, the greatest consequence to this type of housing would be in the South End which was not one of the neighborhoods specifically considered for a Federal intervention, but for which would benefit from the Fort Point Channel Storm Surge Barrier. Risk of flooding will be reduced in other areas with low-elevation, garden-level dwellings such as East Boston, Charlestown, and Dorchester because most of the interventions considered throughout the study area are perimeter-based.

Asset Type	# Distinct Occupancy Types	# Assets	Average of Sqft	Median of Sqft	Min of Sqft	Max of Sqft
Non-Residential Bldgs	42	9889	28,034	5,703	82	4,592,656
Multifamily Residential	21	7877	4,200	2,741	112	1,397,702
Critical Infrastructure	17	174	9,458	3,815	144	62,259
Single Family Residential	9	2011	1,798	1,653	310	12,336
Tunnels	6	6				
Garages / Sheds	5	624	13,177	383	137	553,255
Hotels / Institutional / Dormitories	4	326	6,202	1,655	169	92,535
Total	104	20907	15,630	3,358	82	4,592,656

Figure 42. Number of Structures Available to be Damaged by Occupancy Type and Size

According to the RSMeans residential depreciation schedule, each individual structure was depreciated based on the structure type and effective age for each structure, which came from data from the City of Boston's Assessor's Office. An average condition depreciation rating was assumed for all structures, as opposed to good or poor. This equates to a percentage depreciation equivalent to the effective age for structures 10 years and older, with a cap at 50% for any structure 50 years or older. For non-residential structures, the appropriate construction material and effective age was used to determine the depreciation rate from the RSMeans non-residential depreciation schedule, which varies depending on material, but remains constant for structures 60 years or older.

Residential	Highest	Most Likely	Lowest
	0.65	0.25	0.10
General Commercial	Highest	Most Likely	Lowest

Commented [CH1]: I thought it was capped at 50%?

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	0.70	0.20	0.03
Dormitories	Highest	Most Likely	Lowest
	0.45	0.30	0.15
Industrial	Highest	Most Likely	Lowest
	0.70	0.35	0.08
Office Buildings	Highest	Most Likely	Lowest
	0.35	0.15	0.03
Stores, Supermarkets & Restaurants	Highest	Most Likely	Lowest
	0.35	0.25	0.08
Hotels & Motels	Highest	Most Likely	Lowest
	0.35	0.25	0.08
Schools & Colleges	Highest	Most Likely	Lowest
	0.30	0.15	0.03
Public Facilities (Police Stations, Community Centers, Religious)	Highest	Most Likely	Lowest
	0.70	0.30	0.08
Auditoriums & Stadiums	Highest	Most Likely	Lowest
	0.30	0.20	0.08
Hospitals & Medical Offices	Highest	Most Likely	Lowest
	0.25	0.15	0.03
Apartment Buildings	Highest	Most Likely	Lowest
	0.50	0.25	0.08

Figure 43. Depreciation by Asset Type

This depreciated value was then adjusted by a percentage to equal a regional adjustment of 115% for residential and 113% for commercial, as determined by RS Means for the Boston area. This process was used to calculate a most-likely cost per square foot for each structure. The most-likely depreciated cost per square foot was then multiplied by the square footage calculated for individual structures in each occupancy to obtain a total depreciated cost or value for each structure. The resulting Depreciated Replacement Values (DRV) are in FY2026 values, which was the most current value at the time the analysis was originally completed.

Age (years)	Good Condition	Average Condition	Poor Condition
2	0.02	0.03	0.10
5	0.04	0.06	0.20
10	0.07	0.10	0.25
15	0.10	0.15	0.30
20	0.15	0.20	0.35

25	0.18	0.25	0.40
30	0.24	0.30	0.45
35	0.28	0.35	0.50
40	0.32	0.40	0.55
45	0.36	0.45	0.60
50	0.40	0.50	0.65

Figure 44. Depreciation Proportion used for Residential Structures

Uncertainty in structure valuation is captured by a triangular probability distribution based on the depreciated replacement costs derived for the three quality conditions of building condition ratings (good, average, poor). The most-likely depreciated value was based on the average quality, the minimum value was based on the poor quality, and the maximum value was based on the good quality, as seen in the table above.

Age (years)	Frame	Masonry on Wood	Masonry on Masonry or Steel
1	0.01	0.00	0.00
5	0.06	0.05	0.03
10	0.20	0.15	0.08
15	0.25	0.20	0.15
20	0.30	0.25	0.20
25	0.35	0.30	0.25
30	0.40	0.35	0.30
35	0.45	0.40	0.35
40	0.50	0.45	0.40
45	0.55	0.50	0.45
50	0.60	0.55	0.50
55	0.65	0.60	0.55
60	0.70	0.65	0.60

Figure 45. Depreciation Proportion used for Commercial Structures

For non-residential structures, the distribution was based on adjustment to observed age as well as type of material which equated to 10% less or more than the most likely depreciation. The triangular probability distributions were entered into the G2CRM model to represent the uncertainty surrounding the structure values in each residential occupancy category.

3.3.2 Content-to-Structure Value Ratios

Content-to structure value ratios (CSVs) used in this feasibility study were derived from multiple sources, including the North Atlantic Coastal Comprehensive Study (NACCS); the USACE Institute for Water Resources (IWR) Non-residential Flood Depth-Damage Functions Derived from Expert Elicitation Draft Report, revised 2013 (IWR 2013); the Federal Emergency Management Agency's (FEMA) Hazus data. A content value was computed for each residential and non-residential structure in the study as a percentage of the total depreciated replacement value. The nearly 21,000 assets in Boston's asset base required over 120 building classifications and 34 different CSVs.

A triangular probability distribution was used to represent the uncertainty surrounding the contents-to-structure value ratios (CSVs) for residential structures. The minimum CSV value, 25 percent, most-likely CSV value, 50 percent, and the maximum CSV value, 75 percent, were all based on an estimated range found in the manuals that accompanied the data sources.

3.3.3 First Floor Elevations

First floor elevations and foundation heights were obtained from parcel data, and Google StreetView. For structures updated using Google StreetView, the foundation height was estimated by summing up the number of steps, assuming each to be 7.5 inches high. The foundation height was added to the ground elevation to determine the first-floor elevation of each structure in NAVD88. Structures with ground elevations below zero, were updated to reflect positive ground elevations adjacent to the boundary of the structure. Commercial and industrial properties were assumed to have entry points at ground unless a ramp was visible in Google Street View. There were two components to the uncertainty in first floor elevations. The first of these was underlying ground elevation which has a vertical uncertainty of 7.51 cm (roughly 3 inches). The second was foundation height which was derived by generating a random sample of structures and generating a distribution of foundation heights by building type.

3.3.4 Damage Functions

Damage functions were applied to each building type through G2CRM software. Depth-damage relationships used in this effort came from the NACCS study and IWR's 2013 expert elicitation. These depth-damage functions estimate the likely degree of damage to structure and contents at each elevation of flooding relative to the first floor, expressed as a percentage of structure and content value, based on actual damages

experienced during Hurricane Sandy in the northeast. Structure values are based on depreciated replacement value of the building. A minimum, maximum, and most-likely damage estimate for each depth of flooding was obtained from the accompanying documentation from the reports.

3.4 Engineering Inputs to G2CRM

3.4.1 Storms

The probabilistic storm suite for the G2CRM model was developed from the NACCS hydrodynamic model output data at selected ADCIRC nodes or Save Points throughout the study area. Storm hydrographs from the NACCS coupled with ADCIRC and STWAVE models were used to force the G2CRM model. ADCIRC is a two-dimensional hydrodynamic model that conducts short- and long-term simulations of tide and storm surge elevations and velocities in deep ocean, continental shelves, coastal seas, and small-scale estuarine systems. ADCIRC uses the finite element method to solve the reformulated, depth-averaged shallow water equations. The model runs on a triangulated mesh with elevations derived from a seamless bathymetric/topographic DEM that includes both offshore and overland areas. The triangulated format of the mesh allows variation in the element size, so the study area can have a high concentration of nodes while fewer nodes (with higher element areas) can be placed farther away to make the mesh more efficient without compromising accuracy. STWAVE is a steady-state, finite difference, spectral model based on the wave Action Balance equation. Using the Coastal Storm Modeling System (CSTORM-MS), the ADCIRC and STWAVE models are two-way coupled.

For each MA, storms were sampled from the NACCS suite of 1050 synthetic tropical storms using a radius of 135 miles around each model area save point. This storm sampling resulted in a range of 469 to 495 tropical storms per model area. In addition to the sampled tropical storms, the 100 historical extratropical storms from the NACCS were included in the storm suite for each MA, resulting in a total of 569 to 595 storms per model area.

3.4.2 Stage-Probability Data

Stage-probability relationships were provided for the existing without-project condition through future without project conditions, based on the USACE high sea level change



curve. The high rate was selected to balance the risk of under designing a project using the high or low curves. Further, the study area was not considered to be an abnormally high or low consequence risk area. Water surface profiles were provided for eight annual exceedance probability (AEP) events at various confidence limits. Water surface profiles were provided for eight annual chance exceedance (ACE) events at various confidence limits: fifty percent flood (2-year flood), twenty percent flood (5-year flood), ten percent flood (10-year flood), five percent flood (20-year flood), two percent flood (50-year flood), one percent flood (100-year flood), 0.50 percent flood (200-year flood), and 0.20 percent flood (500-year flood). The without-project water surface profiles were extracted from USACE North Atlantic Coast Comprehensive Study (NACCS) hydrodynamic model output data points through the USACE Coastal Hazards System (<https://chs.erdc.dren.mil/>) at selected ADCIRC nodes or "Save Points" throughout the study area. These ACE event water surface profiles were not used as a direct input in the G2CRM model. Rather, they were used to define floodplains within the study area to formulate alternatives.

The uncertainty is incorporated into the modeling of storm stage probabilities through the range of water levels associated with various confidence levels for each of the defined return periods specified in the previous section on stage-probability relationships. More detail on this can be found in the engineering appendix describing the H5 files used in the G2CRM model. As an example, the range of water levels associated with the 100-year return period ranges from approximately 2 feet for the 16% and 84% confidence levels to almost 4 feet for the 2% and 98% confidence levels.

3.4.3 Save Points

NACCS water level and wave outputs are provided at save points throughout the study area as both annual exceedance probabilities and storm timeseries.

3.4.4 Sea Level Change

For each of these AEP events, the water surface profiles for the years 2040 to 2089 were determined by adding relative sea level rise, as determined by the USACE Sea Level Rise Calculator at Boston, MA, using the USACE High Curve to the Save Point elevations. The mean sea level trend of 4.37 mm/year, or 0.014338 feet/year, with 95% confidence rating +/- 0.57 mm/year, as published for Boston, MA, as of 2023, was used as the sea level change rate using the USACE High Curve. Water level elevations at year 2040 are expected to be between 0.69 and 1.54 feet higher than the current



NTDE. Water elevations at year 2090 are expected to be between 1.41 and 4.97 feet higher than the current NTDE. The use of the intermediate curve was made after assessing historical trends of Sea Level Change and to balance the risk of over- or underestimating future SLC. Performance of the selected plan under alternate SLC scenarios will be conducted following the DP2 milestone and will be detailed in the final feasibility report.

3.4.5 Uncertainty in Ground Elevations

Uncertainty in ground elevations was derived by testing the City of Boston data against Light Detection and Ranging (LiDAR) digital elevation model (DEM) downloaded from the National Elevation Dataset. Considering this, the uncertainty surrounding first-floor elevations was calculated by taking the standard deviation of the foundation height for each occupancy type, then combining the 9-centimeter (~3 inch) uncertainty associated in LiDAR. The final uncertainty value was determined by taking the sum of squares of those combined values.



4 Alternatives Considered

As discussed earlier in this document, Plan Formulation was neighborhood-based because the neighborhoods considered are hydrologically separable. This chapter presents alternatives by neighborhood and explains the reasoning for excluding some of the potential alternatives from further economic analysis. Alternatives and their costs are presented by neighborhood; however, the economic analysis presented in Chapter 5 considers the impact of the intervention on the entire Boston study area as each potential neighborhood intervention should be considered a building block of a comprehensive plan to reduce risk to the city. The costs presented in this chapter are Total Investment Costs which are inclusive of construction, interest during construction, real estate, and for planning, engineering, and design (PED). Costs for Operation, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) will be included in the next iteration of this document and will not affect the project justification of the recommended action or the ordering of the NED alternatives.

Nonstructural interventions such as elevations, floodproofings, and buyouts were removed from general consideration in the final array except in the instance of the Charlestown Community Center which is a relatively simple intervention that provides benefit to a critical infrastructure asset. There were three reasons for their removal from consideration in the overall plan, specifically:

1 - Large scale nonstructural interventions do not meet study objectives for economic and social resilience. Boston's greatest coastal storm risk is nor'easters, which are long duration events. For nonstructural to be effective and meet study objectives, those in the area at risk would be required to evacuate or shelter in place for long periods of time before the storm, as well as recovery time after the storm. The displacement before and after a storm event was considered an additional social cost during the qualitative initial screening of a nonstructural alternative. Employment opportunity lost, business disruption, school disruptions were all considered social costs in addition to economic losses. Therefore, it did not meet the study objectives of economic and social resilience.

2 - Large scale nonstructural interventions were found to be cost prohibitive given the asset pool of the study area. The cost and considerations when adapting multifamily residences, midrise, high rise, as well as historic structures was a primary concern when evaluating nonstructural alternative plans in Boston and the neighborhoods. The cost of these adaptations is much higher than single family structures. When considering the number of

assets in the structure inventory, 20,797 assets, only 2,337 of those are single family residences. Of those 2,337 residences, many are likely also historic in nature, again increasing the cost of adaptation.

3 - Large scale nonstructural interventions increased safety risk compared to managing likelihood of inundation with a structural measure. Nonstructural intervention does not obviate the need for evacuation and nonstructural interventions would still require significant preparation and emergency planning to evacuate 85,000 people for up to 3 or 4 days before, during, and after a storm.

4.1 East Boston Alternatives

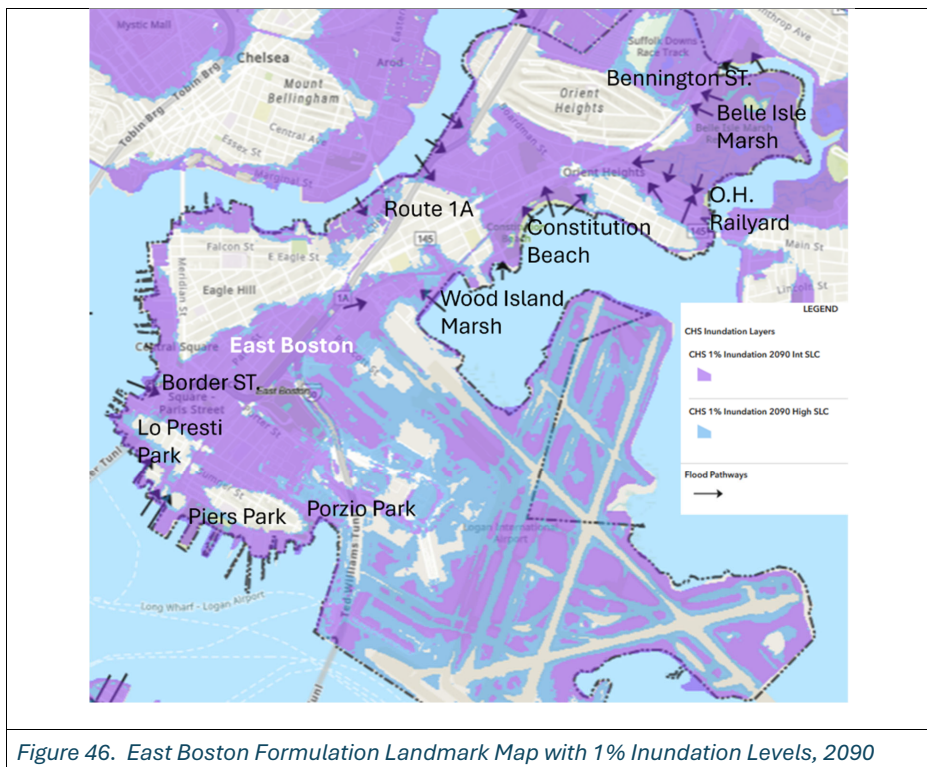


Figure 46. East Boston Formulation Landmark Map with 1% Inundation Levels, 2090

The interventions considered in East Boston are presented below. The shaded alternatives were screened out at this point in the analysis with justification for screening provided in the accompanying italicized text.

EB0	No Action. USACE uses the No Action Alternative (FWOP) as the basis of comparison for all potential interventions.
EB1	Alternative EB1 is a vertical structure at the Orient Heights MBTA Railyard.
EB2	Alternative EB2 includes EB1 and three other components intended to provide coastal storm risk reduction to the Orient Heights neighborhood of East Boston. It includes measures to keep water from entering the MBTA's Blue Line rail portal at Suffolk Downs Station and Orient Heights Railyard. These are: 1) A closure structure at Suffolk Downs MBTA Station; 2) An upland vertical structure behind Constitution Beach with a closure structure across the Blue Line and East Boston Greenway Connector; and 3) An upland vertical barrier along the railroad right of way at the coastal edge of Chelsea Creek.
EB2A	Alternative EB2A includes EB1 and has three other components intended to provide coastal storm risk reduction to the Orient Heights neighborhood of East Boston. It includes measures to keep water from entering the MBTA's Blue Line rail portal at Suffolk Downs Station and Orient Heights Railyard. These are: 1) A closure structure at Suffolk Downs MBTA Station; 2) An upland vertical structure behind Constitution Beach with a closure structure across the Blue Line and East Boston Greenway Connector; and 3) An inland vertical barrier along the Route 1A parallel to the shore of Chelsea Creek. Structures at risk in the area between Route 1A and Chelsea Creek may be appropriate for nonstructural features.
EB2 and EB2A are substitutes and only one would be selected. The difference between EB2 and EB2A is the alignment of the vertical barrier that runs parallel to Chelsea Creek. The barrier in EB1 runs along the coastal edge while the EB1A barrier runs approximately 400 feet inland. These alignments begin to converge north of the Courtyard Marriott Logan Airport and are nearly tangential as they run south toward Addison Street where both features would end. The structures that would be included within the perimeter of EB2 but not the EB2A include airport parking, warehousing/logistics, and a cannabis dispensary. Alternative EB2, the waterside alignment along Chelsea Creek, was found to cost \$70M more for only \$25M in damages prevented so is eliminated from consideration at this point on the basis of cost.	

EB3	Alternative EB3 has five components intended to provide coastal storm risk reduction to the East Boston Waterfront and Atlantic Works areas. This alternative would include the Jeffries Point, Maverick Square, and Central Square neighborhoods. 1) A shallow foundation levee landward of Wood Island Marsh; 2) A closure structure across the Blue Line and East Boston Greenway Connector in the vicinity of Wordsworth Street; 3) A tiered elevated Harborwalk between Porzio Parks and Tomahawk with a tie in at Tomahawk Drive through a grade change in the roadway to reduce inundation risk behind the park and the roadway; 4) An adaptable upland vertical wall along Lewis Street/Carlton Wharf to complement existing features; and 5) An adaptable upland vertical wall from LoPresti Park to Eagle Hill Neighborhood parallel to but west of Border Street. Depending on the height of the intervention, the alternative could prevent water from entering the Wood Island and Airport Blue Line Stations, the Airport Silver Line Station, as well as the entrances to the Sumner, Callahan, and Ted Williams Tunnels.
EB3A	Alternative EB3A has five components intended to provide coastal storm risk reduction to the East Boston Waterfront areas. This alternative would include the Jeffries Point, Maverick Square, and Central Square neighborhoods. 1) A shallow foundation levee landward of Wood Island Marsh; 2) A closure structure across the Blue Line and East Boston Greenway Connector in the vicinity of Wordsworth Street; 3) A tiered elevated Harborwalk between Porzio Parks and Tomahawk with a tie in at Tomahawk Drive through a grade change in the roadway to reduce inundation risk behind the park and the roadway; 4) an adaptable upland vertical wall along Lewis Street/Carlton Wharf to complement existing features; and 5) An adaptable upland vertical wall running from LoPresti Park along New Street tying where it ties-in to high ground then adaptable vertical wall running from Maverick Street along Border Street tying in to meet waterfront north of Atlantic Works, continuing to the Eagle Hill Neighborhood along the waterfront. Depending on the height of the intervention, the alternative could prevent water from entering the Wood Island and Airport Blue Line Stations, the Airport Silver Line Station, as well as the entrances to the Sumner, Callahan, and Ted Williams Tunnels.
EB3 and EB3A are substitutes and only one would be selected. The difference between EB3 and EB3A is element 5) which runs along the water in EB3 but cuts inland toward Maverick Square in EB3A. Alternative EB3, which runs along the western edge of the waterfront, encroaches on designated port areas (working	

<i>waterfront) and costs \$65M more for \$10M benefit and was eliminated from further analysis</i>	
EB4	Non-structural interventions at specific locations in Eagle Hill
<i>EB 4 was removed from further analysis.</i>	
<i>Figure 47. Alternative Matrix for East Boston</i>	

East Boston alternatives considered in the economic analysis are:

Alternative	Alignment	Total Investment Cost (\$FY26)
EB1	Rail Yard	\$258,915,000
EB2A	Constitution Beach + Rail Yard + Middle of Route 1A	\$575,903,000
EB3A	Waterfront West Alt + Marginal Street + Summer Street to Airport + Wood Island	\$798,027,000
EB1 + EB3A	Rail Yard, Waterfront West Alt + Marginal Street + Summer Street to Airport + Wood Island	\$1,085,126,000
EB2A + EB3A	Constitution Beach + Rail Yard + Middle of Route 1A, Waterfront West Alt + Marginal Street + Summer Street to Airport + Wood Island	\$1,426,001,000

Figure 48. East Boston Alternatives with Total Investment Cost of Alternative

4.2 Charlestown Alternatives

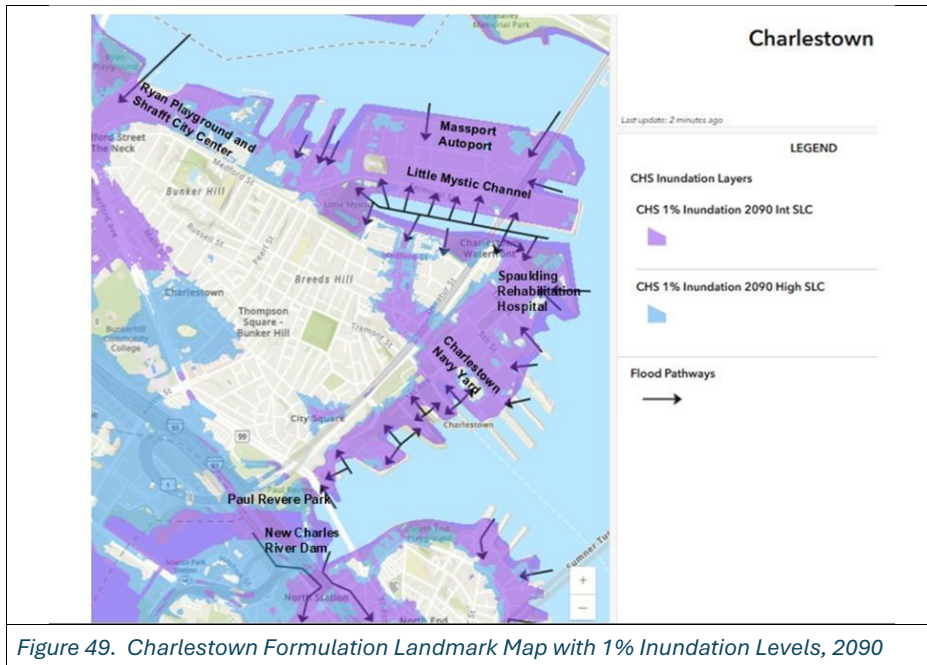


Figure 49. Charlestown Formulation Landmark Map with 1% Inundation Levels, 2090

The interventions considered in Charlestown are presented below. The shaded alternatives were screened out at this point in the analysis with justification for screening provided in the accompanying italicized text.

CH0	No Action. USACE uses the No Action Alternative (FWOP) as the basis of comparison for all potential interventions.
CH1	Alternative CH1 consists of a mixture of shallow foundation berms and upland vertical elements starting in Ryan Playground, north of the Schrafft Center, and tying into the existing Harborwalk alignment. The easternmost element ties into the street grid at Medford Street to the south and east of the Schrafft Center.
CH2	Alternative CH2 has three components. These are: 1) An upland vertical solution between the ball field northwest of the condominium complex tying into an outboard perimeter solution along the south shoreline of the Little Mystic Channel to Barry

	Playground. At Barry Playground it transitions to upland vertical wall that ties into high ground at Chelsea Street; 2) A floodwall with closure structure at Chelsea and Vine Streets; and, 3) NS floodproofing of the Charlestown Community Center.
CH2A	Alternative CH2A has four components. These are 1) an upland vertical solution between the ball field northwest of the condominium complex tying into an outboard perimeter solution along the south shoreline of the Little Mystic Channel to Barry Playground. At Barry Playground it transitions to upland vertical wall that ties into high ground at Chelsea Street; 2) a flood wall with closure structure at Chelsea and Vine Streets; 3) NS floodproofing of the Charlestown Community Center; and, 4) NS intervention at the Boston Autoport. CH2A is an extension of CH2 and only one would be selected. The difference between CH2 and CH2A is element 3) the NS intervention at the Boston Autoport. Alternative CH2A, which included nonstructural interventions at the Boston Autoport was removed from analysis as a result of the current USACE pause on nonstructural interventions. It is anticipated that the alternative will be able to keep the nonstructural measure at the Charlestown Community Center given that it is a very minor intervention that will reduce risk to a critical neighborhood facility.
CH3	CH3 is an outboard perimeter along the Little Mystic Channel east and south to encompass Massachusetts General Hospital/Spaulding Hospital and the Charlestown Navy Yard. The perimeter is approximately 35% upland and 65% outboard/waterside. This alternative includes NS floodproofing of the Charlestown Community Center. It does not include a floodwall and closure structure at Chelsea and Vine Streets.
CH3A	CH3A extends the outboard perimeter from CH2A along the Little Mystic Channel east and south to encompass Massachusetts General Hospital/Spaulding Hospital and the Charlestown Navy Yard and adds NS intervention in the Boston Autoport. The perimeter is approximately 35% upland and 65% outboard/waterside. This alternative includes NS floodproofing of the Charlestown Community Center. It does not include a floodwall and closure structure at Chelsea and Vine Streets. CH3A is an extension of CH3 and only one would be selected. The difference between CH3 and CH3A is the addition of the NS intervention at the Boston Autoport. Alternative CH3A, which included nonstructural interventions at the Boston Autoport was removed from analysis as a result of the current USACE pause on nonstructural interventions. It is anticipated that the alternative will be able to keep the nonstructural measure at the Charlestown Community Center given that it is a very minor intervention that will reduce risk to a critical neighborhood facility.
<i>Figure 50. Alternative Matrix for East Boston</i>	

Charlestown alternatives considered in the economic analysis are:



Alternative	Alignment	Total Investment Cost (\$FY26)
CH1	Schrafft + Ryan Playground + Community Center	\$230,546,000
CH2	Little Mystic + Chelsea Street + Community Center	\$368,739,000
CH3	Little Mystic + Navy Yard + Community Center	\$1,299,226,000
CH1 + CH2	Schrafft + Ryan Playground, Little Mystic + Chelsea Street + Community Center	\$650,275,000
CH1 + CH3	Schrafft + Ryan Playground, Little Mystic + Navy Yard + Community Center	\$1,547,742,000

Figure 51. Charlestown Alternatives with Total Investment Cost of Alternative

4.3 Downtown/North End Alternatives

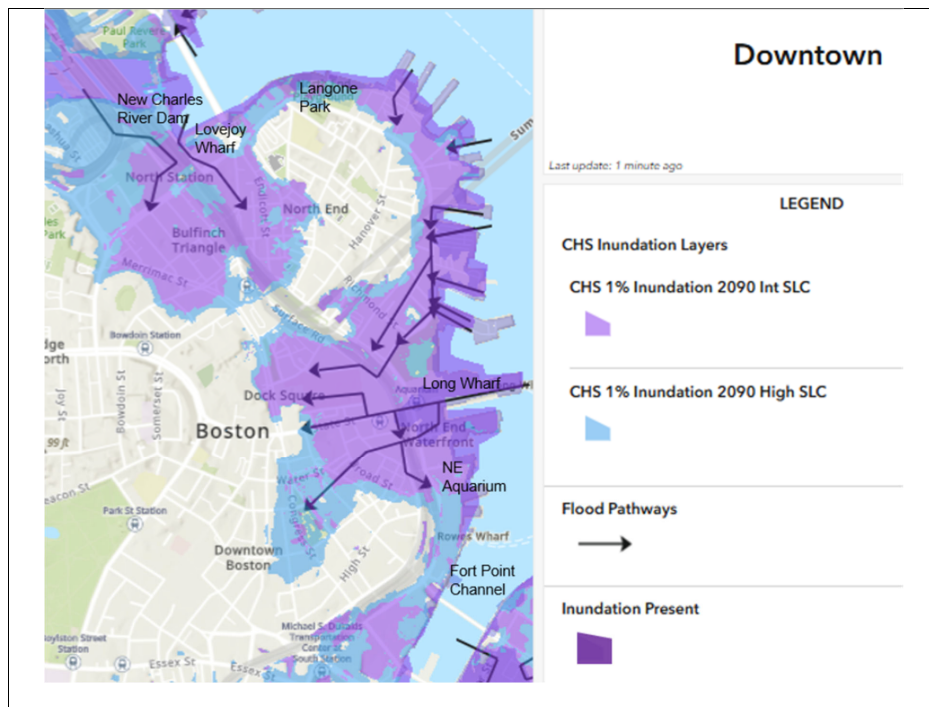


Figure 52. Downtown/North End Formulation Landmark Map with 1% Inundation Levels in 2090

The interventions considered in Downtown (DT) are presented below. The shaded alternatives were screened out at this point in the analysis with justification for screening provided in the accompanying italicized text.

DT0	No Action. USACE uses the No Action Alternative (FWOP) as the basis of comparison for all potential interventions.
DT1	Alternative DT1 has 3 components, which include: 1) A shallow foundation berm at Charlestown's Paul Revere Park which crosses the park and ties into the New Charles River Dam on its north side; 2) On the south side of the dam, an outboard wall around Lovejoy Place which becomes a floodwall tied in at North Washington Street Bridge; and 3) An upland vertical element along Commercial Street transitioning to a speed table at the intersection of Commercial Street and Hull Street.
DT2	Alternative DT2 is an interior wall alignment following Atlantic Avenue that would reduce coastal storm risk to properties to the south of Fleet Street and the west of the Atlantic Avenue. [This alternative reduces risk to the to the Sumner and Callahan Tunnels between downtown and Logan Airport as well as the tunnel beneath the Rose Kennedy Greenway (I-93/Central Artery) and the Blue Line Station at Aquarium as it would keep water out of tunnel entrances.]
DT3	Alternative DT3 is an in-water perimeter wall beginning at Commercial Street and Battery Wharf and continuing along the water/land interface to the Fort Point Channel. [This alternative reduces risk to the to the Sumner and Callahan Tunnels between downtown and Logan Airport as well as the tunnel beneath the Rose Kennedy Greenway (I-93/Central Artery) and the Blue Line Station at Aquarium as it would keep water out of tunnel entrances.]
DT2 and DT3 are substitutes and only one would be selected. The difference between them is that DT2 is an interior alignment that leaves waterfront properties as residual risk while DT3 is a perimeter solution at the water/land interface that would reduce risk to waterfront properties but require extensive real estate and permitting consideration. <i>DT2 was removed from consideration as it would require extensive coordination over time to deploy stopgap walls for storm events. This added labor, which would increase as storms become more frequent, would leave too much risk for the local community.</i>	

DT3A	Alternative DT3A is a hybrid alternative has a waterside perimeter ending at Sargent's Wharf at the north, continuing upland west to across Commercial Street, tying into high ground at Fleet Street.
DT3A is an improvement to Alternative D3. DT3 and DT3A are substitutes and only one would be selected.	
<i>Figure 53. Alternative Matrix for Downtown</i>	

Downtown/North End alternatives considered in the economic analysis are:

Alternative	Alignments	Total Investment Cost (\$FY26)
DT1	Lovejoy Wharf + Paul Revere Park + Commercial Street	\$142,462,000
DT3	Waterside	\$2,718,926,000
DT3A	Hybrid, Waterside north to Fleet St	\$2,034,781,000
DT1 + DT3	Lovejoy Wharf + Paul Revere Park + Commercial Street, Waterside	\$2,875,401,000
DT1 + DT3A	Lovejoy Wharf + Paul Revere Park + Commercial Street, Hybrid, waterside north to Fleet St	\$2,191,261,000
<i>Figure 54. Downtown/North End Alternatives with Total Investment Cost of Alternative</i>		

4.3 South Boston Alternatives

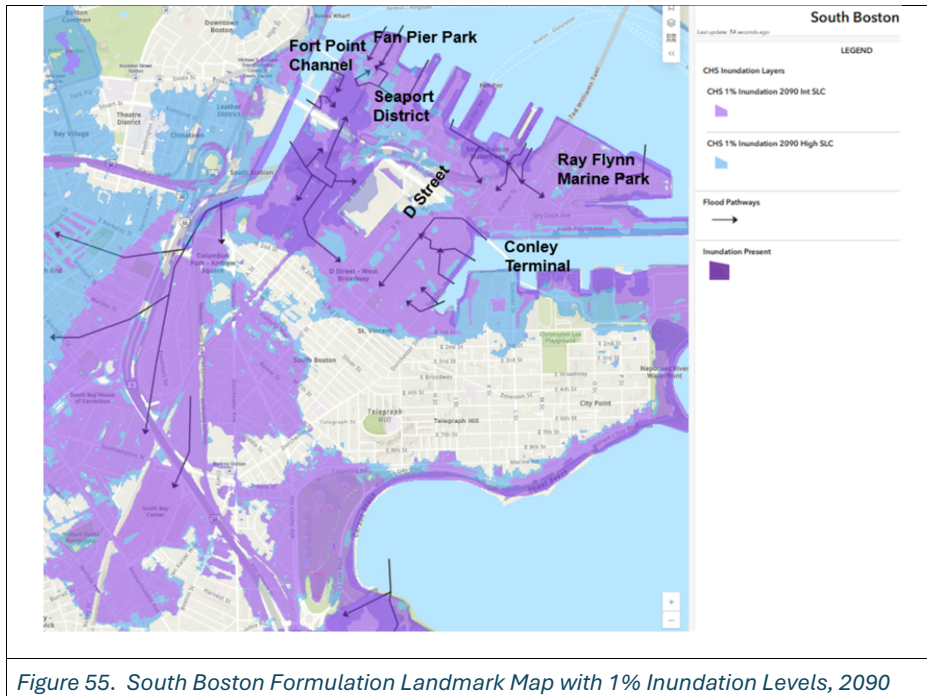


Figure 55. South Boston Formulation Landmark Map with 1% Inundation Levels, 2090

The interventions considered in South Boston are presented below.

SB0	No Action. USACE uses the No Action Alternative (FWOP) as the basis of comparison for all potential interventions.
SB1	Alternative SB1 adds a one-foot addition to existing walls and includes a closure structure from police on-ramp to keep water out of I-90.
SB2	Alternative SB2 builds upon Alternative SB1. Alternative SB2 includes a storm surge barrier at the Fort Point Channel and a perimeter solution from Fan Pier around the Institute for Contemporary Art, cutting back behind Commonwealth Pier and the Boston Fish Pier to D Street. A floodwall will extend up D Street along the existing park to the intersection of D Street and Congress Street. A road grade change speed table-like feature will be constructed at the intersection of D Street and Congress Street to elevation 14' NAVD88 to close the flood pathways in both directions. The alignment resumes as an upland vertical perimeter wall at Summer Street to the

	water's edge along Pappas Way. Depending on the operating regime of the storm surge barrier and height of walls, this alternative may provide coastal storm damage reduction to the Red Line of the MBTA at South Station and Broadway Station, as well as the Silver Line of the MBTA at Tufts Medical Center, Chinatown Station, South Station, Courthouse Way Station, and World Trade Center Station. The operating protocol of the surge barrier may also make it so that interior improvements along the Fort Point Channel may ultimately be incorporated to manage risk during more frequent events.
SB3	Alternative SB3 includes SB1 and SB2 up to D Street. At D Street, it continues upland vertical around the perimeter of RFMP around the terminal to Drydock #3, transitioning to in-water in front of Drydock #3 before transitioning back to upland vertical along Black Falcon Avenue to Pappas Way.
SB2 and SB3 are substitutes and only one would be selected. The difference between them is that SB3 includes the Ray Flynn Industrial Marine Park in South Boston while SB1 does not.	
<i>Figure 56. Alternative Matrix for South Boston</i>	

South Boston alternatives considered in the economic analysis are:

Alternative	Alignments	Total Investment Cost (\$FY26)
SB1	Parapet Wall at Ted Williams Tunnel	\$10,354,000
SB2	Surge Barrier + Fan Pier Park to Seaport Blvd + Seaport Blvd (west of Alt) + D Street + Haul Street + Summer Street to Pappas + Pappas Way	\$2,864,546,000
SB3	Surge Barrier + Fan Pier Park to Seaport Blvd + Seaport Blvd (west of Alt) + Seaport Blvd (east of Alt thru Marine Terminal) + Dry Dock + Pappas Way	\$3,984,936,000

Figure 57. South Boston Alternatives with Total Investment Cost of Alternative

4.5 Dorchester Alternatives

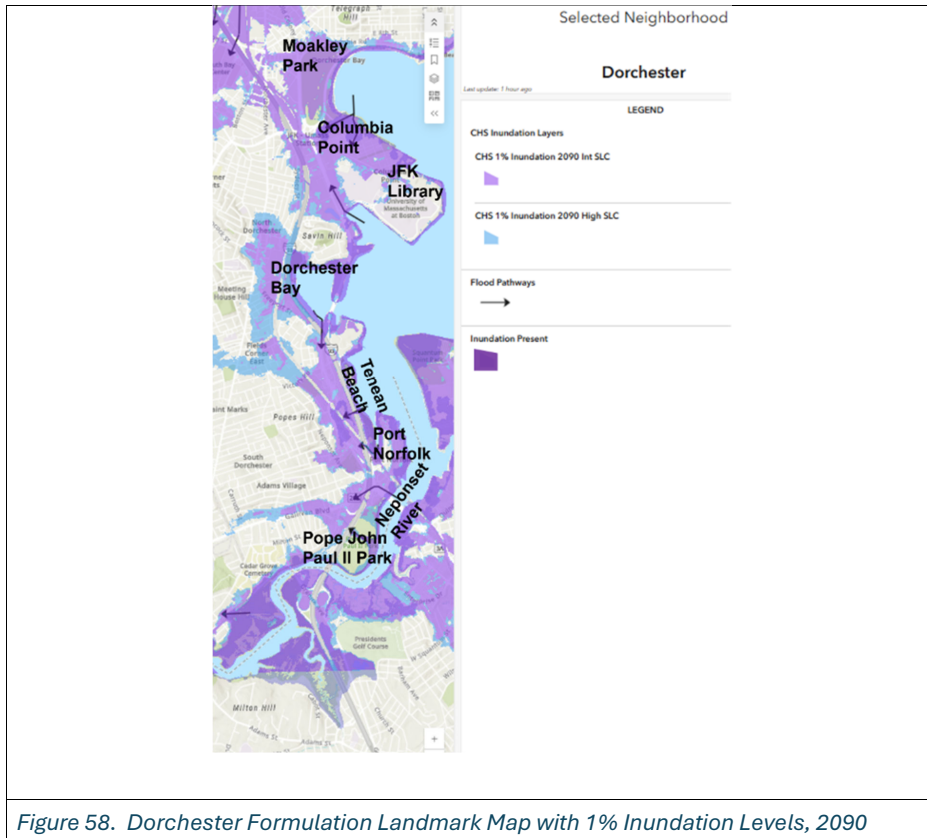


Figure 58. Dorchester Formulation Landmark Map with 1% Inundation Levels, 2090

The interventions considered in Dorchester are presented below. The shaded alternatives were screened out at this point in the analysis with justification for screening provided in the accompanying italicized text.

DOR0	No Action. USACE uses the No Action Alternative (FWOP) as the basis of comparison for all potential interventions.
DOR1	DOR 1 is an upland vertical wall behind Day Boulevard transitioning to a shallow foundation levee feature through the contours of Moakley Park tying into the existing stadium. (Moakley Park and Northern Connector).
DOR2	Alternative DOR2 consists of DOR1 and

	1) A vertical wall tie-in at Moakley Park which transitions to an armored levee with Harborwalk along the Harbor Point community, ending at Calf Pasture I next to UMass Boston's University Lot D; and 2) A road grade change at the intersection of Morrissey Boulevard and Bianculli Boulevard and levee around Pattens Cove to the base of Savin Hill. These interventions are intended to provide coastal storm risk reduction to the Columbia Point section of the Dorchester neighborhood.
DOR3	DOR 3 consists of a road grade change on Conley Street at Tenean Beach tying into a shallow foundation levee feature tying into north side of the Conley Street underpass. On the West side of the MBTA salvage yard underpass of I-93, an upland vertical wall will fill the low ground between highpoints.
DOR4	Alternative DOR4 consists of DOR3, and: 1) upland vertical walls at the south side of the Beades Bridge on Morrissey Boulevard abeam the I-93 underpass; 2) a grade change or berm at the Victory Road offramp along I-93; These interventions are intended to provide coastal storm risk reduction to the Fields Corner sections of Dorchester neighborhood.
DOR5	Nonstructural intervention at Port Norfolk.
<i>Alternative DOR5 was removed from analysis.</i>	
DOR6	Alternative DOR6 is a shallow foundation levee and in-water wall along the Neponset River from the MBTA Red Line's bridge to Pope John Paul II Park. This intervention is intended to provide coastal storm risk reduction to the Neponset Circle and Adams Village sections of Dorchester.
<i>Figure 59. Alternative Matrix for Dorchester</i>	

Dorchester alternatives considered in the economic analysis are

Alternative	Alignments	Total Investment Cost (\$FY26)
DOR1	Moakley Park	\$129,102,000
DOR2	Moakley Park + Harbor Point + Pattens Cove	\$369,039,000
DOR3	Tenean Beach	\$41,422,000
DOR4	Tenean Beach + Victory Road + Morrissey Blvd	\$143,383,000
DOR6	Neponset River	\$112,703,000
DOR1 + DOR3	Moakley Park + Tenean Beach	\$172,331,000

DOR2 + DOR4 + DOR6	Moakley Park + Harbor Point + Pattens Cove, Tenean Beach + Victory Road + Morrissey Blvd, Neponset River	\$686,637,000
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Figure 60. *Dorchester Alternatives with Total Investment Cost of Alternative*

5 Economic Analysis Results

5.1 Results of NED Analysis

Results of the NED benefits analysis are presented below by individual alternative. They are arranged from highest to lowest by net average annualized (AA) NED benefits. USACE economic analysis requires comparison using annualized benefits and cost to account for timing of costs and benefits over the project life. Benefit to Cost Ratios (BCRs) are presented in the last column.

Alternative	Annual NED Benefits (\$FY26)	Annual NED Cost (\$FY26)	Net Annual NED Benefits (\$FY26)	BCR
EB2A + EB3A	\$946,510,000	\$58,081,000	\$888,429,000	16.3
EB1 + EB3A	\$919,010,000	\$44,197,000	\$874,813,000	20.8
EB3A	\$883,940,000	\$32,504,000	\$851,436,000	27.2
DT3A	\$379,640,000	\$82,877,000	\$296,763,000	4.6
DT1 + DT3A	\$384,570,000	\$89,251,000	\$295,319,000	4.3
DT3	\$389,940,000	\$110,743,000	\$279,197,000	3.5
DT1 + DT3	\$394,870,000	\$117,116,000	\$277,754,000	3.4
SB3	\$235,350,000	\$162,308,000	\$73,042,000	1.5
SB2	\$187,710,000	\$116,674,000	\$71,036,000	1.6
DOR2 + DOR4 + DOR6	\$82,130,000	\$27,967,000	\$54,163,000	2.9
DOR2	\$59,210,000	\$15,031,000	\$44,179,000	3.9
EB2A	\$62,570,000	\$23,457,000	\$39,113,000	2.7
EB1	\$35,070,000	\$10,546,000	\$24,524,000	3.3
CH1	\$32,190,000	\$9,390,000	\$22,800,000	3.4
DOR4	\$17,050,000	\$5,840,000	\$11,210,000	2.9
DOR3	\$12,600,000	\$1,687,000	\$10,913,000	7.5
SB1	\$10,510,000	\$422,000	\$10,088,000	24.9
DOR1 + DOR3	\$16,470,000	\$7,019,000	\$9,451,000	2.3
CH1 + CH2	\$32,800,000	\$26,486,000	\$6,314,000	1.2
DOR6	\$5,870,000	\$4,590,000	\$1,280,000	1.3
DT1	\$4,930,000	\$5,803,000	-\$873,000	0.8
DOR1	\$3,870,000	\$5,258,000	-\$1,388,000	0.7
CH2	\$610,000	\$15,019,000	-\$14,409,000	0.0
CH1 + CH3	\$44,630,000	\$63,040,000	-\$18,410,000	0.7
CH3	\$12,440,000	\$52,918,000	-\$40,478,000	0.2

Figure 61. Results Arrayed by Net NED Benefits

The order of alternatives arranged by net NED benefits will not necessarily correspond to BCR as the magnitude of damages prevented varies by alternative. For example, Alternative SB1 provides relatively low net NED benefits, but it has a high BCR because damages to the Ted Williams Tunnel may be prevented for a relatively low cost.

5.2 Life Loss Analysis

NED benefits are only one part of the analysis. Another important element of the analysis is the effect of each alternative on preventing life loss.

Alternative	Life Loss	Life Loss Benefits	Life Loss Reduction Contributed by Alternative(%)
FWOP	125.54	0	0.0%
EB2A + EB3A	55.68	69.87	55.7%
EB3A	75.04	50.51	40.2%
EB1 + EB3A	75.04	50.51	40.2%
DOR2 + DOR4 + DOR6	104.96	20.58	16.4%
EB2A	105.92	19.62	15.6%
DOR2	115.17	10.37	8.3%
SB2	116.09	9.46	7.5%
SB3	116.09	9.46	7.5%
DOR1 + DOR3	118.42	7.12	5.7%
DOR4	119.76	5.79	4.6%
CH1 + CH3	120.39	5.15	4.1%
DOR6	121.12	4.42	3.5%

DOR3	121.31	4.23	3.4%
CH3	122.15	3.39	2.7%
DOR1	122.65	2.89	2.3%
CH1 + CH2	123.61	1.93	1.5%
CH1	123.78	1.76	1.4%
DT1 + DT3	124.19	1.35	1.1%
DT1 + DT3A	124.20	1.35	1.1%
DT1	124.65	0.89	0.7%
DT3	125.09	0.46	0.4%
DT3A	125.09	0.45	0.4%
EB1	125.28	0.26	0.2%
CH2	125.37	0.17	0.1%
SB1	125.54	-	0.0%

Figure 62. Alternatives Arranged by Contribution to Prevention of Loss of Life

While Alternative SB1 has the highest BCR, it is not anticipated to prevent any life loss. The middle column presents the estimated life loss over the period of analysis. SB1, which is not anticipated to prevent any life loss, has a value of 125.54 - the estimated number of lives lost (assume somewhere between 125 and 126 as a coastal storm will not kill a fraction of a person) without the implementation of a remedy in the study area that would prevent loss of life, *i.e.*, the FWOP. Residual risk (RR) is the risk that remains in the study area after the proposed coastal storm risk management project is implemented. Residual risk includes the consequence of capacity exceedance as well as consideration of the project flood risk reduction. The residual risk is the remaining risk that cannot be mitigated given the hydrological, environmental, and economic constraints. The residual risk is assessed here, as required by ER 1105-2-101 Risk Assessment for Flood Risk Management Studies, using remaining expected life loss.

The middle column of values is the residual life loss risk that remains once a particular alternative or combination of alternatives is implemented.

5.3 Residual Risk by Alternative

For each metric, the residual risk of the future with project condition can be calculated by subtracting the impact of the plan from the risk in the future without project condition. Residual risk to the asset inventory is presented below.

Alternative	Remaining Damages (PV, \$FY26)	Benefits (PV, \$FY26)	Residual Risk
EB2A + EB3A	\$31,589,380,395	\$23,238,488,238	57.6%
EB1 + EB3A	\$32,264,633,984	\$22,563,234,649	58.8%
EB3A	\$33,125,579,509	\$21,702,289,123	60.4%
DT1 + DT3	\$45,133,079,724	\$9,694,788,909	82.3%
DT3	\$45,254,113,684	\$9,573,754,949	82.5%
DT1 + DT3A	\$45,386,114,900	\$9,441,753,733	82.8%
DT3A	\$45,507,148,859	\$9,320,719,774	83.0%
SB3	\$49,049,579,157	\$5,778,289,476	89.5%
SB2	\$50,219,229,656	\$4,608,638,977	91.6%
DOR2 + DOR4 + DOR6	\$52,811,497,399	\$2,016,371,234	96.3%
EB2A	\$53,291,669,519	\$1,536,199,114	97.2%
DOR2	\$53,374,139,500	\$1,453,729,133	97.3%
CH1 + CH3	\$53,732,143,462	\$1,095,725,171	98.0%
EB1	\$53,966,923,108	\$860,945,525	98.4%
CH1 + CH2	\$54,022,656,989	\$805,211,644	98.5%
CH1	\$54,037,561,887	\$790,306,746	98.6%
DOR4	\$54,409,377,837	\$418,490,796	99.2%
DOR1 + DOR3	\$54,423,514,284	\$404,354,349	99.3%
DOR3	\$54,518,461,048	\$309,407,585	99.4%
CH3	\$54,522,450,208	\$305,418,425	99.4%
SB1	\$54,569,894,181	\$257,974,452	99.5%
DOR6	\$54,683,717,329	\$144,151,304	99.7%
DT1	\$54,706,834,673	\$121,033,960	99.8%
DOR1	\$54,732,921,869	\$94,946,764	99.8%
CH2	\$54,812,963,735	\$14,904,898	100.0%

Figure 63. Alternatives Arrayed from Lowest to Highest Residual Risk

Residual risk is an important communication tool to manage expectations. The table above shows the estimated damages that remain in the modeled floodplain over all five neighborhoods when the proposed alternative is in place. The No Action Alternative has no risk reduction.

5.4 Risk Reduction by Neighborhood

As the Boston CSRM study focused on hydrologically separable, neighborhood specific remedies, each neighborhood specific series of alternatives and their effects could also be viewed by individual neighborhood. The section below presents the results of the economic modeling by neighborhood to show the effect of the intervention on that neighborhood. The result is particularly striking when considering residual risk, which in this case is the residual risk to the neighborhood after the proposed intervention is in place.

5.4.1 East Boston

	Damages Prevented (FY26\$)	Remaining Damages	Life Loss Prevented	Remaining Life Loss
EB1	\$860,945,525	97%	0.26	100%
EB2A	\$1,536,199,114	95%	19.62	75%
EB3A	\$22,563,234,649	23%	50.51	35%
EB1 + EB3A	\$22,563,234,649	23%	50.51	35%
EB2A + EB3A	\$23,238,488,238	21%	69.87	11%

Figure 64. East Boston Alternatives with Localized Damages Prevented and Residual Risk



Figure 65. Focused Array of Alternatives in East Boston

5.4.2 Charlestown

	Damages Prevented (\$FY26)	Remaining Damages	Life Loss Prevented	Remaining Life Loss
CH1	\$790,306,746	54%	1.76	69%
CH2	\$14,904,898	99%	-	100%
CH3	\$305,418,425	82%	3.22	43%
CH1 + CH2	\$805,211,644	53%	1.76	69%
CH1 + CH3	\$1,095,725,171	37%	4.98	12%

Figure 66. Charlestown Alternatives with Localized Damages Prevented and Residual Risk

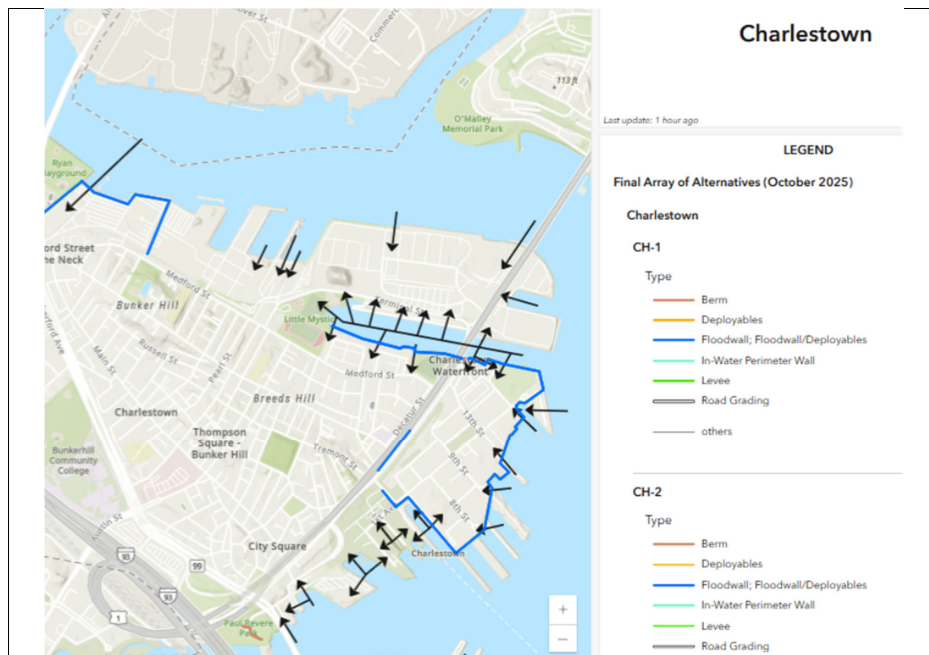


Figure 67. Focused Array of Alternatives in Charlestown

5.4.3 Downtown/North End

	Damages Prevented (\$FY26)	Remaining Damages	Life Loss Prevented	Remaining Life Loss
DT1	\$121,033,960	99%	0.89	63%
DT3	\$9,573,754,949	20%	0.46	81%
DT3A	\$9,320,719,774	22%	0.45	81%
DT1 + DT3	\$9,694,788,909	19%	1.35	45%

DT1 + DT3A	\$9,441,753,733	21%	1.35	45%
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Figure 68. Downtown/North End Alternatives with Localized Damages Prevented and Residual Risk

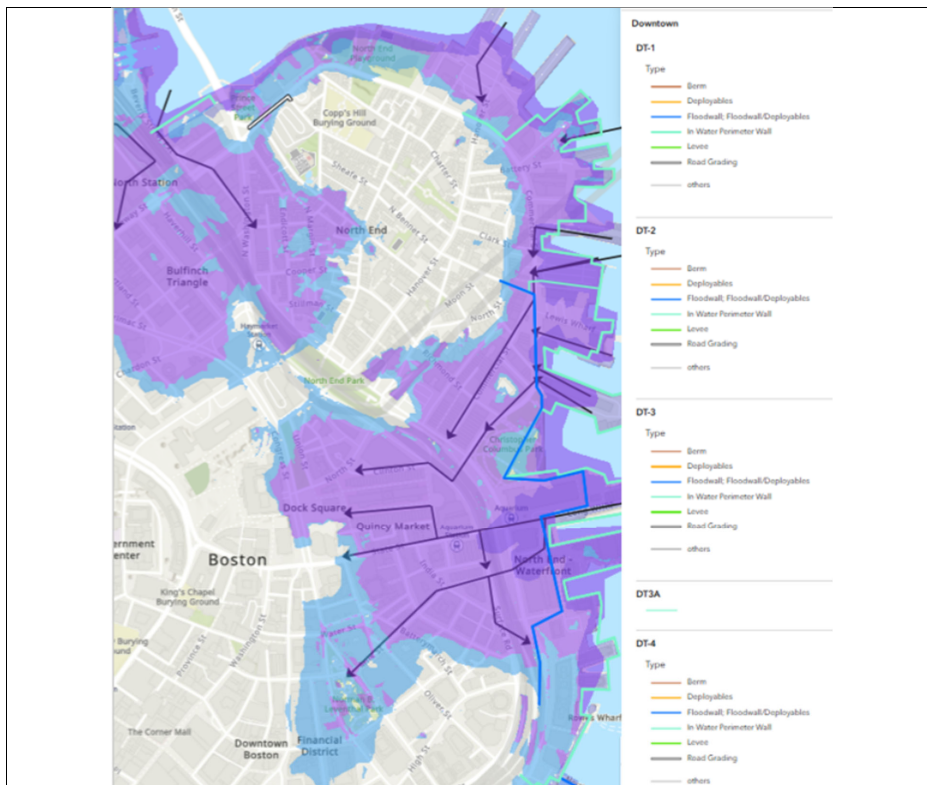


Figure 69. Focused Array of Alternatives in Downtown/North End

5.4.4 South Boston

	Damages Prevented (\$FY26)	Remaining Damages	Life Loss Prevented	Remaining Life Loss
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SB1	\$257,974,452	97%	-	100%
SB2	\$4,608,638,977	50%	9.46	45%
SB3	\$5,778,289,476	37%	9.46	45%

Figure 70. South Boston Alternatives with Localized Damages Prevented and Residual Risk

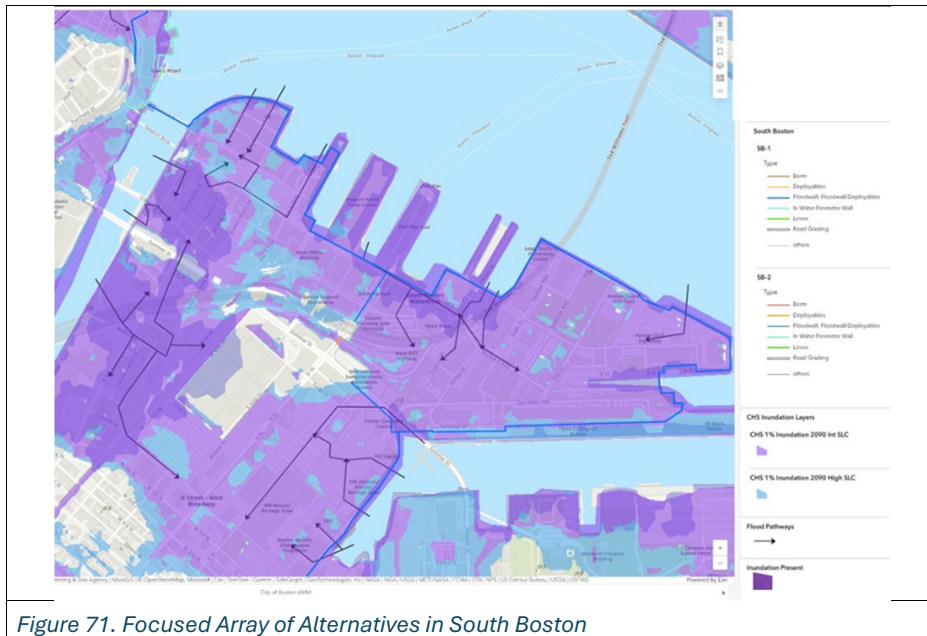


Figure 71. Focused Array of Alternatives in South Boston

5.4.5 Dorchester

	Damages Prevented (\$FY26)	Remaining Damages	Life Loss Prevented	Remaining Life Loss
DOR1	\$94,946,764	96%	2.89	87%
DOR2	\$1,453,729,133	45%	10.37	53%

DOR3	\$309,407,585	88%	4.23	81%
DOR4	\$418,490,796	84%	5.79	74%
DOR6	\$144,151,304	95%	4.42	80%
DOR1 + DOR3	\$404,354,349	85%	7.12	68%
DOR2 + DOR4 + DOR6	\$2,016,371,234	24%	20.58	6%

Figure 72. Dorchester Alternatives with Localized Damages Prevented and Residual Risk

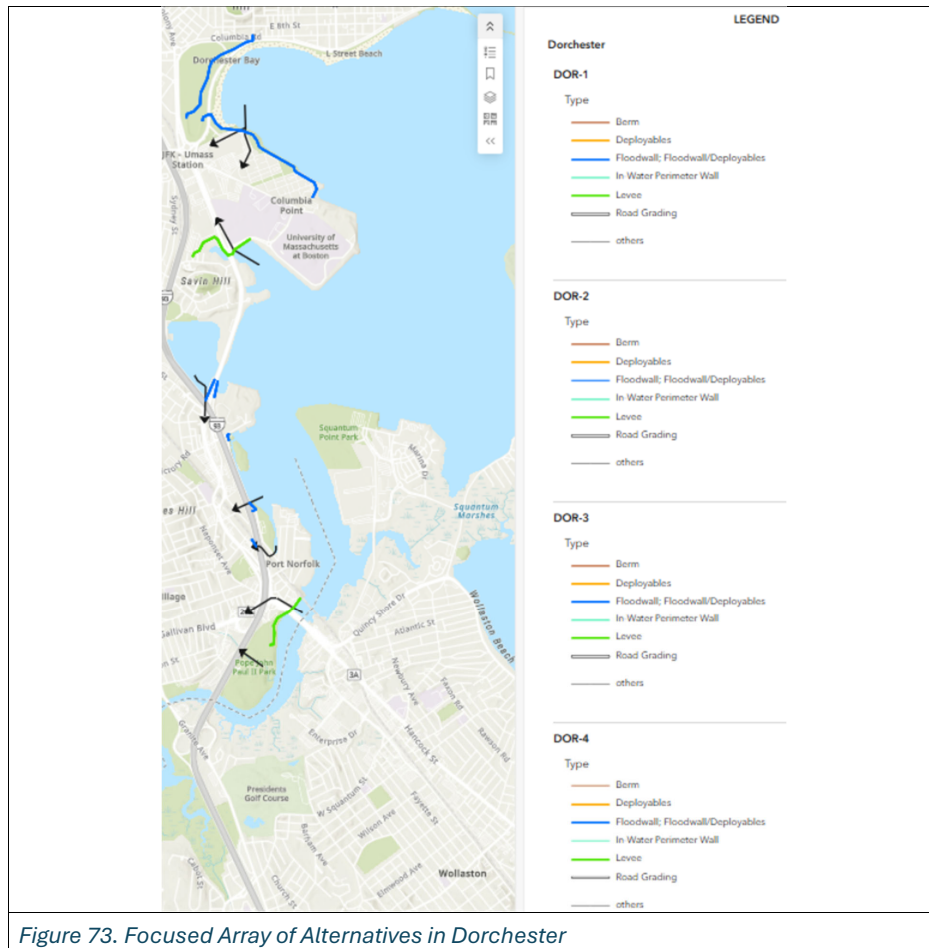


Figure 73. Focused Array of Alternatives in Dorchester

6 System Plan and Early Action Alternative

As presented in Chapter 4, alternatives were first developed within each neighborhood. These alternatives were then evaluated within the larger comprehensive system. All actions were evaluated against the No Action Alternative which forms the basis for all

USACE planning analysis and is referred to as **Action Plan 1** in other sections of this report.

6.1 Comprehensive System Recommendation

The Comprehensive System Plan, referred to as **Action Plan 2** in other sections of this report, is a total net public benefits plan that manages coastal storm risk across the five neighborhoods and 47-mile coastline. This alternative evaluates benefits across the 47-miles of Boston Harbor coastline to the cost of implementing a project. Within Action 2 there are multiple geographically separate alternative plans for each neighborhood made up of measures intended to manage the risk.

By neighborhood, these are:

East Boston, Plan EB2A + EB3A, which is comprised of

- Vertical Structure at Orient Heights Rail Yard
- A closure structure at Suffolk Downs MBTA Station;
- An upland vertical structure behind Constitution Beach with a closure structure across the Blue Line and East Boston Greenway Connector; and
- An inland vertical barrier along the Route 1A parallel to the shore of Chelsea Creek.
- A shallow foundation levee landward of Wood Island Marsh;
- A closure structure across the Blue Line and East Boston Greenway Connector in the vicinity of Wordsworth Street;
- A tiered elevated Harborwalk between Porzio Parks and Tomahawk with a tie in at Tomahawk Drive through a grade change in the roadway to reduce inundation risk behind the park and the roadway;
- an adaptable upland vertical wall along Lewis Street/Carlton Wharf to complement existing features; and
- An adaptable upland vertical wall running from LoPresti Park along New Street tying where it ties-in to high ground then adaptable vertical wall running from Maverick Street along Border Street tying in to meet waterfront north of Atlantic Works, continuing to the Eagle Hill Neighborhood along the waterfront.

The combination of Alternatives EB2A and EB3A provided the highest net NED benefits, the highest reduction in asset damages, and the largest reduction in residual risk of all plans considered.

Charlestown, Alternatives CH1 + CH3, which are comprised of

- A mixture of shallow foundation berms and upland vertical elements starting in Ryan Playground, north of the Schraftt Center, and tying into the existing Harborwalk alignment. The easternmost element ties into the street grid at Medford Street to the south and east of the Schraftt Center.
- Extension the outboard perimeter from CH2 along the Little Mystic Channel east and south to encompass Massachusetts General Hospital/Spaulding Hospital and the Charlestown Navy Yard. The perimeter is approximately 35% upland and 65% outboard/waterside.
- NS floodproofing of the Charlestown Community Center.

Alternative CH1 which is focused on Ryan Playground is the only separable element of in Charlestown that is marginally justified. CH3, which includes the Navy Yard and BCYF Charlestown Community Center were included in the recommendation because of their contributions to community resilience and historic preservation, respectively. The BCYF Charlestown Community Center serves as an evacuation facility for Charlestown neighborhood in hazardous situations. A relatively simple modification of one side of this building would make it floodproof and useable during and after a storm. As discussed in Chapter 1, the Navy Yard is not only a historic property with a National Park, the *U.S.S. Constitution*, and a legacy of the Revolutionary War, but also a major, internationally renowned rehabilitation hospital. Hospital entry and evacuation is accomplished through the Navy Yard. Furthermore, approximately 3,000 Charlestown residents, almost 20% of the neighborhood population, reside in the Navy Yard.

Downtown, Alternatives DT1 and DT3 or 3A, which are comprised of

- A shallow foundation berm at Charlestown's Paul Revere Park which crosses the park and ties into the New Charles River Dam on its north side;
- On the south side of the dam, this alternative also includes an outboard wall around Lovejoy Place which becomes a floodwall tied in at North Washington Street Bridge;
- An upland vertical element along Commercial Street transitioning to a speed table at the intersection of Commercial Street and Hull Street;

And either,

- An in-water perimeter wall beginning at Commercial Street and Battery Wharf and continuing along the water/land interface to the Fort Point Channel;



Or

- A waterside perimeter ending at Sargent's Wharf at the north, continuing upland west to across Commercial Street, tying into high ground at Fleet Street.

Both Alternatives are highly ranked for net NED benefits and risk reduction. The optimization process for the alternative will determine whether which alignment, 3 or 3A, is more appropriate for the site.

South Boston, Alternative SB1 and SB2 or SB3, which are comprised of

- A one-foot addition to existing walls and include a closure structure from police onramp to keep water out of I-90;
- A storm surge barrier at the Fort Point Channel;

And either

- A perimeter solution from Fan Pier around the Institute for Contemporary Art, cutting back behind Commonwealth Pier and the Boston Fish Pier and a road grade change speed table-like feature at the intersection of D Street and Congress Street at elevation 14' NAVD88,

or

- A continuation of the perimeter wall around Ray Flynn Marine Park to Drydock #3, transitioning to in-water in front of Drydock #3 before transitioning back to upland vertical along Black Falcon Avenue to Pappas Way.

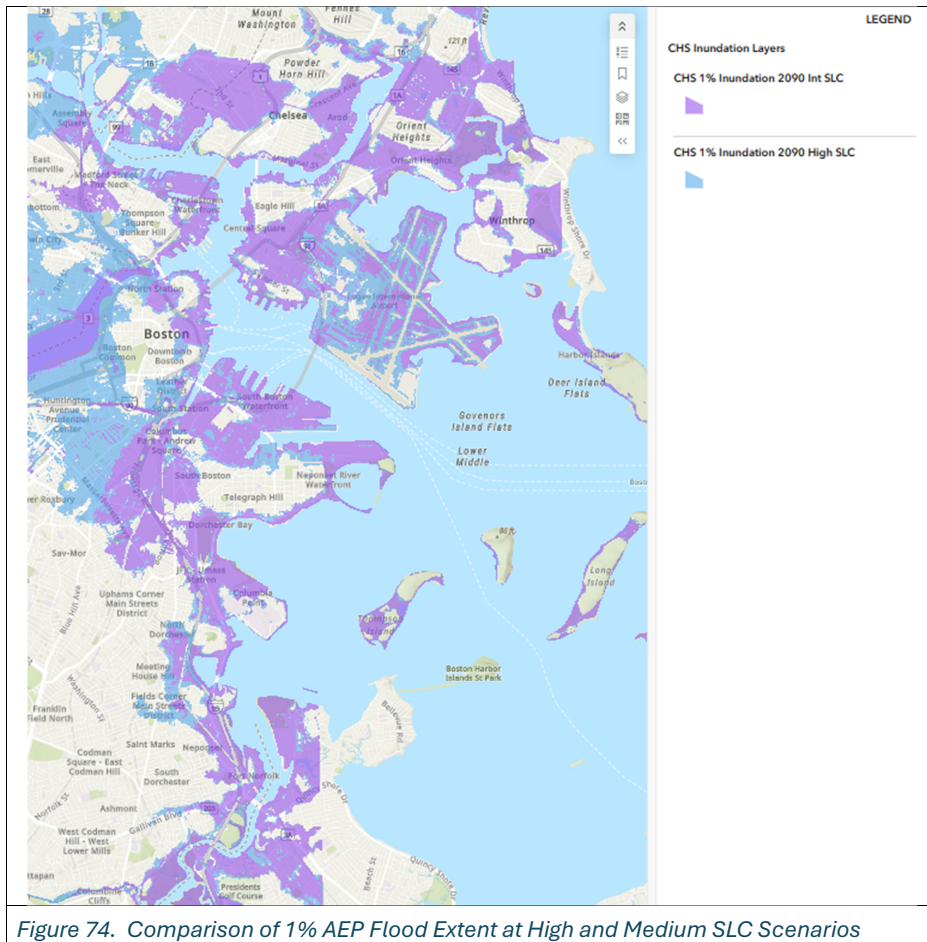
Alternatives SB2 does not include the Ray Flynn Marine Industrial Park while SB3 does. Both are both economically justified and have similar net NED benefits, BCRs, and life loss benefits. SB3 is more expensive; however, it serves as the locus of Boston's fish processing industry and working waterfront. More than 3,000 people are employed in the 191-acre Marine Park area and much of that employment is in industries that are difficult to move elsewhere. For example, Boston's fish processing facilities service just-in-time shipments it receives from and often returns to Logan Airport, approximately 1 mile away.

The final element of the Comprehensive System Plan is Dorchester, Alternatives 2 + 4 + 6, which are comprised of



- An upland vertical wall behind Day Boulevard transitioning to a shallow foundation levee feature through the contours of Moakley Park tying into the existing stadium (Moakley Park and Northern Connector);
- A vertical wall tie-in at Moakley Park which transitions to an armored levee with Harborwalk along the Harbor Point community, ending at Calf Pasture I next to UMass Boston's University Lot D;
- A road grade change at the intersection of Morrissey Boulevard and Bianculli Boulevard and levee around Pattens Cove to the base of Savin Hill;
- A road grade change on Conley Street at Tenean Beach tying into a shallow foundation levee feature tying into north side of the Conley Street underpass;
- On the West side of the MBTA salvage yard underpass of I-93, an upland vertical wall to fill the low ground between highpoints;
- Upland vertical walls at the south side of the Beades Bridge on Morrissey Boulevard abeam the I-93 underpass;
- A grade change or berm at the Victory Road offramp along I-93; and
- A shallow foundation levee and in-water wall along the Neponset River from the MBTA Red Line's bridge to Pope John Paul II Park.

This comprehensive alternative for Dorchester is NED maximizing, relatively inexpensive compared to other neighborhoods, and provides high life loss benefits. These systemwide actions were evaluated under the high sea level rise scenario and will undergo sensitivity analysis under the intermediate scenario in the next iteration of this document; however, as seen in Figure 74, the extent of flooding does not change significantly in the study area between the intermediate and high scenarios.



	CSP [DT3, SB2]	CSP [DT3A, SB2]	CSP [DT3, SB3]	CSP [DT3A, SB3]
Total Investment Cost	\$9,410,680,429	\$8,726,540,306	\$10,531,071,093	\$9,846,930,970
Average Annual Cost	\$383,300,000	\$355,435,000	\$428,934,000	\$401,069,000

Average Annual Benefits	\$1,666,360,000	\$1,656,060,000	\$1,714,000,000	\$1,703,700,000
Net NED Benefits	\$1,283,060,000	\$1,300,625,000	\$1,285,066,000	\$1,302,631,000
BCR	4.3	4.7	4.0	4.2
Damages Prevented	\$40,911,986,980	\$40,658,951,804	\$42,081,637,479	\$41,828,602,303
Residual Risk	25%	26%	23%	24%
Life Loss Prevented	106.24	106.23	106.24	106.23
Residual Risk of Life Loss	15%	15%	15%	15%

Figure 75. Benefits of Comprehensive System Plan for Boston (\$FY26)

Early Actionable Increment

The Early Actionable Increment (EAI), referred to as Action Plan 3, is DOR1, which is comprised of an upland vertical wall behind Day Boulevard transitioning to a shallow foundation levee feature through the contours of Moakley Park tying into the existing stadium (Moakley Park and Northern Connector). DOR 1 is the foundational element to DOR2, which is an integral piece of Action Plan 2, the Comprehensive System Plan but also functions as an incrementally separable element. The decision to select DOR1 as the EAI was based on the following criteria:

- DOR1 does not increase, induce, or transfer risk to other areas;
- DOR1 can be designed to a 35% level and achieve a Class 3 cost estimate for budgeting within remaining time and budget;
- DOR1 is part of a larger system of features but addresses a near-term flood pathway as identified through hydrologic modeling, which makes it a no regret alternative;
- DOR1 is incrementally justified through economic analysis (see discussion below with respect to additional analysis performed upon selection);
- DOR1 aligns with the non-federal sponsor's resilience priorities and plans.

Once DOR1 was identified as the EAI, Action Plan 3, the intervention was reanalyzed with the additional information that became available as a result of that selection. Specifically:

- Selection as an EAI made the timing of the intervention easier to estimate. It was assumed that DOR3 would be complete in 2032, which would change both the timing of the onset of the benefits and costs and the interest during construction that would accrue.
- The specifics of the construction of the EAI are relatively well-understood so the 175% level of contingency that was being used for Action Plan 2, the Comprehensive System Plan, was modified to reflect that. Specifically, the EAI analysis was performed to assume 89.2% contingency added for a 50% confidence level in the cost estimate.

As a result of the modifications above, the cost estimate for the EAI is presented as a range. The contingency-loaded estimates range from \$129M (80% confidence) to \$97M (50% confidence). Based on these estimates, the BCR ranges from 0.7 to 1.03. It is understood that if the cost estimate based on the 35% design, which is to be prepared after the publication of the draft report, results in a BCR below 1.0, an NED policy exception from the Assistant Secretary (Civil Works) may be required.

6.2.1 Public Value of the EAI

Beyond benefit to cost ratio and value as the foundational component of the Harbor Point area, the EAI is in the public interest given that it:

- In NED terms, prevents approximately \$99M in coastal storm damages;
- In RED terms, maximizes local risk reduction;
- In OSE terms, maximizes public safety and maintains the continuity of the City's larger resilience effort which includes wetland restoration seaward of the levee; and
- In EQ terms, minimizes environmental impacts while creating ancillary opportunity for City-planned wetland restoration.

6.2.2 Cost Considerations of the EAI

- **Real Estate** – The estimated total acreage is 0.04 acres, of which 0.01 acres will be permanently impacted at an estimated cost of \$192,000.



- **Contingency** – As the design of the EAI matures, the cost will be refined and the uncertainty reduced, which in turn will reduce the overall cost.
- **Design Elevation** – The current design elevation is 15.5 feet NAVD88. Current modeling reflects the Moakley Park Levee and Northern Connector will be effective up to an elevation of 14.2 feet NAVD88 before it is flanked to the south; however, the team did not reduce the quantities or takeoffs for the plan as it is justified and will function at the 15.5-foot NAVD88 elevation when the Harbor Point, DOR2, element is added.
- **Adaptation** - Reducing such quantities might have slightly decreased cost to the individual EAI, but would add costs to the comprehensive system plan because of added mobilization and potential re-engineering depending on anticipated loading.

6.2.3 Post-Draft Report Considerations for the EAI

After the draft release, further analysis will be completed to determine the final height of the recommended plan. This analysis will focus on design, uncertainty, and potential near-term interventions by the City of Boston to manage flanking of the southern connector. The flanking beyond 14.2 feet NAVD88 does not increase risk with the implementation of DOR1 given the larger risk reduction across the area.

Total Investment Cost	\$97M - \$129M
Average Annual Cost	\$3,939,000 - \$5,258,000
Average Annual Benefits	\$4,040,000
Average Annual Net Benefits	-1,218,000 to 101,000
BCR	0.8 to 1.03
Damages Prevented	\$99,262,000
Residual Risk	99%
Life Loss Prevented	2.91
Residual Risk of Life Loss	97.7%
<i>Figure 76. Revised Economics of EAI (\$FY26)</i>	

This element is supported by the non-federal sponsor and the district. The decision criteria included-

- Does not increase, induce, transfer risk to adjacent areas
- Sufficient design of 35% with Class 3 cost estimate for budgeting
- Is part of the larger system of features and address a more near-term flood pathway as identified through modeling

- Is incrementally justified through economic and socio-economic analyses at the full system level of risk management; or a more frequent event without inducing, increasing, or transferring risk
- Aligns with the non-federal sponsor's resilience priorities and plans

Benefit Exceedance Probability and Probabilistic Performance of EAI

[Write for final.]

Implementation Strategy of the Comprehensive System Plan and Early Actionable Increment

[Write for final.]

