

Boston Coastal Storm Risk Management Study

Coastal Engineering Appendix

July 2026



**US Army Corps
of Engineers®**
New England District

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1.0 Introduction

This appendix presents the results of the Hydrology, Hydraulics and Coastal (HH&C) engineering evaluation and analysis for the Boston Coastal Storm Risk Management (CSRM) Study. This report will discuss the existing information that was reviewed, new work that was conducted, and how this information was used in the HH&C engineering evaluation and analysis.

2.0 Study Area

The Boston CSRM Study investigated the feasibility of various storm damage reduction measures along the City of Boston's coastline. The study area (Figure 1) is comprised 47 miles of shoreline, shown in blue, within five neighborhoods, as defined in the Climate Ready Boston (Boston, 2016) report as being highly vulnerable to coastal storm risk under the existing and future without-project condition. These neighborhoods are, counterclockwise from northeast to south, East Boston, Charlestown, Downtown/North End, South Boston, and Dorchester.



Figure 1. Boston CSRM study area and neighborhoods

2.1 Boston Harbor

Boston Harbor is a large, natural harbor and estuary which constitutes the western extremity of Massachusetts Bay. The harbor is sheltered from Massachusetts Bay and the open Atlantic Ocean by a combination of Winthrop Peninsula and Deer Island to the north, Nantasket Peninsula and Point Allerton to the south, and the Boston Harbor Islands in the middle. The harbor is often described as being split into an inner harbor, northeast of Logan International Airport and Castle Island, and the outer harbor.

The inner harbor (Figure 2) was historically the main port of Boston and is still the site of most of its port facilities as well as the Boston waterfront, which has been redeveloped for residential and recreational uses. The inner harbor extends up to the mouth of the Charles River and includes the Mystic River and Chelsea Creek. The Charlestown and Downtown/North End shorelines are entirely within the inner harbor. Much of the East Boston and South Boston shorelines are also situated on the inner harbor.

The outer harbor extends to the south and east of the inner harbor and is made up of three smaller bays, Dorchester Bay, Quincy Bay, and Hingham Bay (Figure 3).



Figure 2. Boston's Inner Harbor.

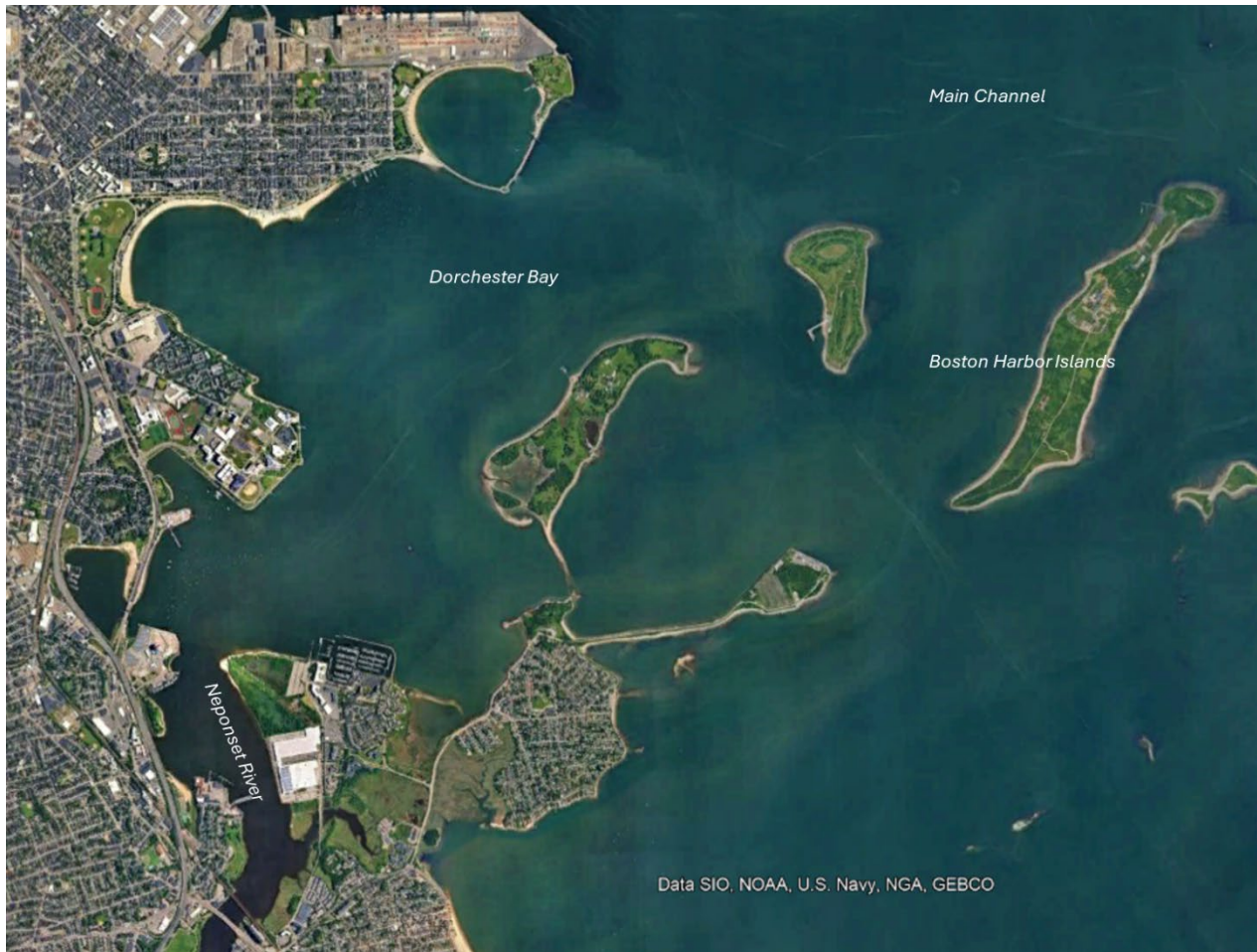


Figure 3. Boston's Outer Harbor within the study area.

2.2 Tributaries

Three main tributaries to Boston Harbor, the Charles River, the Mystic River, and the Neponset River, are all within the study area. Although it is predominantly tidal, Chelsea Creek is also discussed in this section.

A correlation analysis, described in Appendix J: Interior Drainage, examined the correlation and coincidence of rainfall and harbor water levels based on the historical records at Logan Airport (rainfall) and the Boston NOAA tide gage. This analysis concluded that there is minimal and weak correlation and coincidence between rainfall and subtidal (surge) and total water levels in Boston. Therefore, based on the findings of the correlation analysis and previous modeling conducted by Woods Hole Group in their Boston Harbor-Flood Risk Model, it is generally assumed that riverine flows will not significantly contribute to coastal water levels. However, it is suggested that as designs advance combined flooding be analyzed further beyond the historical record.

2.2.1 Charles River

The Charles River flows 80 miles, passing through 23 cities and towns in eastern Massachusetts before emptying into Boston Harbor between Charlestown and the North End. Despite the river's length and relatively large drainage area (308 square miles), its source is only 26 miles from its mouth, and the river drops only 350 feet from source to sea. Its watershed contains more than 8,000 acres of protected wetlands that are important in preventing downstream flooding and providing natural habitats to native species.

Originally a tidal river surrounded by hundreds of acres of salt marsh and mud flats, today's Charles River basin between Boston and Cambridge is almost entirely a work of human design. The first damming of the river's mouth, at today's Boston Museum of Science, was completed in 1910. This dam stabilized the water level from Boston to Watertown by permanently flooding the tidal marshes and mud flats that were formerly tidal.

In 1978, the New Charles River Dam, a flood control structure built by the USACE and owned and operated by the Massachusetts Department of Conservation and Recreation (DCR), replaced the 1910 dam just downstream of the Zakim Bunker Hill Memorial Bridge near Lovejoy Wharf. The dam controls the surface of the river basin, as well as its tributaries upstream, and prevents sea water from entering the Charles River basin during high tides and coastal storms. The dam typically drains freshwater from the basin at low tide through sluice gates. As the tide rises, the sluice gates are closed, keeping saltwater out of the basin. The dam also contains three locks, one for navigation, and six pumps with a combined capacity of about 8,140 cfs.

During a coastal storm, the sluice gates are closed. The interior stage within the Charles River basin is regulated to remain within a two-foot range. As needed, pumps are turned on to evacuate water from the basin into the harbor. In cases where water needs to be drained faster from the basin, the locks can be used.

With its crest at 11.7 feet NAVD88, the dam is vulnerable to coastal flooding and sea level rise by flanking (through Paul Revere Park in Charlestown at elevation 11.1' NAVD88) and overtopping. However, the dam is not within the scope of this CSRM study. Alternatives to close flanking pathways are examined, but modifications to the dam are not considered. USACE NAE has a Planning Assistance to States study underway with DCR to evaluate how dam operations are projected to change under different sea level change scenarios.

2.2.2 Mystic River

The Mystic River enters Boston Harbor north of Charlestown. The 7-mile long river has a 76 square mile watershed and a history similar to the Charles River. Extensive salt

marshes lined the banks of the Mystic until 1909 when locks were first built across the river, converting salt marsh to freshwater marsh and enabling development. In 1966, DCR, with the USACE, constructed the Amelia Earhart Dam between Somerville and Everett, approximately 0.3 miles upstream of Charlestown, to regulate tidal effects and the incursion of saltwater in the upstream river basin. DCR is currently designing a dam hardening project that will increase the height of the Amelia Earhart Dam. The objective of this work is to raise the Amelia Earhart Dam to provide flood hazard mitigation from future coastal storms that could overtop or flank the dam. The dam raising will tie into existing high ground in Everett and the Draw Seven Park resilience project that is nearing completion in Somerville.

Similar to the New Charles River Dam, the Amelia Earhart Dam is also equipped with pumps to evacuate freshwater upstream of the dam when tidal conditions are high. The dam is equipped with three pumps capable of discharging a maximum capacity of roughly 1,400 cfs, and can also use its locks to pass larger flows.

2.2.3 Chelsea Creek

Chelsea Creek is a narrow, 2.6-mile long waterway that runs between Chelsea to the west and north and East Boston and Revere to the south and east, respectively. It empties into Boston Harbor opposite the Mystic River at the head of the harbor. Water flow in Chelsea Creek is dominated by tidal exchange rather than significant freshwater inflow, with minimal contributions from small upstream tributaries like Mill Creek. For this reason, there is little concern for combined flooding along Chelsea Creek. The creek is used heavily by oil tankers transporting fuel to adjacent oil tanks. All of the jet fuel used at Logan International Airport is stored along Chelsea Creek, along with 70-80 percent of the heating fuel in New England, and road salt for approximately 350 communities in the region.

2.2.4 Neponset River

The Neponset River forms the southern boundary of the city of Boston, entering Dorchester Bay between Dorchester and Quincy. The 29-mile long river drains a 130 square mile watershed. The Neponset is tidal up to the Baker Dam where the Lower Mills USGS Gage 011055566, officially known as the Neponset River at Milton Village Gage is located. Because the gage is located just within the reach of tidal influence, flow spikes every 12 hours in its provisional graph during periods of low flow. The effective FEMA Flood Insurance Study lists the Neponset River's 1-percent annual chance peak discharge at the Baker Dam at 3,730 cfs. Described further in Section 5.2.3, the potential for combined flooding on the Neponset was evaluated at a screening level as part of the coastal modeling conducted for this study.

2.3 Land Fill

Boston's history of landmaking is part of what makes it so vulnerable to sea level rise and coastal flooding. As early as 1722, colonists started to change the natural shoreline of Boston by using landfill to build wharves into the harbor, filling in the empty spaces between them with household trash and gravel to expand the city's waterfront. By the early 1800s, Boston's original peninsula had become cramped and craggy. As a result, prominent hills, including Beacon Hill and Copp's Hill, were leveled and used to fill in stagnant Mill Pond, creating Bullfinch Triangle. Filling of mudflats and a foul-smelling tidal basin with millions of tons of sand and gravel brought by train, alongside household waste and mud from the South Bay, created the Back Bay and South End neighborhoods. Industrial areas of the South Boston Waterfront (Seaport) and Logan International Airport were created by filling in tidal flats with dredged harbor material and street sweepings. Most recently, massive amounts of dirt from The Big Dig's Central Artery tunnel project were used to permanently cap and landscape Spectacle Island, turning a former municipal garbage dump into a public park. Today, about one-sixth of Boston sits on landfill, much of it built right above the historic high tide line. As a result, much of that created land is vulnerable to coastal flooding and will become increasingly so due to sea level change. A comparison of the 2016 shoreline to the 1630 shoreline (Figure 4) illustrates the extent of Boston's landfilled area.



Figure 4. Boston shorelines, 1630 and 2016 (Climate Ready Boston, 2016).

2.4 Topography

2.4.1 East Boston

East Boston is located on a peninsula between Chelsea Creek and Belle Isle Marsh and is connected to the mainland through Revere to the north. Within the northern half of East Boston, shown in Figure 5, the Orient Heights Railyard on Belle Isle Marsh and the Route 1A shoreline on Chelsea Creek are the lowest lying coastal edges, with flood entry points as low as 9.5' NAVD88. The Orient Heights model area (shown as EB_OH in Figure 5) is lower than the coastal edge along Chelsea Creek. Therefore, flooding that crosses Route 1A will also inundate structures within EB_OH. The MBTA Blue Line is also a low-lying corridor. Flood waters that come over Constitution Beach and from Belle Isle Marsh will flow along the Blue Line before inundating EB_OH.

The southern half of East Boston, shown in Figure 6, is also bowl-like, with interior elevations lower than those along the coast. Within the East Boston Waterfront model area (EB_WF), flooding along Border Street begins as low as elevation 8' NAVD88. However, the critical elevation to flood the Sumner and Callahan Tunnel Portals, as well as the MBTA Central Tunnel, which connect East Boston to Downtown is 9.3' NAVD88. The coastal runways at Logan International Airport, east of EB_WF, are important areas of high ground, exceeding elevation 14' NAVD88. The critical elevation to flood the Ted Williams Tunnel Portal in East Boston also exceeds elevation 14' NAVD88.

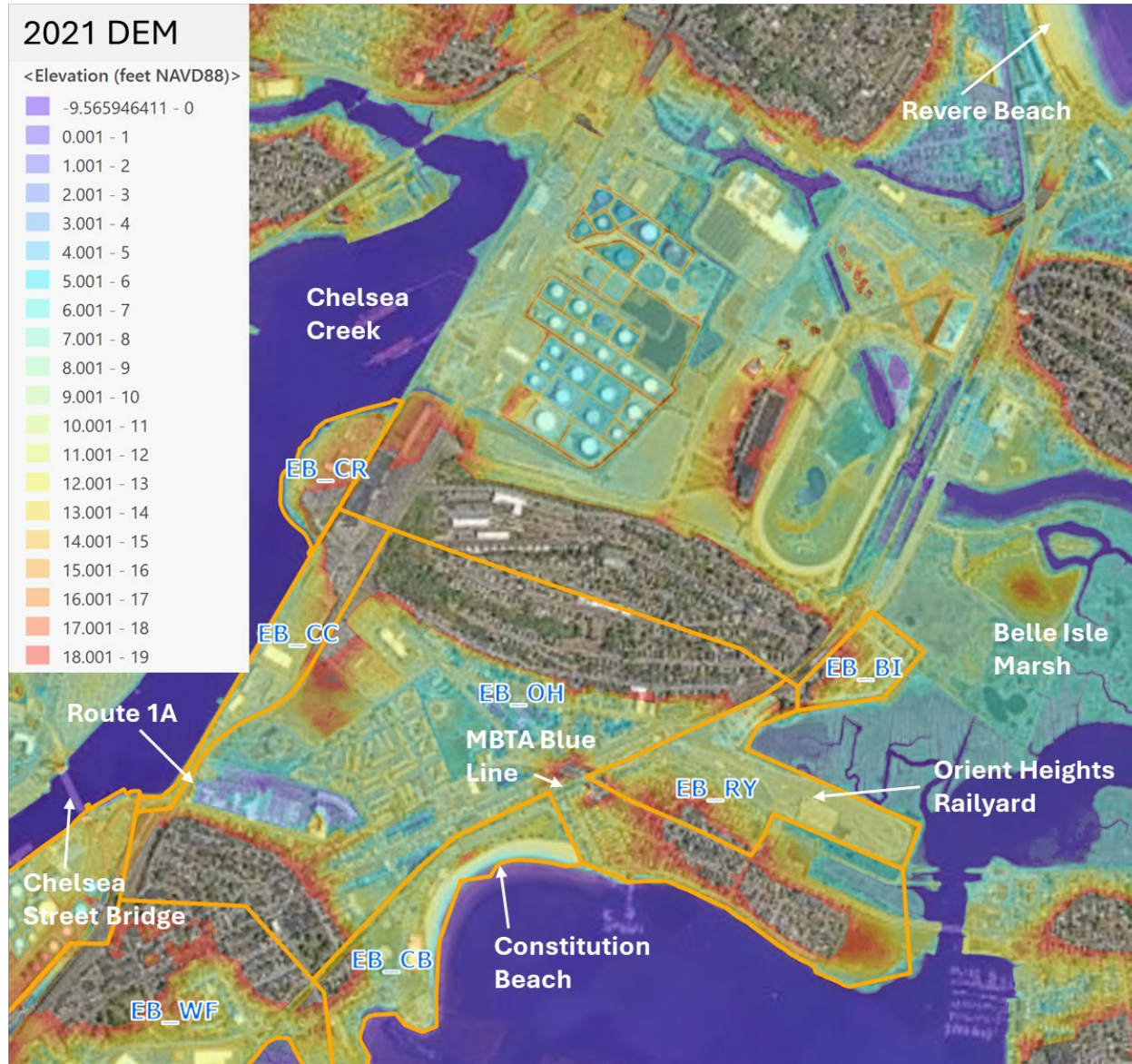


Figure 5. East Boston topography northeast of the Chelsea Street Bridge.

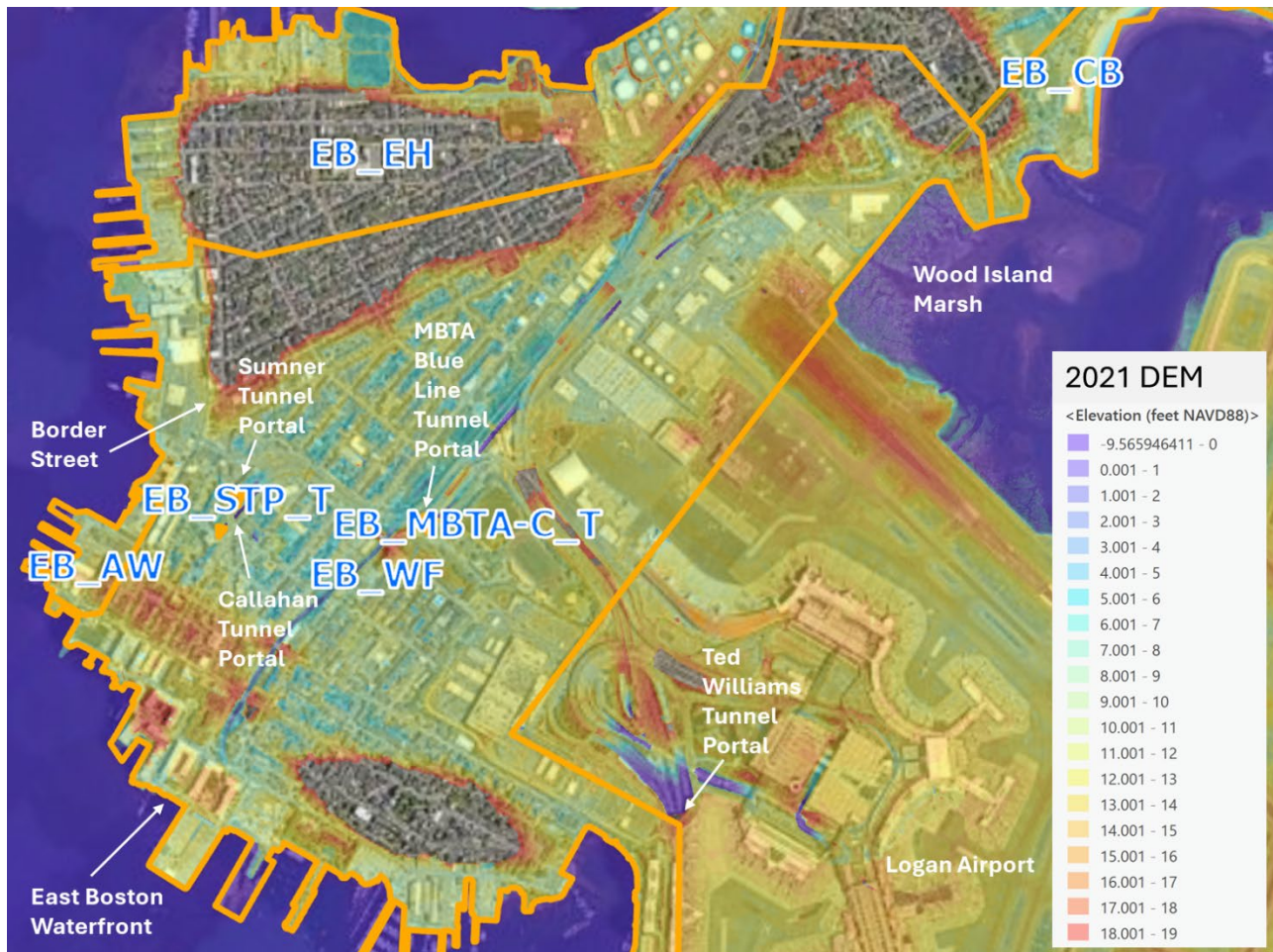


Figure 6. East Boston topography south of the Chelsea Street Bridge.

2.4.2 Charlestown

Coastal flooding in Charlestown begins as low as elevation 8' NAVD88 in the Charlestown Navy Yard (model area CH_NY in Figure 7). A comparison of Figure 7 to Figure 4 shows the lowest lying areas in Charlestown are those that were built on fill. This includes the Navy Yard as well as the Auto Port (CH_AP) and the rail corridor that runs through model areas CH_RP and DT_CR. The shorelines along Little Mystic Channel and the Mystic River in the vicinity of the Schrafft Center are both as low at elevation 9.5' NAVD88, with flooding of the CH_NY model area being separable from CH_LM up to elevation 12.3' NAVD88. Although the New Charles River Dam crest is at elevation 11.7' NAVD88, the dam can be flanked at elevation 11.1' NAVD88 through Paul Revere Park on the north (Charlestown) side of the dam. Model areas CH_RP and DT_CR are divided at approximately the 12' NAVD88 contour. Therefore, flooding within these model areas can potentially come from either or both the Charles River basin and the Mystic River. As the Tobin Approach Tunnel is situated in DT_CR, its critical elevation for flooding is also tied to the flanking of the New Charles River Dam at elevation 11.1' NAVD88.



Figure 7. Charlestown topography from the Charles River to the Mystic River.

2.4.3 Downtown/North End

The Downtown and North End neighborhood is situated between the Charles River to the north and Fort Point Channel to the southeast (Figure 8). As with Charlestown, flooding within the Charles River Basin, upstream of the New Charles River Dam, begins at elevation 11.1' NAVD88. However, flooding of the wharves on the east side of Downtown (DT_WH and DT_WHN) begins as low as elevation 7.5' NAVD88. To the west of the wharves, across Atlantic Avenue and the Rose Kennedy Greenway, the Government Center model area (DT_GC) is as low as 8.5' NAVD88. Within DT_GC, the critical elevation for the Central Artery Tunnel to flood is 10.6' NAVD88. The critical elevations for the Sumner and Callahan Tunnel Portals to flood are both above 19' NAVD88. At the north end of the Downtown peninsula, adjacent to the New Charles River Dam, the shoreline at Lovejoy Wharf is near to the crest of the dam at elevation 11.5' NAVD88. The low point of the boundary between model areas DT_LJ and DT_CR is approximately 12' NAVD88.

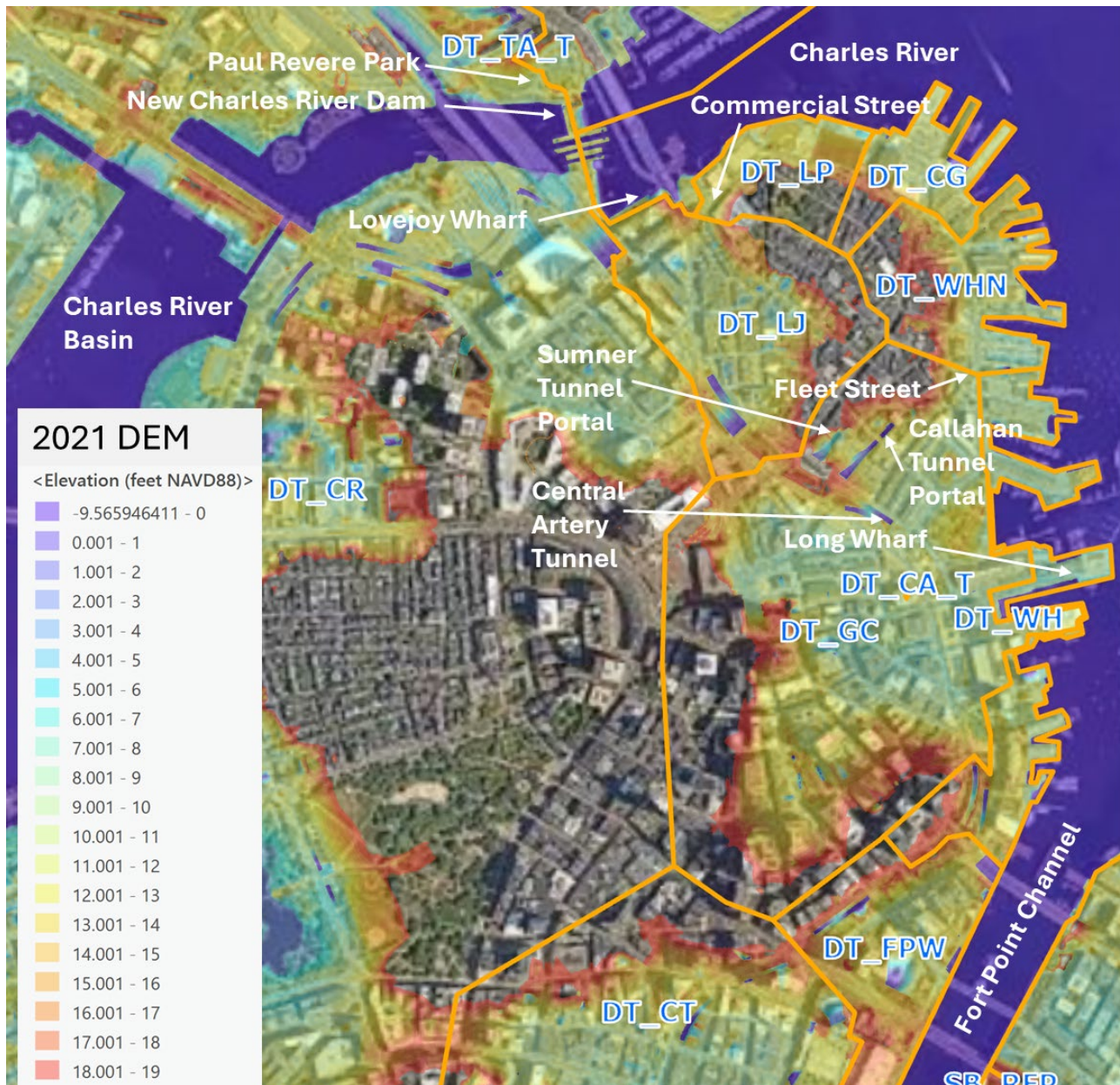


Figure 8. Downtown and North End topography from Fort Point Channel to the Charles River.

2.4.4 South Boston

South Boston extends from Fort Point Channel to Dorchester Bay (Figure 9). However, much of the Southie neighborhood, between Reserved Channel and Dorchester Bay, is high ground. Therefore, the focus in South Boston is generally the filled area at the south end of Fort Point Channel and the Seaport area between Fort Point Channel and Reserved Channel. Currently, the lowest lying shoreline within South Boston is along SB_RFP at the southeast corner of Fort Point Channel. Here, flooding can begin as low as elevation 8' NAVD88. Coastal edge elevations along much of the rest of South Boston are between 9-10' NAVD88. Vulnerable from flooding from multiple sources, the

model areas within South Boston are quite interconnected and have been defined more based on alternative alignments rather than areas of higher ground that separate one model area from the next. Critical elevations for the flooding of the Ted Williams Tunnel Portal and the Fort Point Channel Tunnel Portal are 11.5' and 13' NAVD88, respectively. The critical elevation for the MBTA Silver Line Tunnel is 12.4' NAVD88. Low-lying topography also exists along the rail and I-93 corridors south of Fort Point Channel. While flooding of model area SB_FPS can begin as low as elevation 10' NAVD88, the critical elevation for flooding the South End model area (SB_SE) is 11' NAVD88. Although the West Streets model area (SB_WS) is adjacent to SB_FPS, modeling done by Woods Hole Group for the Massachusetts Coast-Flood Risk Model has shown that flooding of this model area occurs first through the Moakley Park model area (DC-SB_MP) in Dorchester. However, for a large enough storm event, flooding from Fort Point Channel and from Dorchester Bay through Moakley Park can converge in South Boston.



Figure 9. South Boston topography from Fort Point Channel to Dorchester Bay.

2.4.5 Dorchester

The area of Dorchester north of Savin Hill is shown in Figure 10. The lowest lying areas are at the northern shore of Columbia Point (model area DC_CP) and within Moakley

Park (model area DC-SB_MP) at elevations 9.5' and 10' NAVD88, respectively. Inundation of DC_CP can extend inland and north along the rail and I-93 corridors to model area SB_WS (critical elevation of 10.5' NAVD88). The Dorchester neighborhood does not contain any tunnels connecting it to other neighborhoods.

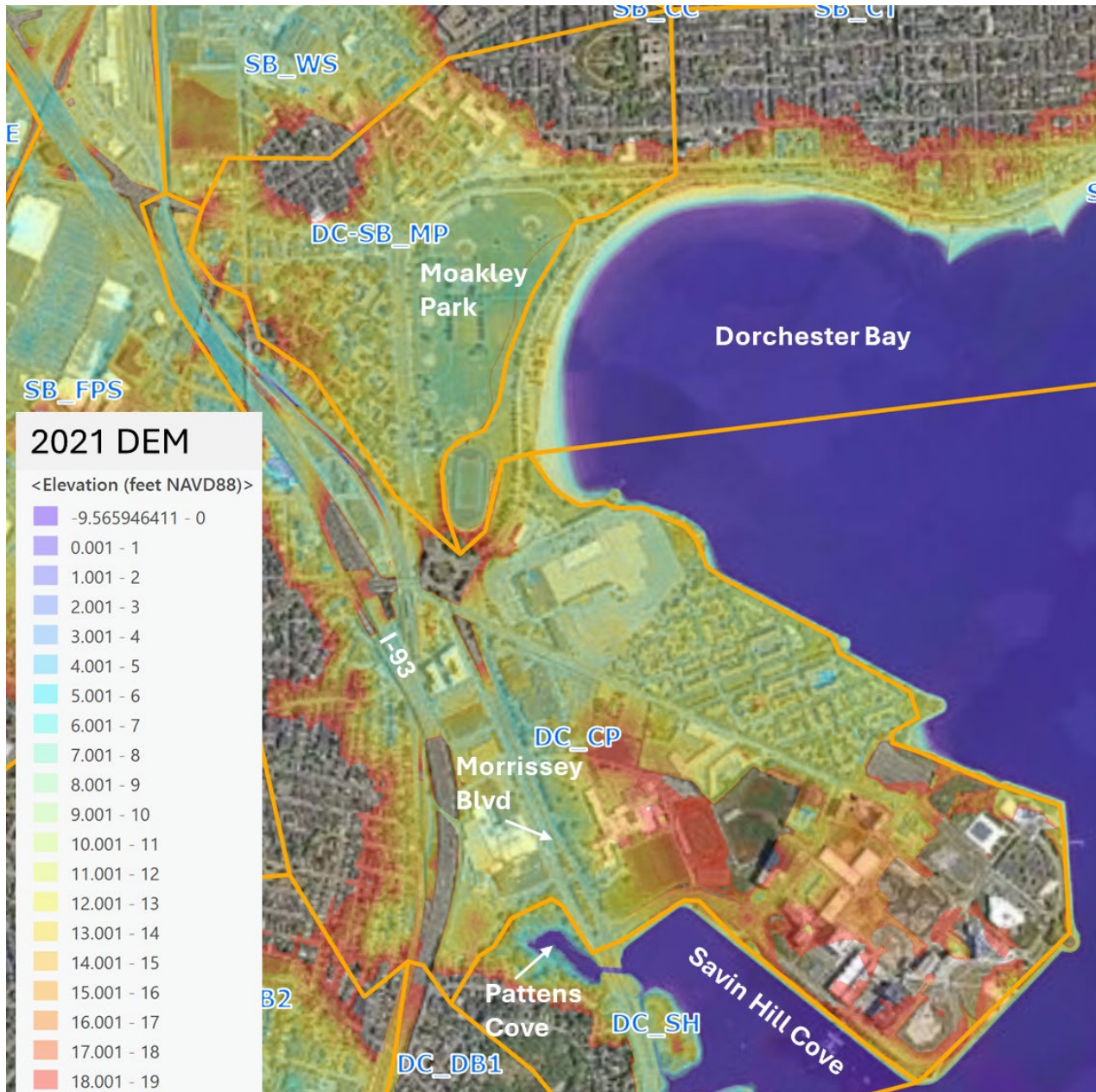


Figure 10. Dorchester topography north of Savin Hill.

The area south of Savin Hill is shown in Figure 11. This area is generally defined by I-93 acting as a levee/high ground, interrupted by a series of underpasses. These include Morrissey Boulevard (9.5' NAVD88), Victory Road, and Conley Street at Tenean Beach (8.5' NAVD88). The lowest elevation of I-93 along this stretch is 13.7' NAVD88 between

model areas DC_DB1 and DC_DB2. Along the Neponset River, the lowest lying structures are situated at about elevation 5.5' NAVD88 near the Neponset Bridge. The Neponset Circle (DC_NC) and Port Norfolk (DC_PN) models are divided by the MBTA Red Line embankment, as it approaches its crossing of the Neponset River.

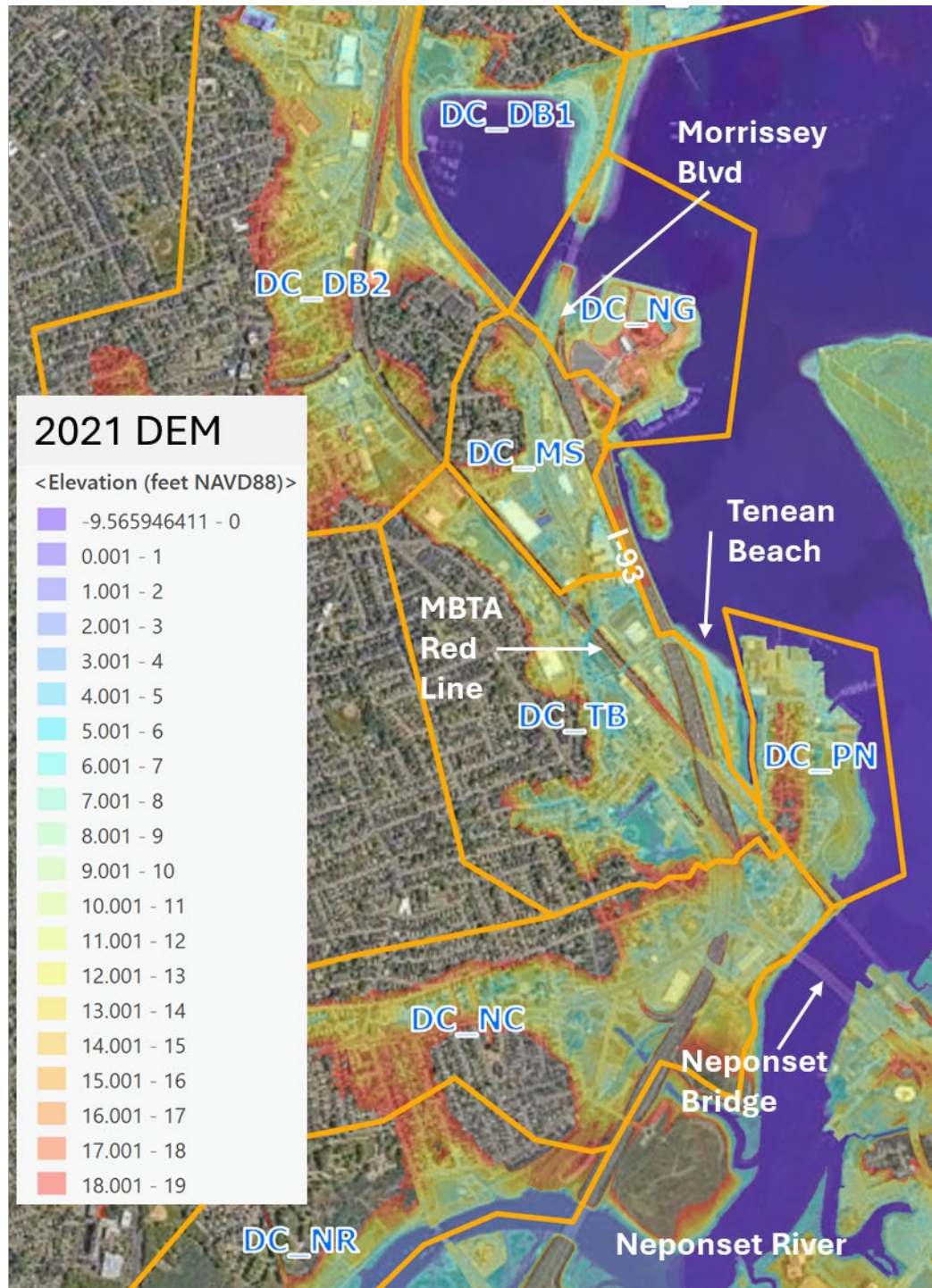


Figure 11. Dorchester topography south of Savin Hill.

3.0 Vertical Datum

In accordance with ER 1110-2-8160 the Boston CSRM Study is designed to North American Vertical Datum of 1988 (NAVD88), the current orthometric vertical reference datum within the National Spatial Reference System (NSRS) in the contiguous United States. The study area is subject to tidal influence and is directly referenced to National Water Level Observation Network (NWLON) tidal gages and coastal hydrodynamic tidal models established and maintained by the National Oceanic and Atmospheric Administration (NOAA). The current NWLON National Tidal Datum Epoch (NTDE) is 1983-2001.

The Boston, MA Station 8443970 is the only active NWLON tidal gage within the study area, located on Fort Point Channel at Seaport Boulevard. Tidal conversions to NAVD88 for Station 8443970 are presented in Table 1.

Table 1. Tidal Datums at Boston, MA (8443970)

Datum¹	Elevation (feet, NAVD88)
Mean Higher High Water (MHHW)	4.77
Mean High Water (MHW)	4.32
NAVD88	0.00
Mean Sea Level (MSL)	-0.30
Mean Low Water (MLW)	-5.17
Mean Lower Low Water (MLLW)	-5.50
Great Diurnal Range (GT) ²	10.27
Mean Range of Tide (MN) ³	9.49

Notes: ¹ Tidal datums based on 1983-2001 tidal epoch

² Great Diurnal Range (GT) = MHHW-MLLW

³ Mean Tidal Range (MN) = MHW-MLW

Hydrodynamic modeling completed for this study was performed in meters, MSL in the current NTDE. Output from the Coastal Hazards System (CHS) has been converted to feet, NAVD88.

4.0 Sea Level Change

4.1 Background on Sea Level Change

Global sea level change (SLC) is often caused by the global change in the volume of water in the world's oceans in response to three climatological processes: 1) ocean mass change associated with long-term forcing of the ice ages ultimately caused by small variations in the orbit of the earth around the sun; 2) density changes from total salinity; and most recently, 3) changes in the heat content of the world's oceans, which recent literature suggests may be accelerating due to global warming. Global SLC can also be caused by basin changes through such processes as seafloor spreading. Thus,

global sea level, also sometimes referred to as global mean sea level, is the average height of all the world's oceans.

Relative (local) SLC is the local change in sea level relative to the elevation of the land at a specific point on the coast. Relative SLC is a combination of both global and local SLC caused by changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns (often caused by changes in regional atmospheric patterns), hydrologic cycles (river flow), and local and/or regional vertical land motion (subsidence or uplift).

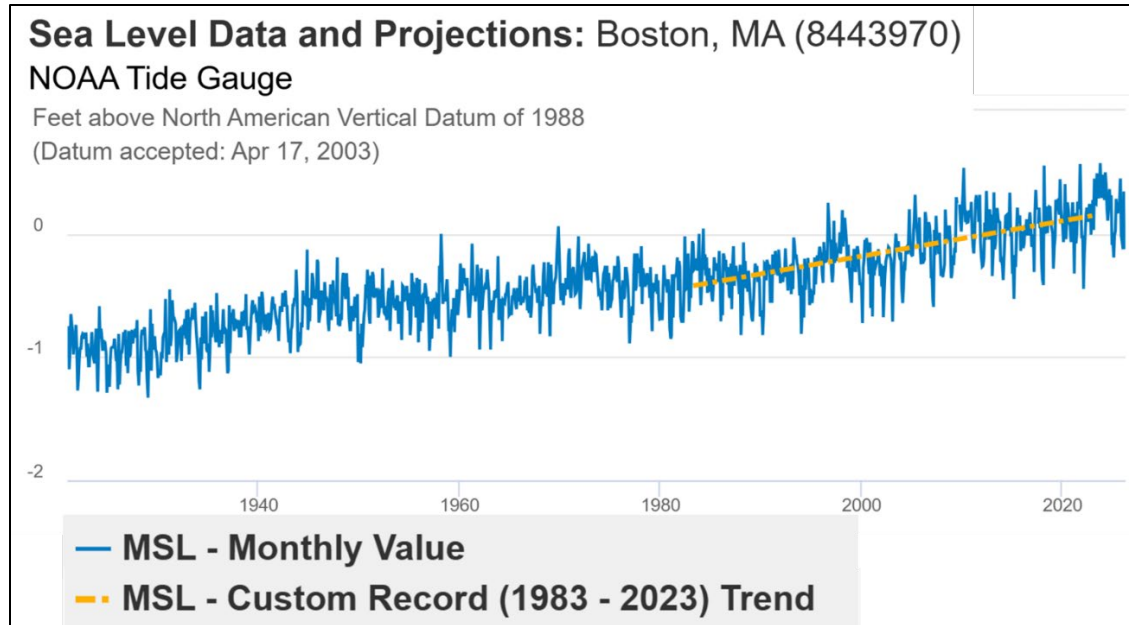
4.2 USACE Guidance

In accordance with ER 1100-2-8162, potential effects of relative sea level change (RSLC) were analyzed over a 50-year economic period of analysis and a 100-year planning horizon. USACE guidance states “the period of analysis shall be the time required for implementation of the lesser of: (1) the period of time over which any alternative plan would have significant beneficial or adverse effects, (2) a period not to exceed 50 years” (ER 1105-2-100). However, because infrastructure often stays in place well beyond the economic period of analysis, a 100-year adaptation planning horizon is used to address robustness and resilience in the time of service of the project that can extend past its original design life. Research by climate science experts predict continued or accelerated climate change for the 21st century and possibly beyond, which would cause a continued or accelerated rise in global mean sea level. ER 1100-2-8162 states that planning studies will formulate alternatives over a range of possible future rates of SLC and consider how sensitive and adaptable the alternatives are to SLC.

ER 1100-2-8162 requires planning studies and engineering designs to consider three future sea level change scenarios: low, intermediate, and high. The historic rate of SLC represents the low rate. The intermediate rate of SLC is estimated using the modified National Research Council (NRC) Curve I. The high rate of SLC is estimated using the modified NRC Curve III. The high rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate the potential rapid loss of ice from Antarctica and Greenland but is within the range of values published in peer-reviewed articles since that time.

4.3 Historical Sea Level Change

Historical RSLC for this study (4.37 mm/yr or 0.014338 ft/yr) is based on the most recent 40-year NOAA tidal record at Boston from April 1983 - March 2023. The most recent 40-year record was selected in place of the gage's full record (2.97 mm/yr for 1921-2025), as it was considered to be most representative of the current sea level trend. The historical record with the 40-year trend at Boston is shown in Figure 12.



Note: The historical SLC rate has changed since the study began in 2022. However, the slight change in rate should not impact the outcome of study findings.

Figure 12. Historical RSLC at Boston, MA NOAA tide gage

The USACE Sea Level Analysis Tool (SLAT) was also used to visualize historic SLC, using monthly sea level (blue), the 5-year moving average (purple), and the 19-year moving average (yellow). Figure 13 and Figure 14 show historical RSLC at Boston for the gage's full record (1921-2025) and from 1983-2023, respectively. It is apparent that over long timescales (19 years) mean sea level is steadily increasing. However, over shorter time scales mean sea level may increase or decrease. The monthly mean sea level (blue), for instance, goes up and down every year capturing the seasonal cycle in mean sea level. The 5-year moving average (purple) captures the interannual variation (2 or more years).

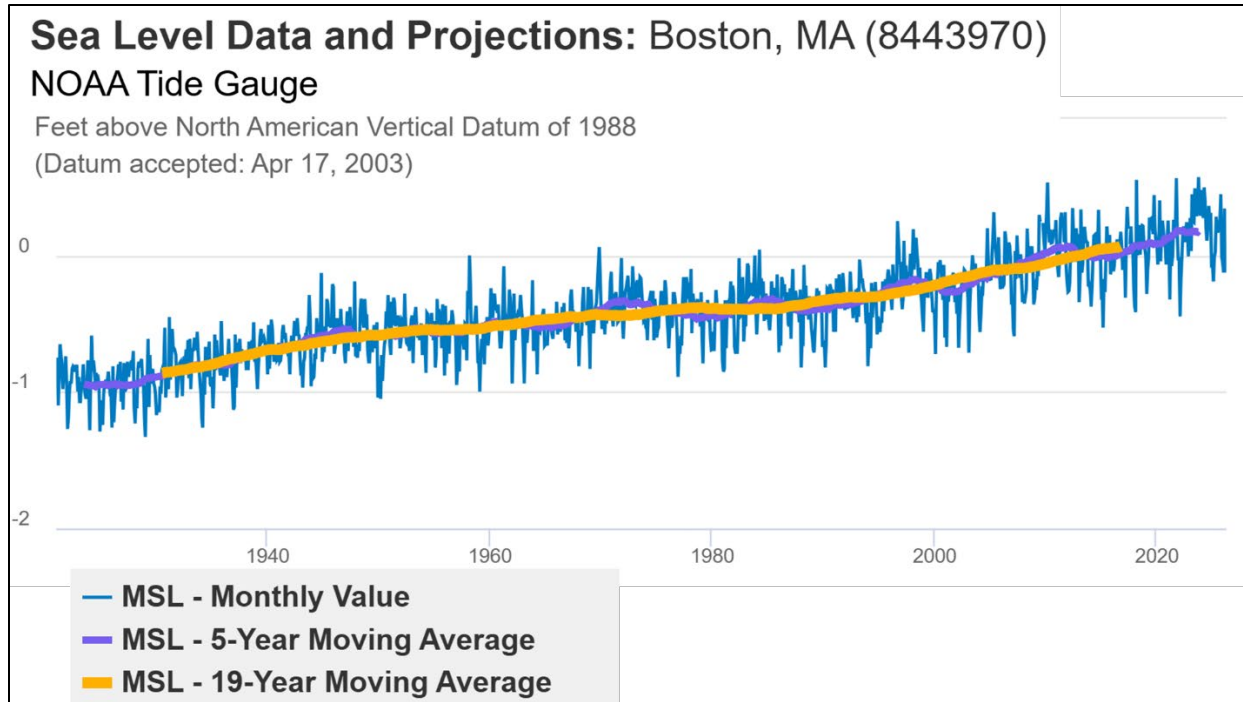


Figure 13. Historical RSLC (1921-2025) at Boston, MA

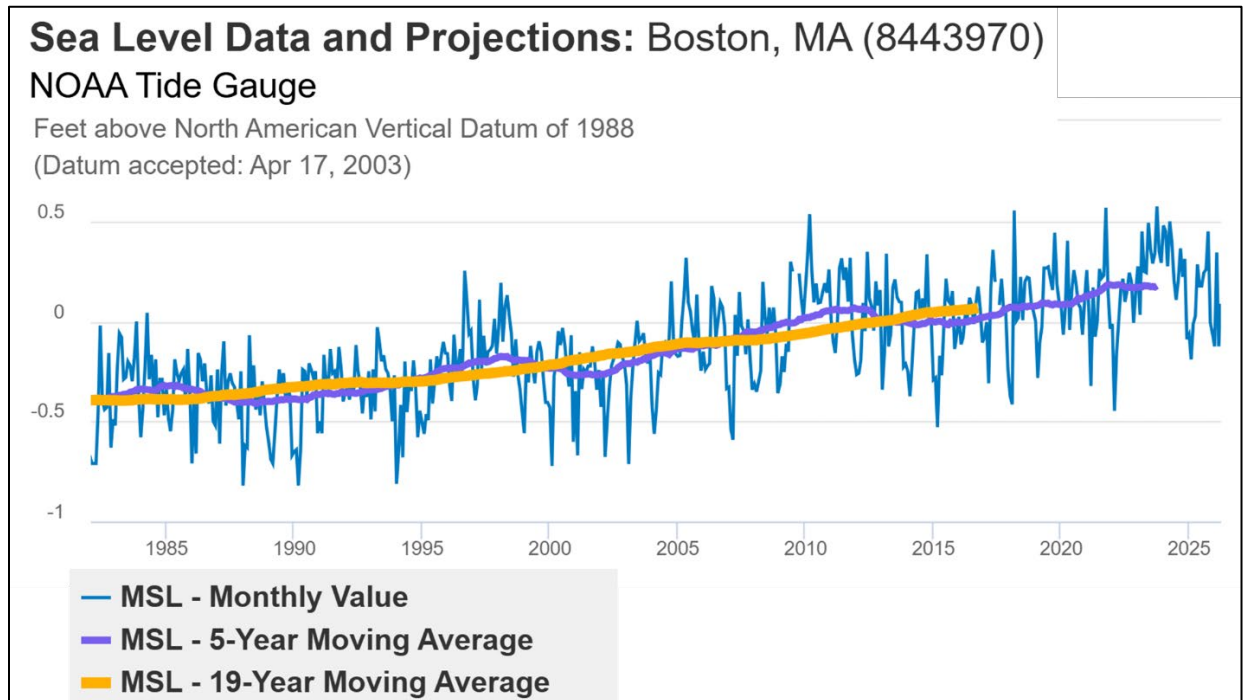


Figure 14. Historical RSLC (1983-2023) at Boston, MA

4.4 USACE SLC Scenarios

USACE low, intermediate, and high SLC scenarios over the 100-year planning horizon at Boston, MA are presented in Table 2 and Figure 15. Water level elevations at year

2040 are expected to be between 0.55 and 1.08 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.

Hydrodynamic modeling for this study was performed using two mean sea levels, the current NTDE (MSL in 1992 = -0.30 ft NAVD88) and for the year 2090 under the USACE high SLC scenario (4.67 ft NAVD88).

Table 2. USACE Sea Level Change Scenarios for Boston, MA (feet, NAVD88)

Boston, MA			
Year	Low	Intermediate	High
1992	-0.30	-0.30	-0.30
2040	0.25	0.37	0.78
2050	0.39	0.59	1.24
2060	0.53	0.83	1.78
2070	0.68	1.09	2.39
2080	0.82	1.36	3.07
2090	0.96	1.65	3.83
2100	1.11	1.96	4.67
2110	1.25	2.29	5.57
2120	1.39	2.63	6.55
2130	1.54	2.99	7.61
2140	1.68	3.37	8.74

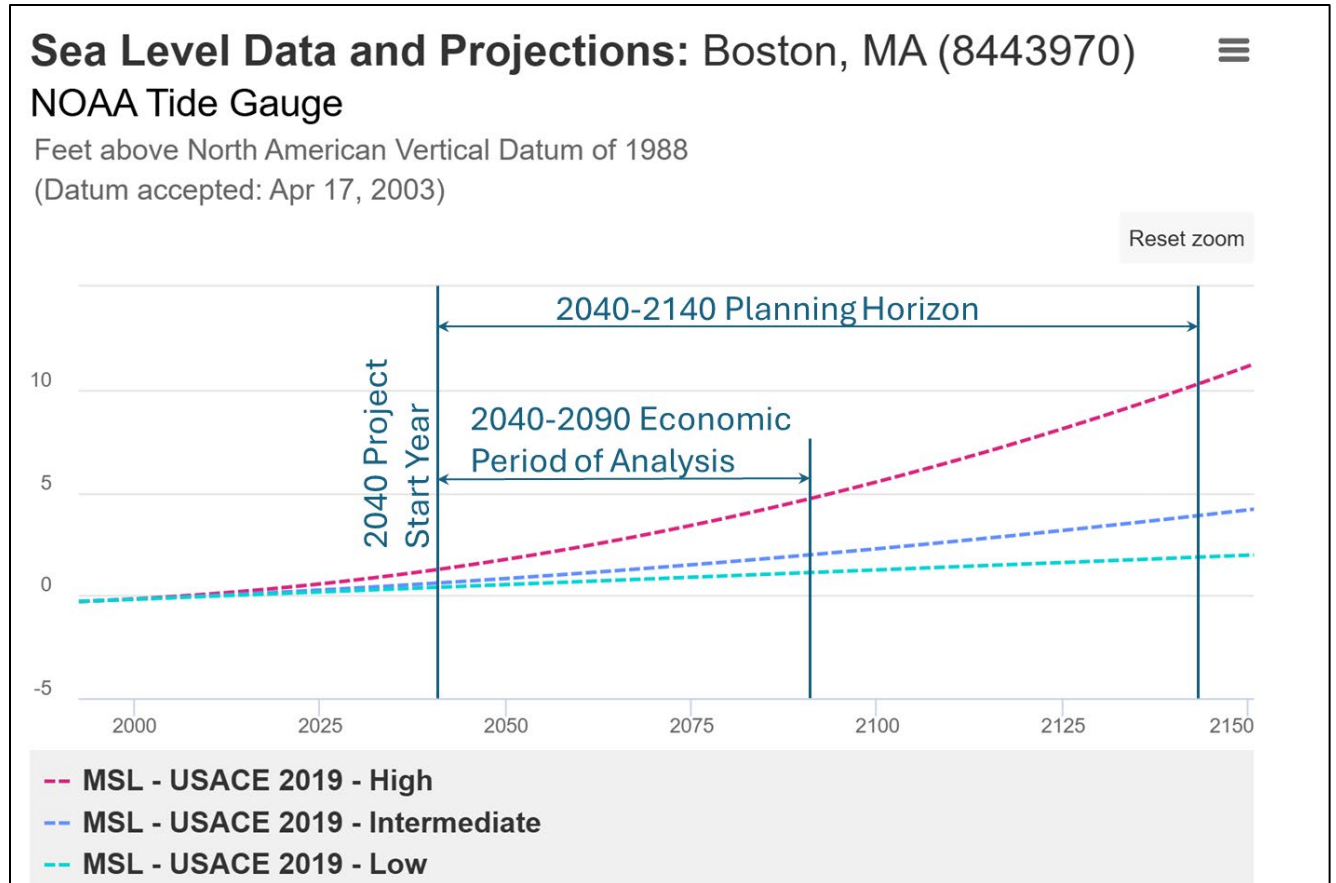


Figure 15. USACE Sea Level Change Scenarios for Boston, MA

4.5 Other Sea Level Change Projections

The USACE SLC curves were compared to other available projections and those that have been used for past and present resilience planning in Boston and Massachusetts. Figure 16 illustrates that the curves fall within the range of projections provided by NOAA and those used in other local planning efforts. Although the USACE curves continue beyond the year 2100, Figure 10 is limited to the year 2100 based on the availability of projections from NOAA.

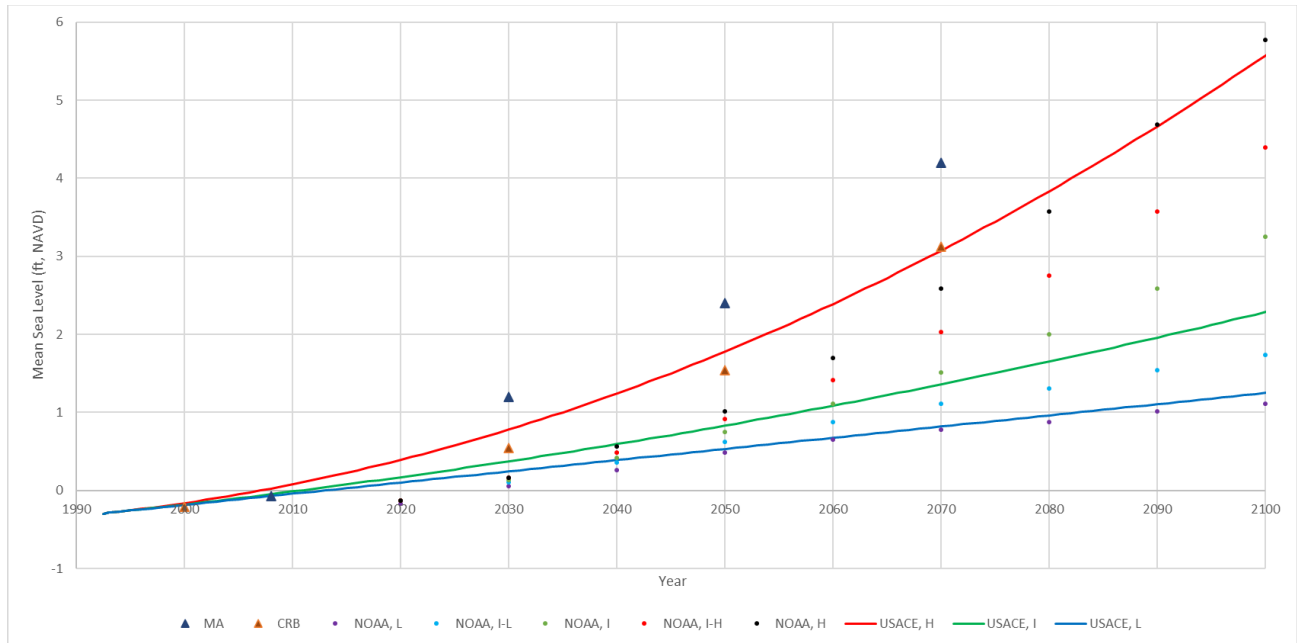


Figure 16. USACE SLC curve comparison to NOAA and local projections

4.5.1 NOAA (2022)

The NOAA (2022) provides SLC projections at 10-year intervals across five climate scenarios—low, intermediate-low, intermediate, intermediate-high, and high. starting from 2020. In Figure 9, these projections are depicted as dots and colored by climate scenario. The NOAA low projections nearly align perfectly with the USACE low curve. The USACE intermediate curve falls between the NOAA intermediate and intermediate-low projections. The USACE high curve projects greater sea level change than the NOAA high scenario over much of the period of analysis, but the two projections converge by 2090 and the end of the century. This illustrates good agreement between the USACE and NOAA projections in the bracketing of potential sea level change futures.

4.5.2 Climate Ready Boston

Climate Ready Boston (CRB) based its sea level rise planning on consensus projections from the Boston Research Advisory Group (BRAG, 2016). The city’s climate initiative plans for sea level change from 2000, projecting 9 inches of sea level rise for the short-term/2030s, 21-inches by mid-century, and 36 inches long-term/2070s. These projections were updated following the 2022 release of the Greater Boston Research Advisory Group’s Climate Change Impacts and Projections for the Greater Boston Area (GBRAG, 2022). The long-term/2070s estimate projecting 40 inches of SLC relative to the year 2000 was used in CRB’s last neighborhood plan, Coastal Resilience Solutions for East Boston & Charlestown Phase II (2022). The CRB projections are depicted as orange triangles in Figure 9.

4.5.3 Massachusetts

The Commonwealth of Massachusetts has a preferred sea level change scenario for use in the assessment of vulnerability and flood risk. These RSLC projections, given for the years 2030, 2050, 2070, and 2100, are listed in Table 3 and shown as blue triangles in Figure 9.

Table 3. Relative mean sea level (feet, NAVD88) projections for Boston, MA

Scenario	2030	2050	2070	2100
MA-High	1.2	2.4	4.2	7.6

The relative sea level change projections developed for the Commonwealth of Massachusetts use a probabilistic approach, closely following the methodology developed by Kopp et al. (2014), with the ice mass model outputs presented by DeConto and Pollard (2016). This methodology produced a continuum of location-specific probability distributions, informed by state-of-the-art process modeling, expert assessment, and expert elicitation. A multi-year reference time period for relative sea level was used to minimize biases caused by tidal, seasonal, and interannual climate variability, following the accepted practice of using a 19-year tidal datum epoch.

Following the approach in the 2017 National Climate Assessment and NOAA's Global and Regional Sea Level Rise Scenarios (2022), conditional probability distributions for sea level change projections were integrated into different scenarios to support planning and decision-making, given uncertainty and future risks. The Commonwealth of Massachusetts selected the High scenario as its preferred scenario for the assessment of vulnerability and flood risk. This scenario is consistent with the following probabilities from Kopp et al. (2017):

- extremely unlikely to be exceeded (99.5%) under RCP 8.5,
- unlikely to exceed (83%) under RCP 8.5 when accounting for possible ice sheet instabilities, and
- extremely unlikely to exceed (95%) under RCP 4.5 when accounting for possible ice sheet instabilities

These projections are used in the Massachusetts Coast Flood Risk Model (MC-FRM), described in Section 5.2.2.2.

5.0 Coastal Hazards

This chapter presents a summary of the coastal hazards that are applicable across the Boston study area in the existing and future without project conditions.

5.1 Astronomical Tide

Daily tidal fluctuations within the study area are semi-diurnal, with a full tidal period that averages 12 hours and 25 minutes; hence there are nearly two full tidal cycles per day. At Boston, the mean tide range (MHW-MLW) is 9.49 feet whereas the great diurnal range (MHHW-MLLW) is 10.27 feet.

The average seasonal cycle of mean sea level, shown in Figure 17, is caused by regular fluctuations in coastal temperatures, salinities, winds, atmospheric pressures, and ocean currents and on average causes a 0.24-foot (0.07 m) difference in sea level from June (highest) to February (lowest).

Interannual (2 or more years) variations in sea level, shown in Figure 18, are caused by irregular fluctuations in coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean current (e.g., El Nino).

Seasonal and interannual variations in sea level can contribute to fluctuations in water levels within the study area.

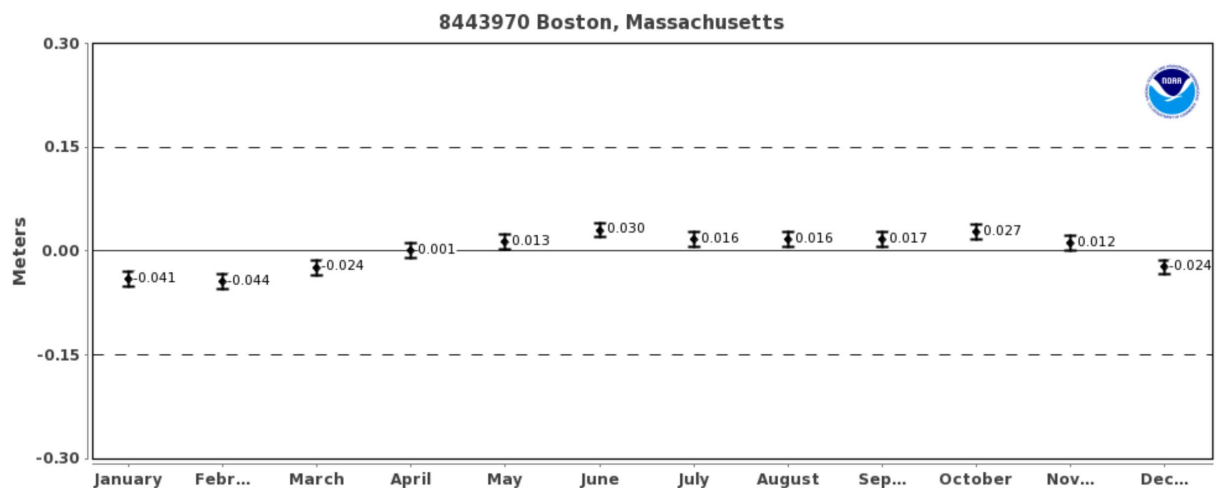


Figure 17. Average seasonal cycle of mean sea level at Boston, MA.

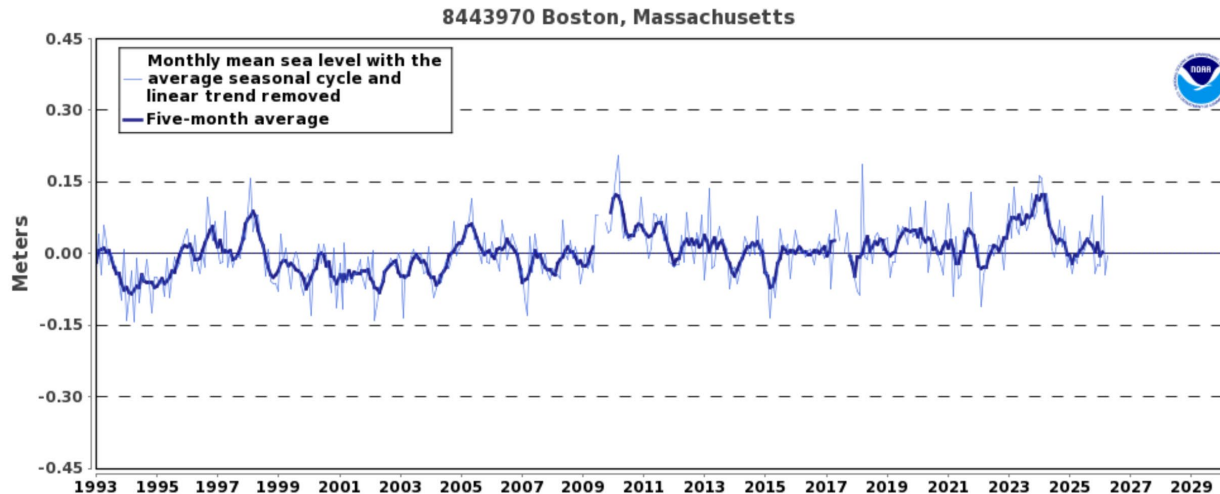


Figure 18. Interannual variation in sea level at Boston, MA since 1990

5.2 Storm Surge

Storm surge is the increased water level above the predicted astronomical tide due to storm winds over the ocean and the resultant wind stress on the ocean surface. The principal factor that creates flood risk for the study area is storm surge generated by tropical and extratropical storms. The magnitude of the storm surge is calculated as the difference between the predicted astronomical tide elevation and the actual water surface elevation. Wind blowing over the ocean surface is capable of generating storm surge. However, the largest and most damaging storm surges develop as a result of either tropical cyclones (hurricanes and tropical storms) or extratropical cyclones (“nor’easters”). Although the meteorological origins of the two storm types differ, both can generate large, low-pressure atmospheric systems with intense wind fields that rotate counterclockwise (in the northern hemisphere). The relatively broad and shallow continental shelf along the east coast allows the generation of larger storm surges than are typically experienced on the U.S. Pacific coast where there is a narrower continental shelf.

5.2.1 Historic Storms

The study area has experienced flooding from both tropical and extratropical cyclones, although extratropical storms predominate the historical record. Table 4 displays the top ten historical storms at the Boston NOAA tide station, all of which are extratropical events. In fact, the largest water level associated with a tropical system is Hurricane Sandy at number 18.

Although extratropical events are the most frequent drivers of high water (the combination of storm surge and astronomical tide) in Boston, the highest storm surge event and three of the top ten storm surge events were tropical cyclones (Table 5). A key takeaway from this data is that the largest storm surge does not always correspond

to the highest total water level. For instance, Hurricane Sandy produced the highest storm surge, but because it did not coincide with a high tide, the total water level was not a record breaker. Conversely, Winter Storm Grayson (January 2018), which had a smaller storm surge, resulted in the highest recorded water level at Boston because it occurred during a particularly high astronomical tide.

Because extratropical cyclones are typically long duration events spanning multiple tidal cycles, there is a greater likelihood that a high tide will occur during the storm surge. The timing of shorter duration tropical cyclones, however, plays a greater role in whether they result in high water events. Because Boston has tidal swings of over 10 feet, the largest storm surges do not always cause the worst flooding. If a massive surge hits at low tide and its total water level falls within the normal tide range, it may not cause noticeable damage. However, if Hurricane Sandy's peak surge had coincided with high tide, it would have shattered historical records and extensively flooded Boston.

Boston is also geographically sheltered from the south and east, directions that have historically borne the brunt of classic landfalling New England hurricanes (e.g., Hurricane of 1938, Hurricane Bob in 1991). Figure 19 shows the 60 historical hurricane tracks that have crossed within 60 miles of Boston between 1851-2025.

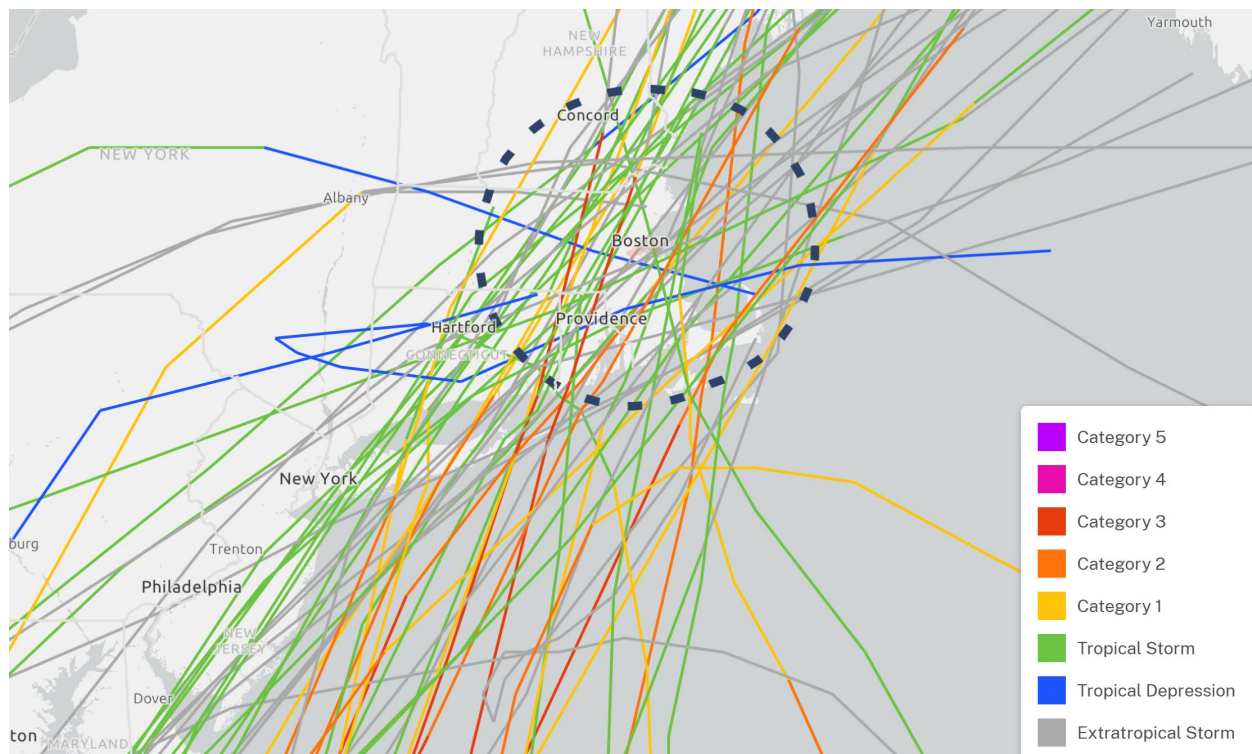


Figure 19. Historical hurricane tracks within 60 miles of Boston.

Table 4. Top 10 recorded water levels at Boston, MA

Date	Peak Height (Feet above MHHW)	Peak Height (Feet NAVD88)	Associated Weather Event	Extratropical (ET) or Tropical (T)
4-Jan-2018	4.89	9.66	Winter Storm Grayson	ET
7-Feb-1978	4.75	9.52	Blizzard of 1978	ET
2-Mar-2018	4.40	9.17	Winter Storm Riley	ET
13-Jan-2024	4.13	8.90	January East Coast Winter Storm	ET
2-Jan-1987	3.92	8.69	New Year's Day Storm	ET
30-Oct-1991	3.89	8.66	"The Perfect Storm"	ET
10-Jan-2024	3.76	8.53	January East Coast Winter Storm	ET
12-Dec-1992	3.72	8.49	Great Nor'easter	ET
23-Dec-2022	3.70	8.47	Coastal Low Pressure & King Tides	ET
24-Jan-1979	3.66	8.43	Nor'easter	ET

Table 5. Top 10 storm surge events at Boston, MA

Date	Peak Storm Surge (feet)	Associated Weather Event	Extratropical (ET) or Tropical (T)
29-Oct-2012	4.76	Hurricane Sandy	T
7-Feb-1978	4.64	Blizzard of 1978	ET
30-Oct-1991	4.10	“The Perfect Storm”	ET
12-Dec-1992	3.95	Great Nor’easter	ET
2-Jan-1987	3.8	New Year’s Day Storm	ET
19-Aug-1991	3.52	Hurricane Bob	T
4-Jan-2018	3.44	Winter Storm Grayson	ET
16-Apr-2007	3.3	Patriots’ Day Storm	ET
31-Aug-1954	3.22	Hurricane Carol	T
24-Jan-2024	3.12	January East Coast Winter Storm	ET

NOAA provides annual exceedance probability curves (Figure 20), represented by the bold black curve, measured in meters or feet relative to MHHW, along with 95% confidence intervals. The curves were calculated by fitting the Generalized Extreme Value (GEV) probability distribution function to annual maximum data (blue dots) from the historical tide record (1921-2025). Water levels for select annual exceedance probabilities are listed in Table 6.

Table 6. Annual exceedance probability water levels at Boston NOAA Station 8443970

Annual Probability of Exceedance (%)	Feet above MHHW (1992)	Feet above NAVD88
99	1.9	6.7
50	2.7	7.5
10	3.6	8.4
1	4.6	9.4

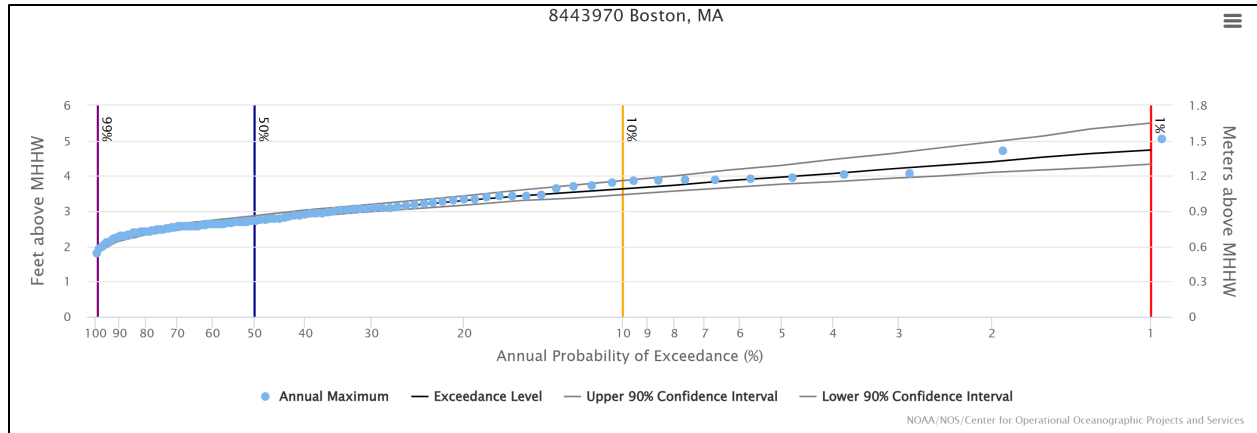


Figure 20. Annual exceedance probability curves for extreme water levels at Boston

5.2.2 Existing Studies

5.2.2.1 NACCS

The North Atlantic Coast Comprehensive Study (NACCS) was authorized under the Disaster Relief Appropriations Act, P. 113-2, in response to Superstorm Sandy. The Act provided the USACE up to \$20 million to conduct a study with the goal to (1) reduce flood risk to vulnerable coastal populations, and (2) promote resilient coastal communities to ensure a sustainable and robust coastal landscape system, considering future sea level change and climate change scenarios.

As part of the NACCS, the U.S. Army Engineer Research and Development Center's Coastal and Hydraulics Laboratory (ERDC-CHL) completed a coastal storm wave and water level modeling effort for the U.S. North Atlantic coast from Virginia to Maine. This modeling study provided nearshore wind, wave, and water level estimates and the associated marginal and joint probabilities critical for effective coastal storm risk management. This modeling effort involved the application of a suite of high-fidelity ADCIRC and STWAVE numerical models within the Coastal Storm Modeling System (CSTORM-MS) to 1050 synthetic tropical storms and 100 historical extratropical storms. Documentation of the numerical modeling effort is provided in Cialone et al. (2015) and documentation of the statistical evaluation is provided in Nadal-Caraballo et al. (2015). Products of the study are available for viewing and download on the Coastal Hazards System (CHS) website: <https://chs.erdrc.dren.mil/>.

The availability of NACCS points through the CHS is shown in Figure 21. While there appear to be an adequate number of points in Figure 21, inspection of the NACCS mesh (Figure 22) showed there were areas that lacked adequate resolution to capture changes in topography and bathymetry associated with critical flood pathways.

Aside from the harbor's main channel, the mesh elements were too largely sized on smaller waterways including Chelsea Creek, Little Mystic Channel, Fort Point Channel,

Reserved Channel, and the Neponset River. Further, the New Charles River Dam and Amelia Earhart Dam flood control structures which impede coastal flood waters were not built into the NACCS mesh. Given these shortcomings of the NACCS within the Boston CSRM study area, the NACCS output could only be used as a starting point.

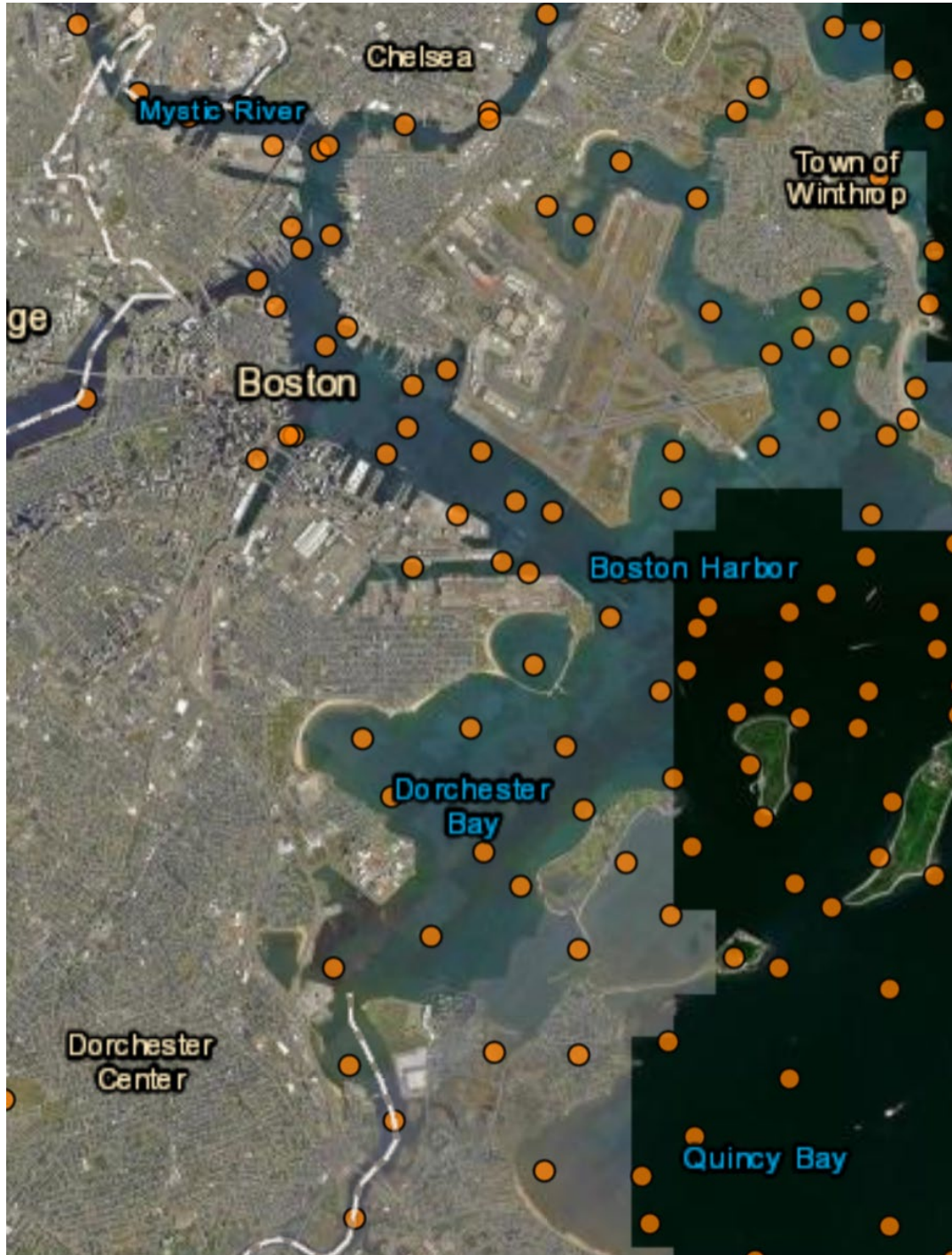


Figure 21. NACCS CHS points within the study area

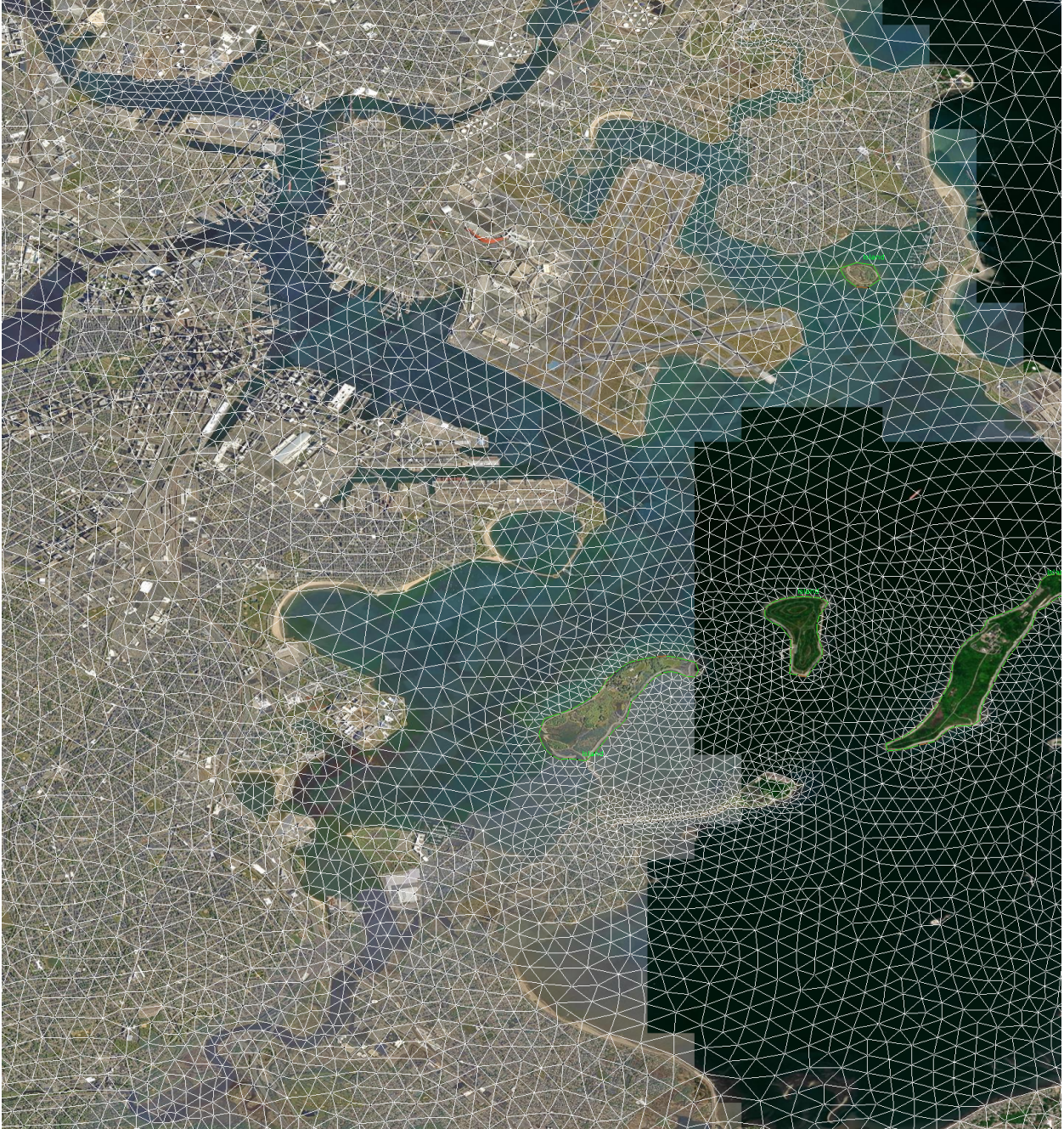


Figure 22. NACCS mesh within the study area

The AEP water levels for Save Point 9572 in the main channel between Seaport and Jeffries Point are provided in Table 7.

Table 7. NACCS Water Levels in feet NAVD88 at Save Point 9572

Average Recurrence Interval (Years)	Water Level (feet NAVD88), Best Estimate
1	6.4
2	7.0
5	7.8
10	8.4
20	8.9
50	9.6
100	10.1
200	10.5
500	11.2

5.2.2.2 MC-FRM

The Massachusetts Coast Flood Risk Model (MC-FRM) was developed by Woods Hole Group to examine the impacts of sea level rise and increased tidal and storm surge flooding throughout the Commonwealth of Massachusetts. The MC-FRM expanded and improved the Boston Harbor Flood Risk Model (BH-FRM), a dynamic, probabilistic sea level rise and storm surge model that focused on Boston Harbor to assess the vulnerability of the Central Artery Tunnel system (Bosma et al., 2015; Douglas et al., 2016). Like NACCS, the MC-FRM used the ADCIRC model to capture circulation and flooding. However, MC-FRM couples ADCIRC with the unstructured version of SWAN, a wave model comparable in its physics and fidelity to STWAVE.

Unlike NACCS which was developed for a regional scale, the BH-FRM and MC-FRM meshes contained far greater detail and resolution focused on the Boston Harbor and Massachusetts coastlines. Node spacing in overland areas is on the order of 5-10 meters (16-33 feet) and as resolved as 2-3 meters (5-10 feet) in highly populated and developed areas. The New Charles River and Amelia Earheart Dams, as well as their operations, are also included within MC-FRM. Figure 23 shows the comparison of mesh element resolution near Boston Logan International Airport, with the finer MC-FRM mesh on the left and the coarser existing NACCS mesh on the right.

The MC-FRM uses the Massachusetts “High” SLC scenario, described in Section 4.5.3. Thus, MC-FRM models coastal hazards for the years 2030, 2050, and 2070 (or MSL at 1.2, 2.4, and 4.2 feet NAVD88).

BH-FRM and MC-FRM were used as the basis for developing resilience solutions in CRB. MC-FRM has further been adopted by the Commonwealth of Massachusetts for defining flood hazards and coastal vulnerability.

Given the precedent of using MC-FRM in CRB and state planning efforts, as well as the more detailed representation of the study area compared to NACCS, an effort was

made early in the Boston CSRM study to adopt the results from MC-FRM. However, the incompatibility of MC-FRM output with G2CRM proved insurmountable.



Figure 23. Comparison element resolution near Logan Airport between the MC-FRM (left) and NACCS (right) ADCIRC meshes.

5.2.3 CHS Modeling for Boston

To attain high fidelity coastal hazard output that could be ingested by G2CRM, NAE tasked ERDC-CHL with refining the NACCS mesh and conducting simulations of a reduced storm suite (RSS) to evaluate existing and future coastal storm risks within the study area.

The NACCS modeling suite and statistical results served as a major starting point for the Boston CSRM study. Leveraging the calibrated and validated numerical modeling domains resolved sufficiently for large-scale regional studies allowed for much less calibration and validation when updating the numerical tools with enhanced resolution in the project area. Two ADCIRC meshes describing the existing and future without-project conditions were created using the NACCS mesh, the MC-FRM mesh, and early alternative alignments. The New Charles River Dam on the Charles River, Amelia Earhart Dam on the Mystic River, and the Baker Dam on the Neponset River were also added to the model as weir pairs, allowing them to be overtopped at their given elevations.

An RSS of 60 synthetic tropical storms and 15 historical extratropical storms was selected from the existing NACCS storm suite to use as representative storms for the project area to estimate water levels and wave heights. The RSS also included the two historic 2018 extratropical storms. Statistical evaluations of the existing and future without project conditions were completed using the CHS Probabilistic Framework. Hazard curves were developed for storm surge, stillwater level, significant wave height, and peak wave period throughout the study area. Time series output was saved at the existing NACCS save points within the study area as well as 440 new locations placed around proposed alternative alignments and other key locations within the city (Figure

24). Output at select save points from this aggregation was packaged as h5 files for input to G2CRM.

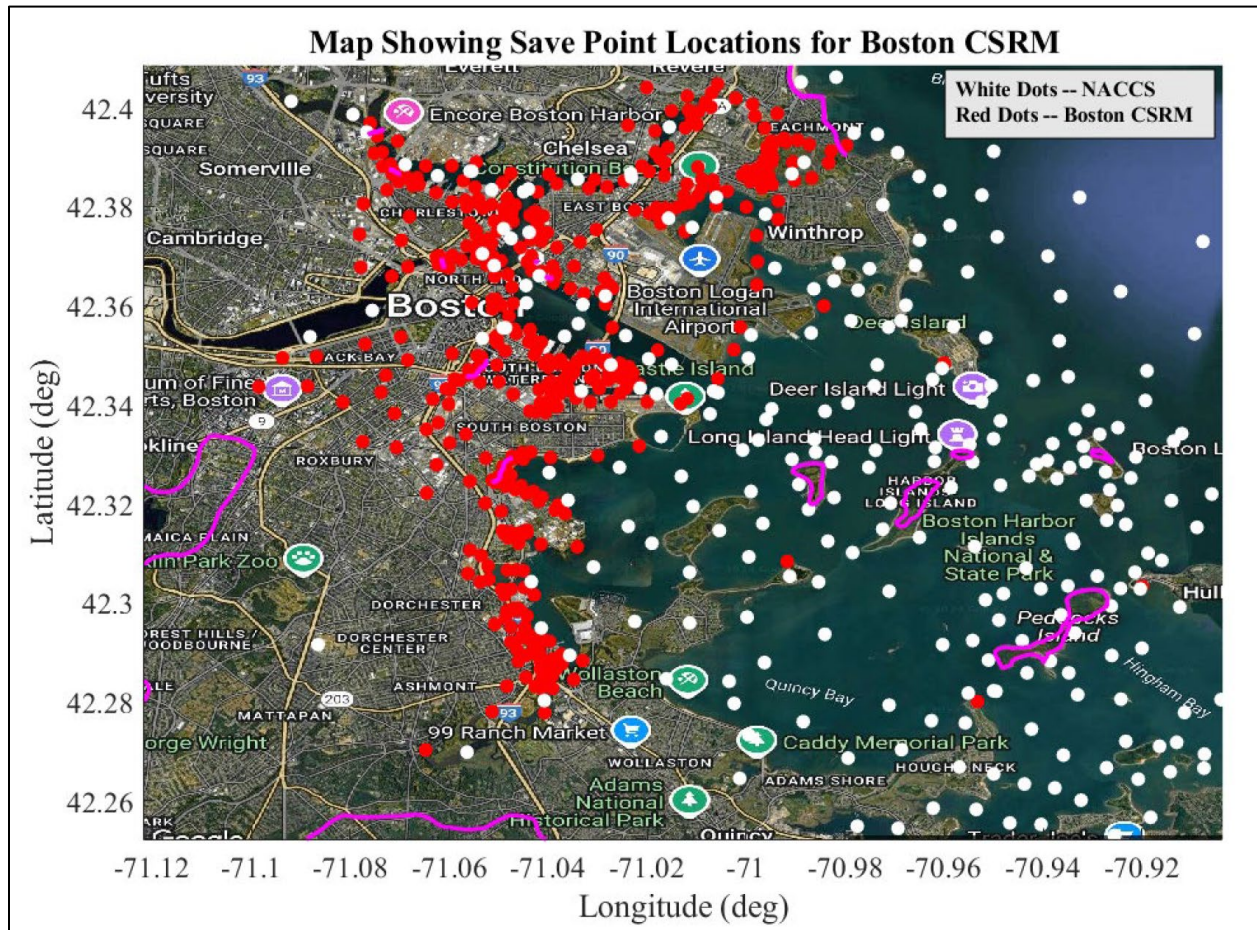


Figure 24. Map of save point locations from the NACCS and Boston CSRM

Due to the presence of the New Charles River Dam and the Amelia Earhart Dam flood risk management structures on the Charles and Mystic Rivers, respectively, flows from these rivers were not included in the ADCIRC simulations. However, on the Neponset River which flows freely into Dorchester Bay, sensitivity testing was conducted to evaluate the potential for combined coastal and riverine flooding. Simulations of eight coastal storm events with and without the 1-percent annual exceedance probability flow at the Baker Dam showed combined coastal and riverine flooding could be an issue upstream of Granite Avenue. However, no change in water surface elevation was observed farther downstream in the vicinity of the Neponset Avenue Bridge, where coastal flooding dominates and the only alternative on the Neponset is located (Figure 25). For this reason, further combined coastal and riverine modeling was suspended and no river flows were used in the production simulations.

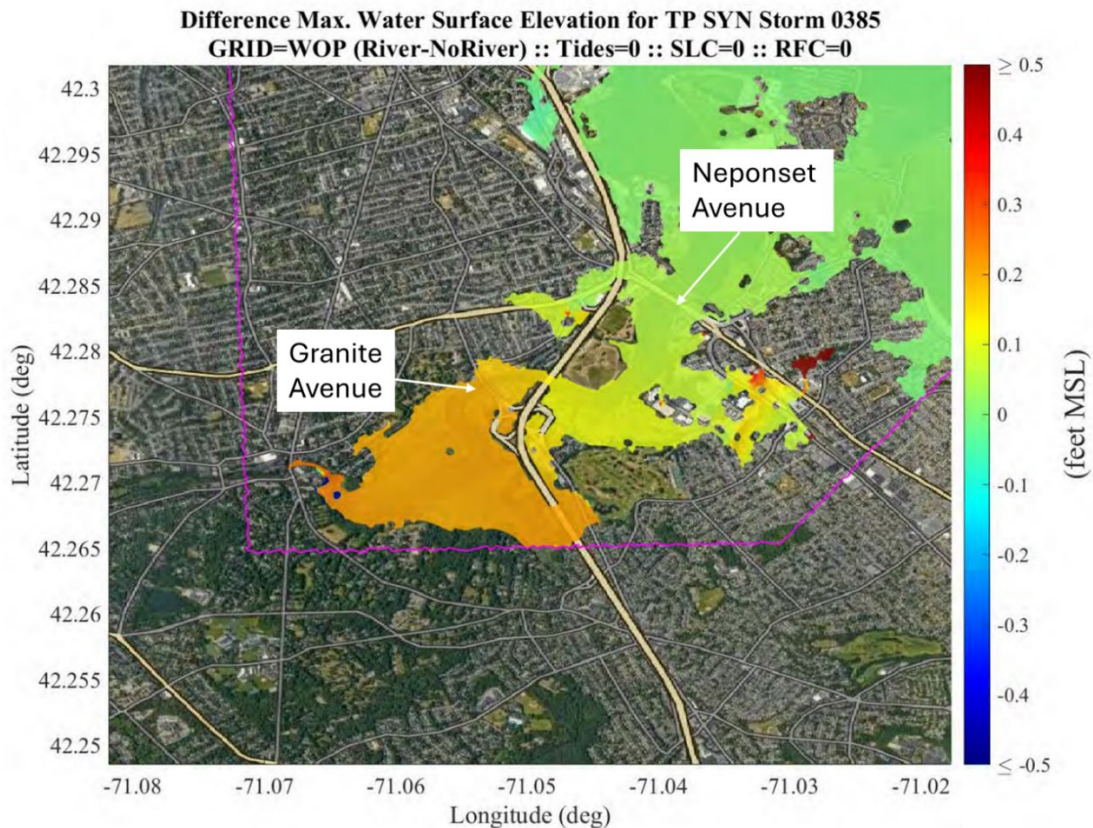


Figure 25. Difference plot comparing water surface elevations with and without river flows on the Neponset for NACCS Tropical Storm 385.

The draft report detailing the ERDC modeling and statistics is provided as an Attachment to this appendix.

The study area was discretized into regions known as model areas for G2CRM. This discretization was based on the 1-percent AEP water levels, study area topography, and flood sources. A representative save point was selected for use in the G2CRM model for each model area. The model areas, representative save points, and best estimate 1-percent annual exceedance probability floodplain for the year 2090 under the USACE high SLC scenario are shown by neighborhood in Figure 26 through Figure 30. Table 8 through Table 11 list the best estimate and 90% confidence limit average recurrence interval (ARI) water levels by save point for the present tidal epoch (MSL = -0.3' NAVD88, 1992) and the year 2090 under the USACE high SLC scenario (MSL = 4.6' NAVD88). These ARI water levels include tides and storm surge. The 2090 ARI water levels also include sea level change.

Note that at this stage only the without-project simulations have been run. The hydraulic and wave parameters utilized to evaluate alternative performance, therefore, do not account for the proposed alternatives within the project area. The physical addition of

barriers may alter local hydrodynamics and result in risk transference. Without the with-project simulations, we have a limited understanding of any increases in flooding that may be caused by the addition of the project. Where with-project modeling has not been conducted, it will need to be completed as the design advances to a 35% design (level 3 cost estimate).



Figure 26. East Boston model areas, save points, and 1% AEP floodplain (best estimate) in 2090 under the USACE High SLC scenario.



Figure 27. Charlestown model areas, save points, and 1% AEP floodplain (best estimate) in 2090 under the USACE High SLC scenario.

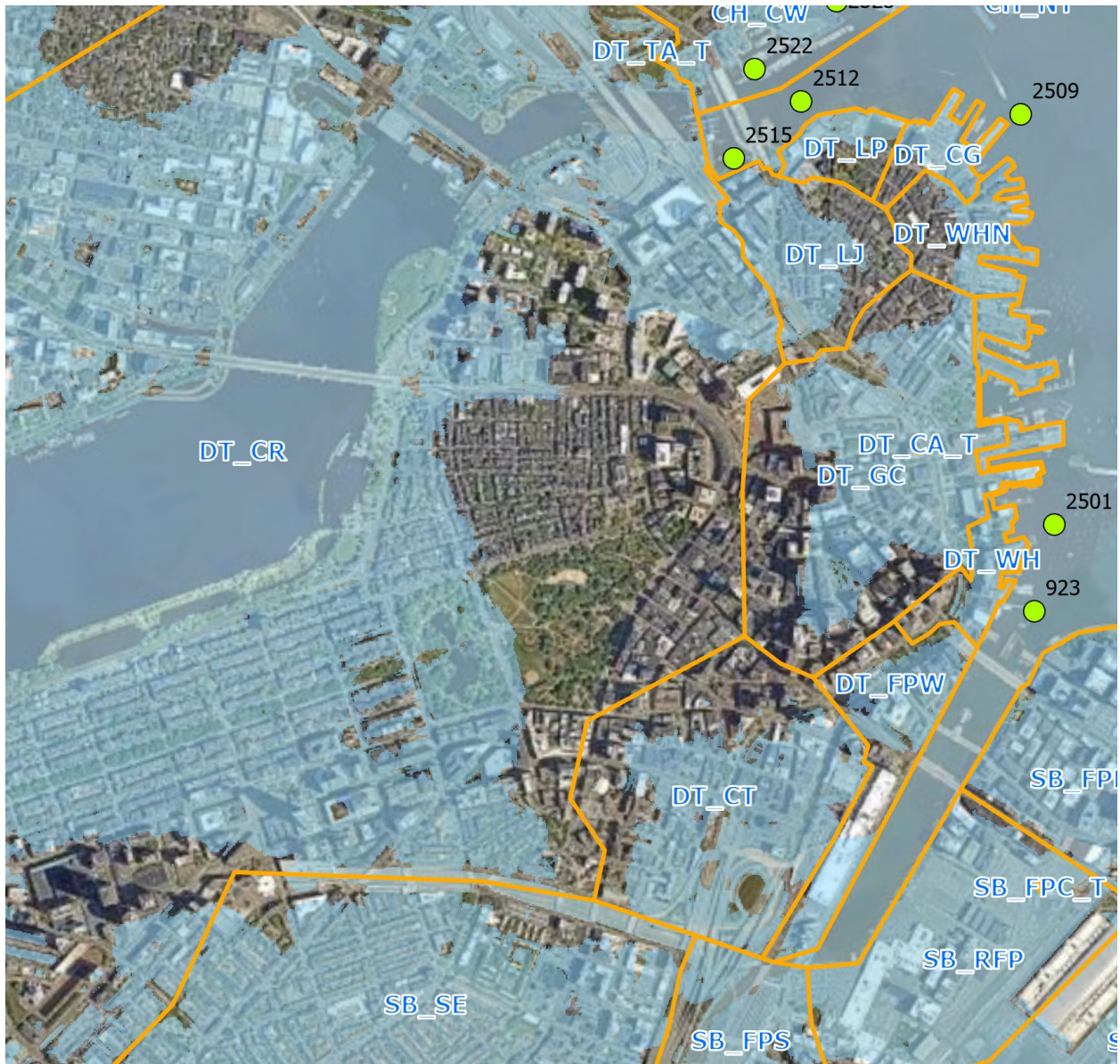


Figure 28. Downtown/North End model areas, save points, and 1% AEP floodplain (best estimate) in 2090 under the USACE High SLC scenario.

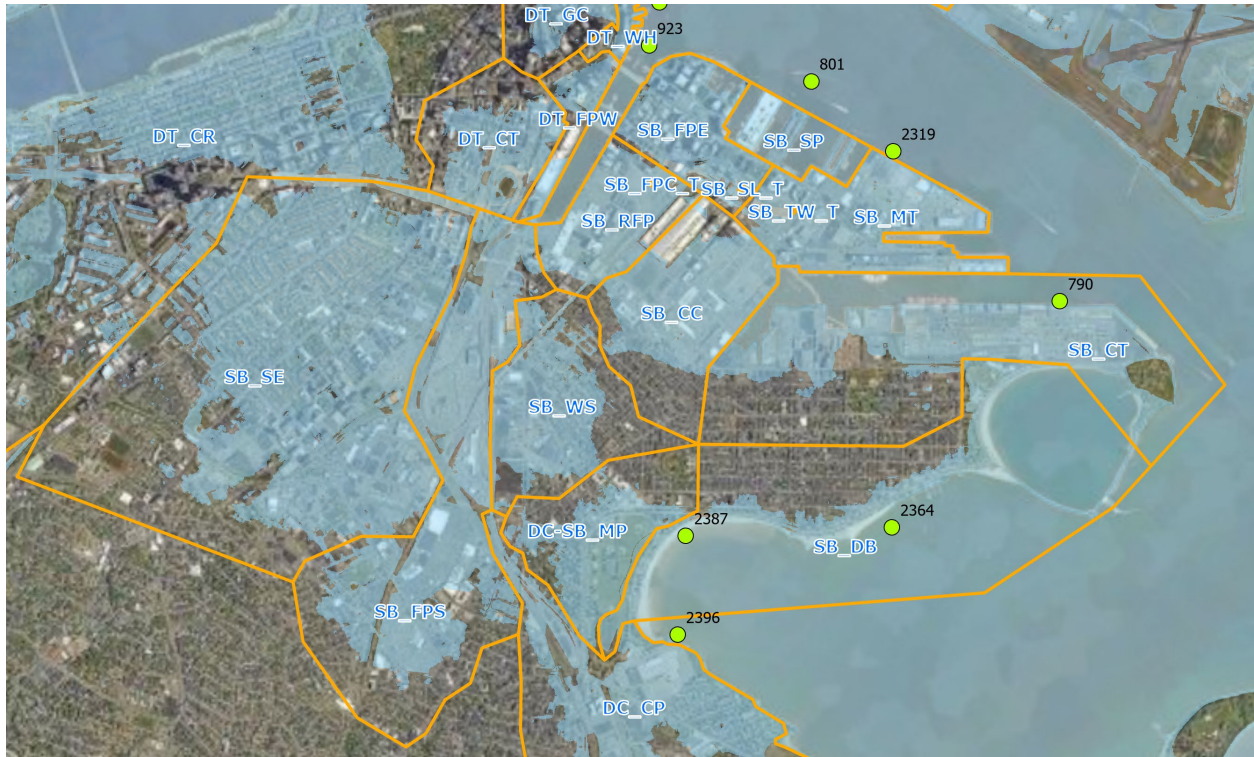


Figure 29. South Boston model areas, save points, and 1% AEP floodplain (best estimate) in 2090 under the USACE High SLC scenario.

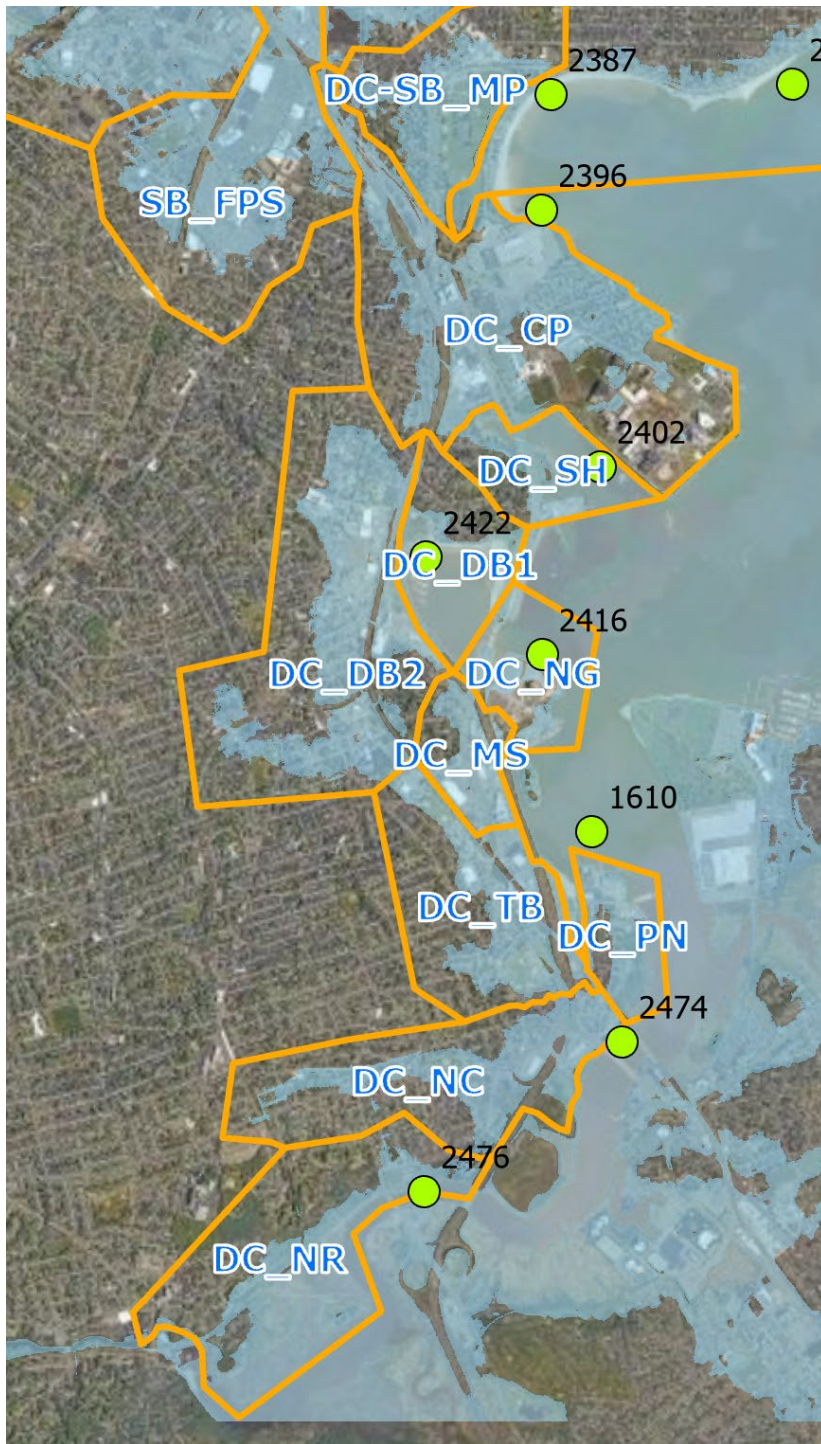


Figure 30. Dorchester model areas, save points, and 1% AEP floodplain (best estimate) in 2090 under the USACE High SLC scenario.

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Table 8. Average Recurrence Interval Best Estimate Water Levels by Model Area in Feet NAVD88 (MSL = -0.3' NAVD88 (1992))

Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	6.8	7.5	8.1	8.6	9.2	9.7	10.2	12.1	13.2
EB_BI	Belle Isle	2675	6.3	7.0	7.5	8.0	8.6	9.1	9.6	10.2	10.7
EB_CB	Constitution Beach	2651	6.7	7.5	8.1	8.5	9.1	9.6	10.3	12.0	13.2
EB_CC	Chelsea Creek	2611	7.6	8.3	8.7	9.2	10.0	10.7	11.5	12.4	13.1
EB_CR	Car Rental	2624	7.5	8.3	8.8	9.3	10.0	10.5	11.2	12.4	13.1
EB_CTP_T	Callahan Tunnel Portal	2579	6.8	7.5	8.1	8.6	9.2	9.7	10.2	12.1	13.2
EB_RY	Railyard	2675	6.3	7.0	7.5	8.0	8.6	9.1	9.6	10.2	10.7
EB_OH	Orient Heights	2611	7.6	8.3	8.7	9.2	10.0	10.7	11.5	12.4	13.1
EB_EH	Eagle Hill	2595	6.6	7.4	7.9	8.4	9.1	9.7	10.4	11.8	12.6
EB_MBTA-C_T	MBTA Central Tunnel	2579	6.8	7.5	8.1	8.6	9.2	9.7	10.2	12.1	13.2
EB_STP_T	Sumner Tunnel Portal	2579	6.8	7.5	8.1	8.6	9.2	9.7	10.2	12.1	13.2
EB_WF	Waterfront	2579	6.8	7.5	8.1	8.6	9.2	9.7	10.2	12.1	13.2
Charlestown											
CH_AP	Auto Port	813	6.8	7.5	8.1	8.6	9.2	9.7	10.4	12.1	13.3
CH_CG	Charlestown Garage	2556	6.8	7.6	8.1	8.6	9.2	9.7	10.5	12.3	13.4
CH_CW	Constitution Wharf	2523	6.8	7.5	8.1	8.7	9.6	10.4	11.4	12.3	13.1
CH_LM	Little Mystic	2538	6.7	7.5	8.0	8.6	9.3	9.8	10.4	12.0	13.1
CH_NY	Navy Yard	2531	6.8	7.5	8.0	8.5	9.2	9.8	10.3	12.0	13.2
CH_RP	Ryan Playground	2552	6.8	7.5	8.1	8.6	9.2	9.6	10.4	12.2	13.4
Downtown											
DT_CA_T	Central Artery Tunnel	2501	6.8	7.6	8.1	8.6	9.2	9.7	10.3	12.0	13.1
DT_CG	Coast Guard	2509	6.8	7.5	8.0	8.6	9.2	9.8	10.3	12.1	13.2
DT_CR	Charles River	2522	6.2	6.6	6.8	7.3	8.2	9.2	10.4	12.1	13.2
DT_CT	Chinatown	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
DT_FPW	Fort Point West	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
DT_GC	Government Center	2501	6.8	7.6	8.1	8.6	9.2	9.7	10.3	12.0	13.1

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Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	7.3	8.5	9.1	9.6	10.1	10.4	10.6	12.1	13.2
DT_LP	Langone-Puopolo	2512	6.9	7.8	8.4	9.0	9.6	10.1	10.6	12.0	13.3
DT_TA_T	Tobin Approach Tunnel	2522	6.2	6.6	6.8	7.3	8.2	9.2	10.4	12.1	13.2
DT_WH	Wharves	2501	6.8	7.6	8.1	8.6	9.2	9.7	10.3	12.0	13.1
DT_WHN	Wharves North	2501	6.8	7.6	8.1	8.6	9.2	9.7	10.3	12.0	13.1
South Boston											
SB_CC	Convention Center	790	6.7	7.5	8.0	8.5	9.1	9.5	9.9	11.8	13.4
SB_CT	Conley Terminal	790	6.7	7.5	8.0	8.5	9.1	9.5	9.9	11.8	13.4
SB_DB	Dorchester Bay	2364	6.8	7.6	8.1	8.6	9.2	9.7	10.2	11.8	13.6
SB_FPC_T	Fort Point Channel Tunnel	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_FPE	Fort Point East	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_FPS	Fort Point South	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_MT	Marine Terminal	2319	6.8	7.6	8.1	8.6	9.3	9.8	10.4	12.1	13.7
SB_RFP	Resilient Fort Point	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_SE	South End	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_SL_T	Silver Line Tunnel	923	6.8	7.6	8.1	8.6	9.2	9.7	10.4	12.0	13.1
SB_SP	Seaport	801	6.7	7.4	8.0	8.5	9.2	9.9	10.6	11.9	13.1
SB_TW_T	Ted Williams Tunnel	2319	6.8	7.6	8.1	8.6	9.3	9.8	10.4	12.1	13.7
SB_WS	West Streets	2396	6.8	7.6	8.1	8.7	9.4	9.9	10.5	12.0	13.7
Dorchester											
DC_CP	Columbia Point	2396	6.8	7.6	8.1	8.7	9.4	9.9	10.5	12.0	13.7
DC_DB1	Dorchester Basin 1	2422	6.8	7.5	8.2	8.9	9.8	10.4	11.0	11.8	13.5
DC_DB2	Dorchester Basin 2	2422	6.8	7.5	8.2	8.9	9.8	10.4	11.0	11.8	13.5
DC-SB_MP	Moakley Park	2387	6.8	7.5	8.1	8.6	9.3	9.8	10.3	11.6	13.2
DC_MS	Morrissey South	1610	6.8	7.6	8.2	8.7	9.4	9.9	10.5	12.1	13.1
DC_NC	Neponset Circle	2474	6.9	7.6	8.3	8.8	9.5	10.0	10.6	12.4	14.3
DC_NG	National Grid	2416	6.8	7.7	8.2	8.8	9.5	10.0	10.6	12.2	13.9

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Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	7.2	7.8	8.3	8.8	9.6	10.3	11.2	12.1	13.8
DC_PN	Port Norfolk	1610	6.8	7.6	8.2	8.7	9.4	9.9	10.5	12.1	13.1
DC_SH	Savin Hill	2402	6.8	7.6	8.2	8.7	9.4	9.9	10.4	12.1	13.7
DC_TB	Tenean Beach	1610	6.8	7.6	8.2	8.7	9.4	9.9	10.5	12.1	13.1

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Table 9. Average Recurrence Interval 90% Confidence Limit Water Levels by Model Area in Feet NAVD88 (MSL = -0.3' NAVD88 (1992))

Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.6	14.7
EB_BI	Belle Isle	2675	7.8	8.5	9.0	9.5	10.1	10.6	11.1	11.7	12.2
EB_CB	Constitution Beach	2651	8.2	9.0	9.5	10.0	10.6	11.1	11.8	13.5	14.7
EB_CC	Chelsea Creek	2611	9.1	9.8	10.2	10.7	11.5	12.2	13.0	13.9	14.7
EB_CR	Car Rental	2624	9.0	9.8	10.3	10.9	11.5	12.0	12.7	13.9	14.7
EB_CTP_T	Callahan Tunnel Portal	2579	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.6	14.7
EB_RY	Railyard	2675	7.8	8.5	9.0	9.5	10.1	10.6	11.1	11.7	12.2
EB_OH	Orient Heights	2611	9.1	9.8	10.2	10.7	11.5	12.2	13.0	13.9	14.7
EB_EH	Eagle Hill	2595	8.1	8.8	9.4	9.9	10.6	11.2	12.0	13.4	14.1
EB_MBTA-C_T	MBTA Central Tunnel	2579	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.6	14.7
EB_STP_T	Sumner Tunnel Portal	2579	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.6	14.7
EB_WF	Waterfront	2579	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.6	14.7
Charlestown											
CH_AP	Auto Port	813	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.6	14.9
CH_CG	Charlestown Garage	2556	8.3	9.1	9.6	10.1	10.8	11.2	12.0	13.9	15.0
CH_CW	Constitution Wharf	2523	8.3	9.0	9.6	10.2	11.1	11.9	12.9	13.8	14.7
CH_LM	Little Mystic	2538	8.2	8.9	9.5	10.1	10.8	11.3	11.9	13.6	14.7
CH_NY	Navy Yard	2531	8.2	8.9	9.5	10.0	10.7	11.3	11.8	13.6	14.8
CH_RP	Ryan Playground	2552	8.3	9.0	9.6	10.1	10.7	11.1	11.9	13.7	15.0
Downtown											
DT_CA_T	Central Artery Tunnel	2501	8.2	9.0	9.6	10.1	10.7	11.2	11.8	13.5	14.6
DT_CG	Coast Guard	2509	8.2	8.9	9.5	10.0	10.7	11.3	11.8	13.6	14.7
DT_CR	Charles River	2522	7.6	8.0	8.3	8.7	9.7	10.7	11.9	13.6	14.7
DT_CT	Chinatown	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
DT_FPW	Fort Point West	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
DT_GC	Government Center	2501	8.2	9.0	9.6	10.1	10.7	11.2	11.8	13.5	14.6

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Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	8.8	10.0	10.6	11.1	11.6	11.9	12.1	13.6	14.7
DT_LP	Langone-Puopolo	2512	8.4	9.3	9.9	10.4	11.1	11.6	12.1	13.5	14.8
DT_TA_T	Tobin Approach Tunnel	2522	7.6	8.0	8.3	8.7	9.7	10.7	11.9	13.6	14.7
DT_WH	Wharves	2501	8.2	9.0	9.6	10.1	10.7	11.2	11.8	13.5	14.6
DT_WHN	Wharves North	2501	8.2	9.0	9.6	10.1	10.7	11.2	11.8	13.5	14.6
South Boston											
SB_CC	Convention Center	790	8.2	8.9	9.5	10.0	10.5	11.0	11.4	13.3	14.9
SB_CT	Conley Terminal	790	8.2	8.9	9.5	10.0	10.5	11.0	11.4	13.3	14.9
SB_DB	Dorchester Bay	2364	8.2	9.0	9.6	10.1	10.7	11.2	11.7	13.3	15.1
SB_FPC_T	Fort Point Channel Tunnel	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_FPE	Fort Point East	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_FPS	Fort Point South	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_MT	Marine Terminal	2319	8.2	9.0	9.6	10.1	10.8	11.3	11.9	13.5	15.2
SB_RFP	Resilient Fort Point	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_SE	South End	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_SL_T	Silver Line Tunnel	923	8.2	9.0	9.6	10.1	10.7	11.2	11.9	13.5	14.6
SB_SP	Seaport	801	8.2	8.9	9.4	10.0	10.7	11.4	12.1	13.4	14.6
SB_TW_T	Ted Williams Tunnel	2319	8.2	9.0	9.6	10.1	10.8	11.3	11.9	13.5	15.2
SB_WS	West Streets	2396	8.2	9.0	9.6	10.1	10.8	11.4	12.0	13.4	15.2
Dorchester											
DC_CP	Columbia Point	2396	8.2	9.0	9.6	10.1	10.8	11.4	12.0	13.4	15.2
DC_DB1	Dorchester Basin 1	2422	8.3	8.9	9.6	10.4	11.2	11.8	12.5	13.3	15.0
DC_DB2	Dorchester Basin 2	2422	8.3	8.9	9.6	10.4	11.2	11.8	12.5	13.3	15.0
DC-SB_MP	Moakley Park	2387	8.3	9.0	9.6	10.1	10.7	11.2	11.8	13.1	14.7
DC_MS	Morrissey South	1610	8.3	9.1	9.6	10.2	10.9	11.4	11.9	13.6	14.6
DC_NC	Neponset Circle	2474	8.3	9.1	9.7	10.3	10.9	11.4	12.1	13.9	15.7
DC_NG	National Grid	2416	8.3	9.1	9.7	10.2	10.9	11.5	12.1	13.7	15.4

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Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	8.6	9.2	9.7	10.2	11.1	11.8	12.6	13.5	15.3
DC_PN	Port Norfolk	1610	8.3	9.1	9.6	10.2	10.9	11.4	11.9	13.6	14.6
DC_SH	Savin Hill	2402	8.3	9.1	9.7	10.2	10.8	11.3	11.9	13.6	15.2
DC_TB	Tenean Beach	1610	8.3	9.1	9.6	10.2	10.9	11.4	11.9	13.6	14.6

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Table 10. Average Recurrence Interval Best Estimate Water Levels by Model Area in Feet NAVD88 (MSL = 4.7' NAVD88 (2090 USACE High SLC))

Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.9	17.3
EB_BI	Belle Isle	2675	12.3	12.8	13.0	13.2	13.5	13.7	14.0	14.3	14.4
EB_CB	Constitution Beach	2651	12.2	12.6	13.0	13.3	13.7	14.0	14.4	14.9	15.0
EB_CC	Chelsea Creek	2611	12.2	12.7	12.9	13.2	13.6	14.0	14.5	20.0	23.4
EB_CR	Car Rental	2624	12.3	12.8	13.0	13.2	13.6	14.0	14.5	19.3	23.2
EB_CTP_T	Callahan Tunnel Portal	2579	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.9	17.3
EB_RY	Railyard	2675	12.3	12.8	13.0	13.2	13.5	13.7	14.0	14.3	14.4
EB_OH	Orient Heights	2611	12.2	12.7	12.9	13.2	13.6	14.0	14.5	20.0	23.4
EB_EH	Eagle Hill	2595	12.2	12.7	13.0	13.4	14.0	14.5	15.1	15.9	17.4
EB_MBTA-C_T	MBTA Central Tunnel	2579	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.9	17.3
EB_STP_T	Sumner Tunnel Portal	2579	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.9	17.3
EB_WF	Waterfront	2579	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.9	17.3
Charlestown											
CH_AP	Auto Port	813	12.2	12.6	13.0	13.4	13.9	14.4	15.0	15.9	17.5
CH_CG	Charlestown Garage	2556	12.2	12.6	12.8	13.1	13.5	13.8	14.4	15.6	17.0
CH_CW	Constitution Wharf	2523	12.1	12.6	13.0	13.4	13.9	14.3	14.9	16.1	17.6
CH_LM	Little Mystic	2538	12.2	12.6	12.9	13.2	13.6	14.0	14.5	16.0	17.4
CH_NY	Navy Yard	2531	12.2	12.6	13.0	13.4	13.9	14.4	14.9	15.9	17.5
CH_RP	Ryan Playground	2552	12.2	12.6	12.8	13.1	13.4	13.8	14.5	15.7	17.1
Downtown											
DT_CA_T	Central Artery Tunnel	2501	12.2	12.6	13.0	13.4	13.9	14.3	14.8	16.0	17.6
DT_CG	Coast Guard	2509	12.2	12.7	13.0	13.4	14.0	14.4	14.9	15.9	17.4
DT_CR	Charles River	2522	12.1	12.5	12.8	13.1	13.5	13.8	14.5	16.0	17.4
DT_CT	Chinatown	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
DT_FPW	Fort Point West	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
DT_GC	Government Center	2501	12.2	12.6	13.0	13.4	13.9	14.3	14.8	16.0	17.6

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Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	12.3	12.8	13.0	13.2	13.5	14.0	14.7	16.2	17.5
DT_LP	Langone-Puopolo	2512	12.2	12.6	12.9	13.3	13.6	14.0	14.5	16.0	17.4
DT_TA_T	Tobin Approach Tunnel	2522	12.1	12.5	12.8	13.1	13.5	13.8	14.5	16.0	17.4
DT_WH	Wharves	2501	12.2	12.6	13.0	13.4	13.9	14.3	14.8	16.0	17.6
DT_WHN	Wharves North	2501	12.2	12.6	13.0	13.4	13.9	14.3	14.8	16.0	17.6
South Boston											
SB_CC	Convention Center	790	12.1	12.6	13.0	13.4	13.9	14.2	14.6	15.9	17.5
SB_CT	Conley Terminal	790	12.1	12.6	13.0	13.4	13.9	14.2	14.6	15.9	17.5
SB_DB	Dorchester Bay	2364	12.2	12.7	13.1	13.4	13.9	14.2	14.5	16.0	17.6
SB_FPC_T	Fort Point Channel Tunnel	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_FPE	Fort Point East	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_FPS	Fort Point South	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_MT	Marine Terminal	2319	12.2	12.7	13.1	13.5	13.9	14.2	14.7	16.2	17.8
SB_RFP	Resilient Fort Point	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_SE	South End	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_SL_T	Silver Line Tunnel	923	12.1	12.6	12.9	13.3	13.9	14.5	15.2	16.2	17.9
SB_SP	Seaport	801	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.8	17.3
SB_TW_T	Ted Williams Tunnel	2319	12.2	12.7	13.1	13.5	13.9	14.2	14.7	16.2	17.8
SB_WS	West Streets	2396	12.3	12.8	13.2	13.6	14.1	14.5	15.0	16.0	17.4
Dorchester											
DC_CP	Columbia Point	2396	12.2	12.7	13.0	13.4	13.9	14.2	14.6	15.8	17.3
DC_DB1	Dorchester Basin 1	2422	12.3	12.8	13.1	13.3	13.6	14.1	14.8	16.1	17.3
DC_DB2	Dorchester Basin 2	2422	12.3	12.8	13.1	13.3	13.6	14.1	14.8	16.1	17.3
DC-SB_MP	Moakley Park	2387	12.2	12.7	12.9	13.2	13.5	14.0	14.7	16.2	17.7
DC_MS	Morrissey South	1610	12.3	12.8	13.2	13.5	13.9	14.2	14.8	16.4	17.9
DC_NC	Neponset Circle	2474	12.3	12.9	13.3	13.6	14.1	14.4	14.7	16.0	17.4
DC_NG	National Grid	2416	12.2	12.7	13.1	13.5	13.9	14.3	14.8	16.5	18.0

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Model Area	Description	Save Point	Water level (ft, NAVD88) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	12.7	13.5	14.1	14.8	15.7	16.5	17.1	17.9	18.4
DC_PN	Port Norfolk	1610	12.3	12.8	13.2	13.5	13.9	14.2	14.8	16.4	17.9
DC_SH	Savin Hill	2402	12.2	12.7	13.1	13.5	13.9	14.3	14.7	16.4	17.9
DC_TB	Tenean Beach	1610	12.3	12.8	13.2	13.5	13.9	14.2	14.8	16.4	17.9

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Table 11. Average Recurrence Interval 90% Confidence Limit Water Levels by Model Area in Feet NAVD88 (MSL = 4.6' NAVD88 (2090 USACE High SLC))

Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	13.7	14.2	14.5	14.9	15.4	15.7	16.1	17.4	18.8
EB_BI	Belle Isle	2675	13.9	14.3	14.5	14.7	15.0	15.2	15.5	15.9	16.0
EB_CB	Constitution Beach	2651	13.7	14.2	14.5	14.8	15.2	15.6	15.9	16.5	16.5
EB_CC	Chelsea Creek	2611	13.8	14.2	14.5	14.7	15.1	15.5	16.1	21.5	24.9
EB_CR	Car Rental	2624	13.8	14.3	14.5	14.7	15.1	15.5	16.0	20.9	24.7
EB_CTP_T	Callahan Tunnel Portal	2579	13.7	14.2	14.5	14.9	15.4	15.7	16.1	17.4	18.8
EB_RY	Railyard	2675	13.9	14.3	14.5	14.7	15.0	15.2	15.5	15.9	16.0
EB_OH	Orient Heights	2611	13.8	14.2	14.5	14.7	15.1	15.5	16.1	21.5	24.9
EB_EH	Eagle Hill	2595	13.7	14.2	14.6	15.0	15.5	16.0	16.6	17.4	18.9
EB_MBTA-C_T	MBTA Central Tunnel	2579	13.7	14.2	14.5	14.9	15.4	15.7	16.1	17.4	18.8
EB_STP_T	Sumner Tunnel Portal	2579	13.7	14.2	14.5	14.9	15.4	15.7	16.1	17.4	18.8
EB_WF	Waterfront	2579	13.7	14.2	14.5	14.9	15.4	15.7	16.1	17.4	18.8
Charlestown											
CH_AP	Auto Port	813	13.7	14.2	14.5	14.9	15.5	15.9	16.5	17.5	19.0
CH_CG	Charlestown Garage	2556	13.7	14.1	14.4	14.6	15.0	15.3	16.0	17.1	18.5
CH_CW	Constitution Wharf	2523	13.7	14.1	14.5	14.9	15.4	15.8	16.4	17.6	19.1
CH_LM	Little Mystic	2538	13.7	14.1	14.4	14.7	15.2	15.5	16.1	17.5	18.9
CH_NY	Navy Yard	2531	13.7	14.1	14.5	14.9	15.4	15.9	16.4	17.4	19.0
CH_RP	Ryan Playground	2552	13.7	14.1	14.4	14.6	14.9	15.3	16.0	17.3	18.6
Downtown											
DT_CA_T	Central Artery Tunnel	2501	13.7	14.1	14.5	14.9	15.4	15.8	16.3	17.5	19.2
DT_CG	Coast Guard	2509	13.7	14.2	14.5	15.0	15.5	15.9	16.4	17.4	18.9
DT_CR	Charles River	2522	13.6	14.1	14.3	14.6	15.0	15.3	16.0	17.5	19.0
DT_CT	Chinatown	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
DT_FPW	Fort Point West	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
DT_GC	Government Center	2501	13.7	14.1	14.5	14.9	15.4	15.8	16.3	17.5	19.2

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Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	13.8	14.3	14.5	14.7	15.0	15.5	16.2	17.7	19.0
DT_LP	Langone-Puopolo	2512	13.7	14.1	14.5	14.8	15.2	15.5	16.0	17.5	18.9
DT_TA_T	Tobin Approach Tunnel	2522	13.6	14.1	14.3	14.6	15.0	15.3	16.0	17.5	19.0
DT_WH	Wharves	2501	13.7	14.1	14.5	14.9	15.4	15.8	16.3	17.5	19.2
DT_WHN	Wharves North	2501	13.7	14.1	14.5	14.9	15.4	15.8	16.3	17.5	19.2
South Boston											
SB_CC	Convention Center	790	13.6	14.1	14.5	14.9	15.4	15.8	16.1	17.4	19.0
SB_CT	Conley Terminal	790	13.6	14.1	14.5	14.9	15.4	15.8	16.1	17.4	19.0
SB_DB	Dorchester Bay	2364	13.7	14.2	14.5	14.9	15.4	15.7	16.0	17.5	19.1
SB_FPC_T	Fort Point Channel Tunnel	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_FPE	Fort Point East	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_FPS	Fort Point South	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_MT	Marine Terminal	2319	13.7	14.2	14.6	15.0	15.4	15.7	16.2	17.6	19.3
SB_RFP	Resilient Fort Point	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_SE	South End	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_SL_T	Silver Line Tunnel	923	13.6	14.1	14.4	14.8	15.4	16.0	16.7	17.7	19.4
SB_SP	Seaport	801	13.7	14.2	14.5	14.9	15.4	15.8	16.1	17.3	18.8
SB_TW_T	Ted Williams Tunnel	2319	13.7	14.2	14.6	15.0	15.4	15.7	16.2	17.6	19.3
SB_WS	West Streets	2396	13.7	14.3	14.7	15.1	15.6	16.0	16.5	17.5	18.9
Dorchester											
DC_CP	Columbia Point	2396	13.7	14.2	14.5	14.9	15.4	15.8	16.1	17.3	18.8
DC_DB1	Dorchester Basin 1	2422	13.7	14.2	14.5	14.8	15.1	15.6	16.3	17.6	18.8
DC_DB2	Dorchester Basin 2	2422	13.7	14.2	14.5	14.8	15.1	15.6	16.3	17.6	18.8
DC-SB_MP	Moakley Park	2387	13.7	14.2	14.4	14.7	15.0	15.5	16.2	17.7	19.2
DC_MS	Morrissey South	1610	13.7	14.3	14.6	15.0	15.4	15.7	16.3	17.9	19.4
DC_NC	Neponset Circle	2474	13.8	14.4	14.7	15.1	15.5	15.9	16.2	17.4	18.9
DC_NG	National Grid	2416	13.7	14.2	14.6	15.0	15.4	15.8	16.3	18.0	19.5

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Model Area	Description	Save Point	Water level (ft, NAVD88) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	14.2	15.0	15.6	16.3	17.2	17.9	18.6	19.4	19.9
DC_PN	Port Norfolk	1610	13.7	14.3	14.6	15.0	15.4	15.7	16.3	17.9	19.4
DC_SH	Savin Hill	2402	13.7	14.2	14.6	15.0	15.4	15.8	16.2	17.9	19.4
DC_TB	Tenean Beach	1610	13.7	14.3	14.6	15.0	15.4	15.7	16.3	17.9	19.4

5.3 Waves

The wave climate in Boston Harbor is overall a sheltered, low-energy estuarine environment. This wave regime is primarily the result of the Boston Harbor Islands and surrounding peninsulas, which act as a natural barrier that blocks and absorbs the high-energy ocean waves propagating from Massachusetts Bay. As a result, typical waves inside the harbor are fetch-limited and remain quite small, though extreme storm events can still drive temporary wave action.

The National Data Buoy Center's (NDBC) Boston Buoy, located 16 nautical miles east of Boston in approximately 200 feet of water, has been collecting standard meteorological data including significant wave height since 1984. USACE has also performed wind and wave hindcast in the Wave Information Study (WIS) for selected locations off the coast from 1980 to 2024. The nearest WIS site to the coast and directly east of Boston, in the vicinity of NDBC 44013, is ST63053 in 68 m (223 ft) of water. The annual significant wave height at this point is 4.7 m (15.3 ft). The 1-percent AEP significant wave height at this station is estimated to be 7.7 m (25.4 ft).

There is not a long record of wave data within Boston Harbor. In 2021, Stone Living Lab (SLL) installed a wave buoy just north of Rainsford Island in about 25 feet of water (Figure 31.). A comparison of the wave heights recorded at NDBC Boston Buoy (44013) and the SLL buoy during the December 2022, illustrates the protective nature that the Harbor Islands provide (Figure 32). Whereas the waves in Massachusetts Bay ranged from half a meter to nearly 6 meters, the wave heights in Boston Harbor did not exceed 1 meter.

Within the study area, wave heights are greatest between South Boston's Raymond L. Flynn Marine Park and Dorchester's Columbia Point where the shoreline is exposed to the longest fetches. Conversely, wave heights are smallest in the most sheltered areas including Belle Isle Marsh, Chelsea Creek, and up the Neponset River.

The CHS modeling effort also provided statistical wave output at the save points shown in Figure 24. Table 12 through Table 15 provide the best estimate and 90% confidence limit average recurrence interval wave heights at the chosen model area save points for the present NTDE (1992) and for the year 2090 under the USACE high SLC scenario. The present 1-percent ARI wave heights are all less than 3 feet at mean confidence. 2090 wave heights are comparable to the present NTDE wave heights, with most save points experiencing little change up to a 1-foot increase in the future. Again, this is due to the fetch-limited wave climate that limits wave growth. Two save points in Dorchester Bay are the exception, with increases in wave height of approximately 1.5 feet.



Figure 31. NDBC buoy 44013 in Massachusetts Bay and SLL's Rainsford buoy within Boston Harbor.

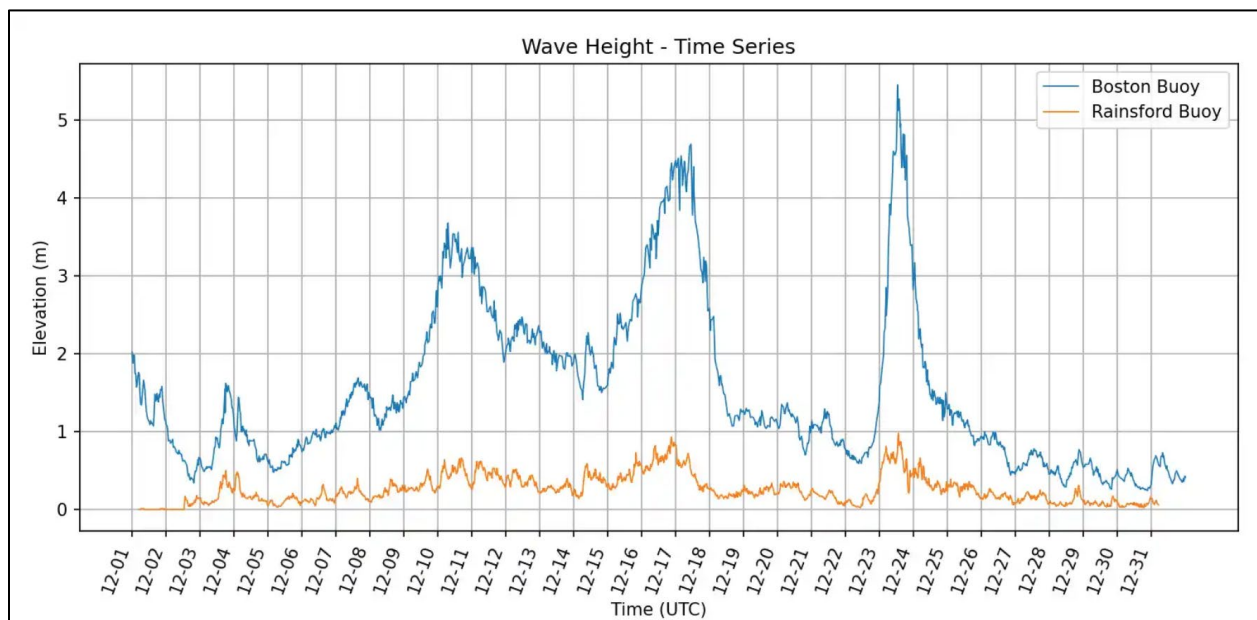


Figure 32. Wave heights at NDBC 44013 in Massachusetts Bay (blue) and SLL's Rainsford buoy (orange) for December 2022.

Boston Coastal Storm Risk Management Study

Table 12. Average Recurrence Interval Best Estimate Wave Heights by Model Area in Feet (MSL = -0.3' NAVD88 (1992))

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
EB_BI	Belle Isle	2675	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9
EB_CB	Constitution Beach	2651	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.7
EB_CC	Chelsea Creek	2611	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4
EB_CR	Car Rental	2624	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.0
EB_CTP_T	Callahan Tunnel Portal	2579	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
EB_RY	Railyard	2675	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9
EB_OH	Orient Heights	2611	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4
EB_EH	Eagle Hill	2595	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.2
EB_MBTA-C_T	MBTA Central Tunnel	2579	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
EB_STP_T	Sumner Tunnel Portal	2579	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
EB_WF	Waterfront	2579	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1
Charlestown											
CH_AP	Auto Port	813	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	1.9
CH_CG	Charlestown Garage	2556	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3
CH_CW	Constitution Wharf	2523	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.9
CH_LM	Little Mystic	2538	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.2
CH_NY	Navy Yard	2531	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.7
CH_RP	Ryan Playground	2552	1.0	1.2	1.3	1.4	1.5	1.5	1.6	1.6	1.7
Downtown											
DT_CA_T	Central Artery Tunnel	2501	1.8	1.9	2.0	2.1	2.3	2.3	2.4	2.5	2.6
DT_CG	Coast Guard	2509	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3
DT_CR	Charles River	2522	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5
DT_CT	Chinatown	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
DT_FPW	Fort Point West	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
DT_GC	Government Center	2501	1.8	1.9	2.0	2.1	2.3	2.3	2.4	2.5	2.6

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.4
DT_LP	Langone-Puopolo	2512	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4
DT_TA_T	Tobin Approach Tunnel	2522	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5
DT_WH	Wharves	2501	1.8	1.9	2.0	2.1	2.3	2.3	2.4	2.5	2.6
DT_WHN	Wharves North	2501	1.8	1.9	2.0	2.1	2.3	2.3	2.4	2.5	2.6
South Boston											
SB_CC	Convention Center	790	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5
SB_CT	Conley Terminal	790	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5
SB_DB	Dorchester Bay	2364	1.6	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.2
SB_FPC_T	Fort Point Channel Tunnel	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_FPE	Fort Point East	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_FPS	Fort Point South	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_MT	Marine Terminal	2319	1.4	1.5	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_RFP	Resilient Fort Point	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_SE	South End	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_SL_T	Silver Line Tunnel	923	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_SP	Seaport	801	1.8	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.7
SB_TW_T	Ted Williams Tunnel	2319	1.4	1.5	1.7	1.8	1.9	1.9	2.0	2.1	2.1
SB_WS	West Streets	2396	1.9	2.2	2.4	2.5	2.7	2.8	2.9	3.1	3.1
Dorchester											
DC_CP	Columbia Point	2396	1.9	2.2	2.4	2.5	2.7	2.8	2.9	3.1	3.1
DC_DB1	Dorchester Basin 1	2422	1.1	1.2	1.4	1.5	1.6	1.6	1.7	1.8	1.8
DC_DB2	Dorchester Basin 2	2422	1.1	1.2	1.4	1.5	1.6	1.6	1.7	1.8	1.8
DC-SB_MP	Moakley Park	2387	1.5	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9
DC_MS	Morrissey South	1610	1.1	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0
DC_NC	Neponset Circle	2474	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.1	2.2
DC_NG	National Grid	2416	1.4	1.7	1.9	2.1	2.3	2.4	2.5	2.7	2.7

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0
DC_PN	Port Norfolk	1610	1.1	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0
DC_SH	Savin Hill	2402	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.1
DC_TB	Tenean Beach	1610	1.1	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0

Boston Coastal Storm Risk Management Study

Table 13. Average Recurrence Interval 90% Confidence Limit Wave Heights by Model Area in Feet (MSL = -0.3' NAVD88 (1992))

Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9
EB_BI	Belle Isle	2675	0.8	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2
EB_CB	Constitution Beach	2651	1.7	1.9	2.0	2.0	2.1	2.2	2.3	2.3	2.4
EB_CC	Chelsea Creek	2611	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.9	1.9
EB_CR	Car Rental	2624	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.4
EB_CTP_T	Callahan Tunnel Portal	2579	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9
EB_RY	Railyard	2675	0.8	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2
EB_OH	Orient Heights	2611	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.9	1.9
EB_EH	Eagle Hill	2595	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.6
EB_MBTA-C_T	MBTA Central Tunnel	2579	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9
EB_STP_T	Sumner Tunnel Portal	2579	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9
EB_WF	Waterfront	2579	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9
Charlestown											
CH_AP	Auto Port	813	1.8	1.9	2.0	2.1	2.3	2.3	2.4	2.6	2.7
CH_CG	Charlestown Garage	2556	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8
CH_CW	Constitution Wharf	2523	2.0	2.1	2.1	2.2	2.2	2.3	2.4	2.5	2.6
CH_LM	Little Mystic	2538	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.6
CH_NY	Navy Yard	2531	1.9	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3
CH_RP	Ryan Playground	2552	1.4	1.6	1.8	1.9	2.0	2.1	2.2	2.3	2.3
Downtown											
DT_CA_T	Central Artery Tunnel	2501	2.4	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.5
DT_CG	Coast Guard	2509	2.0	2.2	2.3	2.4	2.6	2.7	2.8	3.0	3.2
DT_CR	Charles River	2522	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.0
DT_CT	Chinatown	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
DT_FPW	Fort Point West	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
DT_GC	Government Center	2501	2.4	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.5

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = -0.3' NAVD88 (1992)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9
DT_LP	Langone-Puopolo	2512	1.4	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.0
DT_TA_T	Tobin Approach Tunnel	2522	1.6	1.6	1.7	1.7	1.8	1.8	1.9	2.0	2.0
DT_WH	Wharves	2501	2.4	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.5
DT_WHN	Wharves North	2501	2.4	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.5
South Boston											
SB_CC	Convention Center	790	2.3	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.4
SB_CT	Conley Terminal	790	2.3	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.4
SB_DB	Dorchester Bay	2364	2.2	2.4	2.4	2.5	2.6	2.7	2.8	2.9	3.0
SB_FPC_T	Fort Point Channel Tunnel	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_FPE	Fort Point East	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_FPS	Fort Point South	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_MT	Marine Terminal	2319	1.9	2.1	2.3	2.4	2.6	2.7	2.8	2.9	2.9
SB_RFP	Resilient Fort Point	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_SE	South End	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_SL_T	Silver Line Tunnel	923	2.0	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9
SB_SP	Seaport	801	2.5	2.7	2.9	2.9	3.1	3.2	3.3	3.5	3.7
SB_TW_T	Ted Williams Tunnel	2319	1.9	2.1	2.3	2.4	2.6	2.7	2.8	2.9	2.9
SB_WS	West Streets	2396	2.6	3.0	3.2	3.4	3.7	3.9	4.0	4.2	4.3
Dorchester											
DC_CP	Columbia Point	2396	2.6	3.0	3.2	3.4	3.7	3.9	4.0	4.2	4.3
DC_DB1	Dorchester Basin 1	2422	1.5	1.7	1.9	2.0	2.2	2.3	2.3	2.4	2.5
DC_DB2	Dorchester Basin 2	2422	1.5	1.7	1.9	2.0	2.2	2.3	2.3	2.4	2.5
DC-SB_MP	Moakley Park	2387	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.6
DC_MS	Morrissey South	1610	1.6	1.9	2.1	2.2	2.4	2.5	2.6	2.7	2.8
DC_NC	Neponset Circle	2474	1.6	1.9	2.0	2.2	2.4	2.6	2.8	2.9	3.0
DC_NG	National Grid	2416	2.0	2.4	2.7	2.9	3.2	3.3	3.5	3.7	3.7

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Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = -0.3' NAVD88 (1992)								
			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	1.2	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4
DC_PN	Port Norfolk	1610	1.6	1.9	2.1	2.2	2.4	2.5	2.6	2.7	2.8
DC_SH	Savin Hill	2402	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5
DC_TB	Tenean Beach	1610	1.6	1.9	2.1	2.2	2.4	2.5	2.6	2.7	2.8

Boston Coastal Storm Risk Management Study

Table 14. Average Recurrence Interval Best Estimate Wave Heights by Model Area in Feet (MSL = 4.7' NAVD88 (2090 USACE High SLC))

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	1.2	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
EB_BI	Belle Isle	2675	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3
EB_CB	Constitution Beach	2651	1.5	1.7	1.9	2.0	2.1	2.1	2.2	2.3	2.3
EB_CC	Chelsea Creek	2611	1.3	1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.8
EB_CR	Car Rental	2624	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.2	1.3
EB_CTP_T	Callahan Tunnel Portal	2579	1.2	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
EB_RY	Railyard	2675	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.3
EB_OH	Orient Heights	2611	1.3	1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.8
EB_EH	Eagle Hill	2595	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4
EB_MBTA-C_T	MBTA Central Tunnel	2579	1.2	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
EB_STP_T	Sumner Tunnel Portal	2579	1.2	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
EB_WF	Waterfront	2579	1.2	1.4	1.5	1.6	1.7	1.7	1.8	1.9	1.9
Charlestown											
CH_AP	Auto Port	813	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1
CH_CG	Charlestown Garage	2556	1.1	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.8
CH_CW	Constitution Wharf	2523	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9
CH_LM	Little Mystic	2538	1.3	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.0
CH_NY	Navy Yard	2531	1.6	1.8	2.0	2.1	2.3	2.3	2.4	2.5	2.5
CH_RP	Ryan Playground	2552	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.6	1.7
Downtown											
DT_CA_T	Central Artery Tunnel	2501	2.1	2.3	2.4	2.5	2.7	2.9	3.0	3.1	3.3
DT_CG	Coast Guard	2509	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.4
DT_CR	Charles River	2522	1.4	1.6	1.6	1.7	1.8	1.8	1.9	1.9	1.9
DT_CT	Chinatown	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
DT_FPW	Fort Point West	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
DT_GC	Government Center	2501	2.1	2.3	2.4	2.5	2.7	2.9	3.0	3.1	3.3

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	1.3	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.6
DT_LP	Langone-Puopolo	2512	1.0	1.1	1.2	1.2	1.4	1.5	1.5	1.7	1.7
DT_TA_T	Tobin Approach Tunnel	2522	1.4	1.6	1.6	1.7	1.8	1.8	1.9	1.9	1.9
DT_WH	Wharves	2501	2.1	2.3	2.4	2.5	2.7	2.9	3.0	3.1	3.3
DT_WHN	Wharves North	2501	2.1	2.3	2.4	2.5	2.7	2.9	3.0	3.1	3.3
South Boston											
SB_CC	Convention Center	790	1.8	2.0	2.2	2.3	2.5	2.6	2.6	2.7	2.8
SB_CT	Conley Terminal	790	1.8	2.0	2.2	2.3	2.5	2.6	2.6	2.7	2.8
SB_DB	Dorchester Bay	2364	2.5	2.9	3.2	3.3	3.4	3.5	3.6	3.7	3.8
SB_FPC_T	Fort Point Channel Tunnel	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_FPE	Fort Point East	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_FPS	Fort Point South	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_MT	Marine Terminal	2319	1.7	1.8	2.0	2.0	2.1	2.2	2.2	2.3	2.3
SB_RFP	Resilient Fort Point	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_SE	South End	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_SL_T	Silver Line Tunnel	923	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.3
SB_SP	Seaport	801	1.8	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.7
SB_TW_T	Ted Williams Tunnel	2319	1.7	1.8	2.0	2.0	2.1	2.2	2.2	2.3	2.3
SB_WS	West Streets	2396	2.1	2.5	2.8	3.1	3.4	3.6	3.7	3.9	4.0
Dorchester											
DC_CP	Columbia Point	2396	2.1	2.5	2.8	3.1	3.4	3.6	3.7	3.9	4.0
DC_DB1	Dorchester Basin 1	2422	1.3	1.5	1.5	1.6	1.7	1.8	1.9	1.9	2.0
DC_DB2	Dorchester Basin 2	2422	1.3	1.5	1.5	1.6	1.7	1.8	1.9	1.9	2.0
DC-SB_MP	Moakley Park	2387	2.2	2.5	2.8	3.0	3.2	3.3	3.4	3.4	3.5
DC_MS	Morrissey South	1610	1.4	1.8	2.1	2.3	2.5	2.6	2.7	2.8	2.9
DC_NC	Neponset Circle	2474	1.3	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.6
DC_NG	National Grid	2416	1.8	2.2	2.5	2.7	3.0	3.1	3.2	3.4	3.5

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) Best Estimate, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4
DC_PN	Port Norfolk	1610	1.4	1.8	2.1	2.3	2.5	2.6	2.7	2.8	2.9
DC_SH	Savin Hill	2402	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.5
DC_TB	Tenean Beach	1610	1.4	1.8	2.1	2.3	2.5	2.6	2.7	2.8	2.9

Boston Coastal Storm Risk Management Study

Table 15. Average Recurrence Interval 90% Confidence Limit Wave Heights by Model Area in Feet (MSL = 4.6' NAVD88 (2090 USACE High SLC))

Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
East Boston											
EB_AW	Atlantic Works	2579	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7
EB_BI	Belle Isle	2675	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
EB_CB	Constitution Beach	2651	2.1	2.4	2.6	2.7	2.9	3.0	3.0	3.1	3.2
EB_CC	Chelsea Creek	2611	1.8	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.5
EB_CR	Car Rental	2624	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
EB_CTP_T	Callahan Tunnel Portal	2579	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7
EB_RY	Railyard	2675	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
EB_OH	Orient Heights	2611	1.8	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.5
EB_EH	Eagle Hill	2595	1.4	1.6	1.7	1.7	1.8	1.8	1.8	1.9	1.9
EB_MBTA-C_T	MBTA Central Tunnel	2579	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7
EB_STP_T	Sumner Tunnel Portal	2579	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7
EB_WF	Waterfront	2579	1.7	1.9	2.0	2.2	2.3	2.4	2.5	2.6	2.7
Charlestown											
CH_AP	Auto Port	813	1.9	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9
CH_CG	Charlestown Garage	2556	1.5	1.8	2.0	2.1	2.2	2.3	2.4	2.5	2.5
CH_CW	Constitution Wharf	2523	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.7
CH_LM	Little Mystic	2538	1.8	2.0	2.2	2.3	2.4	2.5	2.6	2.7	2.8
CH_NY	Navy Yard	2531	2.2	2.5	2.8	2.9	3.1	3.2	3.3	3.4	3.5
CH_RP	Ryan Playground	2552	1.7	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.3
Downtown											
DT_CA_T	Central Artery Tunnel	2501	2.9	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.4
DT_CG	Coast Guard	2509	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.1	3.2
DT_CR	Charles River	2522	2.0	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7
DT_CT	Chinatown	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
DT_FPW	Fort Point West	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
DT_GC	Government Center	2501	2.9	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.4

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
Average Recurrence Interval (Years)			1	2	5	10	20	50	100	200	500
DT_LJ	Lovejoy Wharf	2515	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.2	2.3
DT_LP	Langone-Puopolo	2512	1.4	1.5	1.6	1.7	1.9	2.1	2.1	2.3	2.4
DT_TA_T	Tobin Approach Tunnel	2522	2.0	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7
DT_WH	Wharves	2501	2.9	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.4
DT_WHN	Wharves North	2501	2.9	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.4
South Boston											
SB_CC	Convention Center	790	2.4	2.8	3.0	3.2	3.4	3.5	3.6	3.8	3.8
SB_CT	Conley Terminal	790	2.4	2.8	3.0	3.2	3.4	3.5	3.6	3.8	3.8
SB_DB	Dorchester Bay	2364	3.5	4.0	4.3	4.5	4.7	4.8	4.9	5.0	5.1
SB_FPC_T	Fort Point Channel Tunnel	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_FPE	Fort Point East	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_FPS	Fort Point South	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_MT	Marine Terminal	2319	2.3	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.1
SB_RFP	Resilient Fort Point	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_SE	South End	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_SL_T	Silver Line Tunnel	923	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2
SB_SP	Seaport	801	2.5	2.8	2.9	3.1	3.3	3.4	3.5	3.6	3.7
SB_TW_T	Ted Williams Tunnel	2319	2.3	2.6	2.7	2.8	2.9	3.0	3.0	3.1	3.1
SB_WS	West Streets	2396	2.9	3.5	3.9	4.3	4.6	4.9	5.1	5.3	5.4
Dorchester											
DC_CP	Columbia Point	2396	2.9	3.5	3.9	4.3	4.6	4.9	5.1	5.3	5.4
DC_DB1	Dorchester Basin 1	2422	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.7
DC_DB2	Dorchester Basin 2	2422	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.7
DC-SB_MP	Moakley Park	2387	3.0	3.5	3.9	4.2	4.4	4.5	4.6	4.7	4.8
DC_MS	Morrissey South	1610	1.9	2.5	2.9	3.1	3.4	3.6	3.8	3.9	4.0
DC_NC	Neponset Circle	2474	1.9	2.2	2.4	2.6	2.9	3.1	3.3	3.5	3.6
DC_NG	National Grid	2416	2.4	3.0	3.4	3.7	4.0	4.3	4.4	4.6	4.7

Boston Coastal Storm Risk Management Study

Model Area	Description	Save Point	Wave Height (ft) 90% CL, MSL = 4.6' NAVD88 (2090 USACE High SLC)								
			1	2	5	10	20	50	100	200	500
DC_NR	Neponset River	2476	1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.9	1.9
DC_PN	Port Norfolk	1610	1.9	2.5	2.9	3.1	3.4	3.6	3.8	3.9	4.0
DC_SH	Savin Hill	2402	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.0
DC_TB	Tenean Beach	1610	1.9	2.5	2.9	3.1	3.4	3.6	3.8	3.9	4.0

6.0 G2CRM Modeling

The Generation II Coastal Risk Model (G2CRM) is a computer model that implements an object-oriented Probabilistic Life Cycle Analysis (PLCA) model using event-driven Monte Carlo Simulation. This allows for incorporation of time-dependent and stochastic event-dependent behaviors such as sea level change, tide, and structure raising and removal. The model is based on driving forces (storms) that affect a coastal region (study area). The study area is comprised of individual sub-areas of different types that may interact hydraulically and may be protected by coastal defense measures that serve to shield the areas and the assets they contain from storm damage (USACE, 2018). To determine the damage for a specific event and time, G2CRM compares the total water level (sum of storm surge, tide, SLC, and potential wave inputs) to asset first floor elevations within Future Without Project (FWOP) or Protective System Element (PSE) elevations and then first floor elevations within the Future With Project (FWP) condition. G2CRM consists of multiple engineering inputs to accurately represent the study area which are described in the sections below. See Appendix E: Economics for more information regarding the development of the G2CRM economic inputs.

6.1 Digital Elevation Model

A Digital Elevation Model (DEM) consists of arrays of regularly spaced land surface elevation values referenced to a horizontal reference datum. The elevation data for the study area was derived from the 2021 USGS Lidar for Central Eastern Massachusetts. The cell size of the DEM is 0.5 m. The vertical accuracy, tested to meet vertical root mean square error ($RMSE_z$) in open terrain, is 3.8 cm and the horizontal accuracy, compiled to meet $RMSE_r$, is 11 cm.

6.2 Model Areas

Model areas (MAs) are areas that comprise the overall study area. The water level in the modeled area is used to determine consequences to the assets contained within the area (USACE, 2018). The study area was divided into MAs based on similar storm surge values at the 2090 1-percent annual exceedance probability and flood source. The DEM was used to determine separability of flood sources where inundation occurred from multiple sources. Tunnels were also identified as separate MAs. Tunnel model areas were located and assigned to a neighborhood based on their lowest tunnel portal elevation that could be flooded. Figure 19 through Figure 23, displayed above, show the location of the 53 model areas, 8 of which are tunnel entrances shown as triangles.

6.3 Protective System Elements

A protective system element (PSE) is the infrastructure that defines the coastal boundary; be it a coastal defense system that protects the modeled areas from coastal flooding (levees, pumps, closure structures, etc.) or a locally developed coastal boundary comprised of bulkheads and/or hardened shoreline (USACE, 2018). PSEs were applied in MAs where structural measures such as closure structures and floodwalls were considered in the FWP. Within the FWOP, the top elevation of the PSE was set equal to the lowest ground elevation along the PSE. Within the FWP, the top elevation of the PSE corresponded to the selected design elevation, described further in Section 8.0 and depicted in Appendix I, Civil Engineering.

6.4 Meteorological Driving Forces

Meteorological driving forces are location-specific storm hydrographs (surge and waves) which are generated externally from high fidelity storm surge and nearshore wave models such as ADCIRC and STWAVE (USACE, 2018). Additionally, the number of storms per year and relative storm probability are incorporated into G2CRM and further described below.

6.4.1 Storm Hydrographs

Storm hydrographs from the CHS coupled 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.

The G2CRM storm suite consisted of the 60 synthetic tropical storms and 17 historic extratropical storms from the reduced storm suite and modeled in CHS. In addition, hydrographs for the remaining 85 historic extratropical storms were generated using a regression model and included in each h5 file to provide a greater number of extratropical storms for G2CRM to sample.

While the hydrodynamic modeling completed in CHS and used in this study was performed in meters, MSL, G2CRM uses units of feet and the NAVD88 vertical datum. Therefore, the datum conversion from MSL to NAVD88 at the Boston tide gage was provided.

6.4.2 Wave Generation

G2CRM can represent wave hazards within a MA through several approaches. First, if wave model data is available through STWAVE, it can read in the wave information as is. Second, if wave data is not available, it can generate wave heights using a depth-limited wave assumption whereby the wave height will be 0.78 times the water depth within the MA. The third approach is to use the wave model data but apply depth-limitation if the STWAVE wave height exceeds the depth-limited wave height for the MA. Because the CHS points containing the STWAVE output were located offshore and MAs were typically above MSL, this third approach was used throughout the study area. As such, STWAVE model output was applied directly to all model areas with depth-limitation applied as applicable. This approach was selected as it was important to include wave hazards in damage computations at the shoreline. To limit the inclusion of waves in dense urban environments and interior areas, existing bulkhead and high ground elevations were included in the G2CRM model to depth limit wave heights. However, there is potential that in spite of the depth-limited breaking, wave heights in interior areas of dense development may be overstated. Overall, this risk is considered low and will not impact alternative development, screening, and selection.

6.4.3 Storms Per Season

To determine the storm event generation, G2CRM first selects the tropical and extratropical events to occur through each season within the year. This study implemented two storm seasons within each year: February and May through November as the tropical storm season and October through April as the extratropical storm season. G2CRM then uses the Poisson distribution to randomly select the number of storms that occur within each season based on the predetermined average number of storms in a season input. Tropical storm seasonality was based on the HURDAT database occurrences near Boston for the period of 1938-2021. Extratropical storm seasonality was defined using a peaks over threshold approach to identify events in the nontidal residual record at Boston from 1938-2024. The threshold was defined as the mean nontidal residual plus two standard deviations, or 0.36 m, and a 5-day inter-event time was used to ensure independence of events. This approach resulted in an extratropical storm frequency of 10.47 storms per year. This frequency was assigned to a low magnitude extratropical event. To account for the remainder of the extratropical events used in G2CRM, 101 storms over 77 years, an additional 1.31 storms per year were added to the peaks over threshold value, resulting in 11.8 storms per year. This approach was coordinated with ERDC-CHL. As a point of reference, Woods Hole

Group's peaks over threshold analysis used for defining storm frequency in MC-FRM used the 99th percentile nontidal residual as the threshold and a 3-day inter-event time, resulting in 6 extratropical events per year. Table 16 summarizes the season definitions and average number of storms per season.

Table 16. Storms per season

Season Description	Season Type	Average Storms per Season
Trop Season February	Tropical	0.01098575
Trop Season May	Tropical	2.29E-02
Trop Season June	Tropical	0.077858688
Trop Season July	Tropical	0.119601884
Trop Season August	Tropical	0.264870481
Trop Season September	Tropical	0.195450266
Trop Season October	Tropical	7.46E-02
Trop Season November	Tropical	5.99E-03
Etrop Season October	Extratropical	1.088166518
Etrop Season November	Extratropical	1.373162511
Etrop Season December	Extratropical	2.020880677
Etrop Season January	Extratropical	2.085652494
Etrop Season February	Extratropical	2.059743767
Etrop Season March	Extratropical	1.891337044
Etrop Season April	Extratropical	1.282481968

6.4.4 Relative Storm Probability

After G2CRM selects the number of storms occurring in each season the model then chooses which storms will occur in each season by randomly selecting storms out of the available storm suite using bootstrap sampling with replacement (higher probability storms are chosen more often). Relative tropical storm probabilities for the reduced storm suite were provided by ERDC-CHL. Extratropical storms were initially all assigned equal relative storm probabilities. However, this resulted in unreasonably high damage estimates in G2CRM. This conclusion was reached after evaluating the damages reported and the storms sampled in the near term (2020s) which did not align with the present storm climate and recent history. Consequently, the approach described in Section 6.4.3 was developed in coordination with ERDC-CHL. Storm 1982102510, a low magnitude event, was assigned a relative probability of 10.47. A relative storm probability of 0.013 was given to the remaining 101 extratropical events. A comparison of the G2CRM water levels to the save point hazard curves was conducted to confirm storms were sampled at appropriate rates. This comparison is shown in Figure 33 for save point 2501 at the Downtown-Wharves (DT_WH) model area from a 10 iteration run.

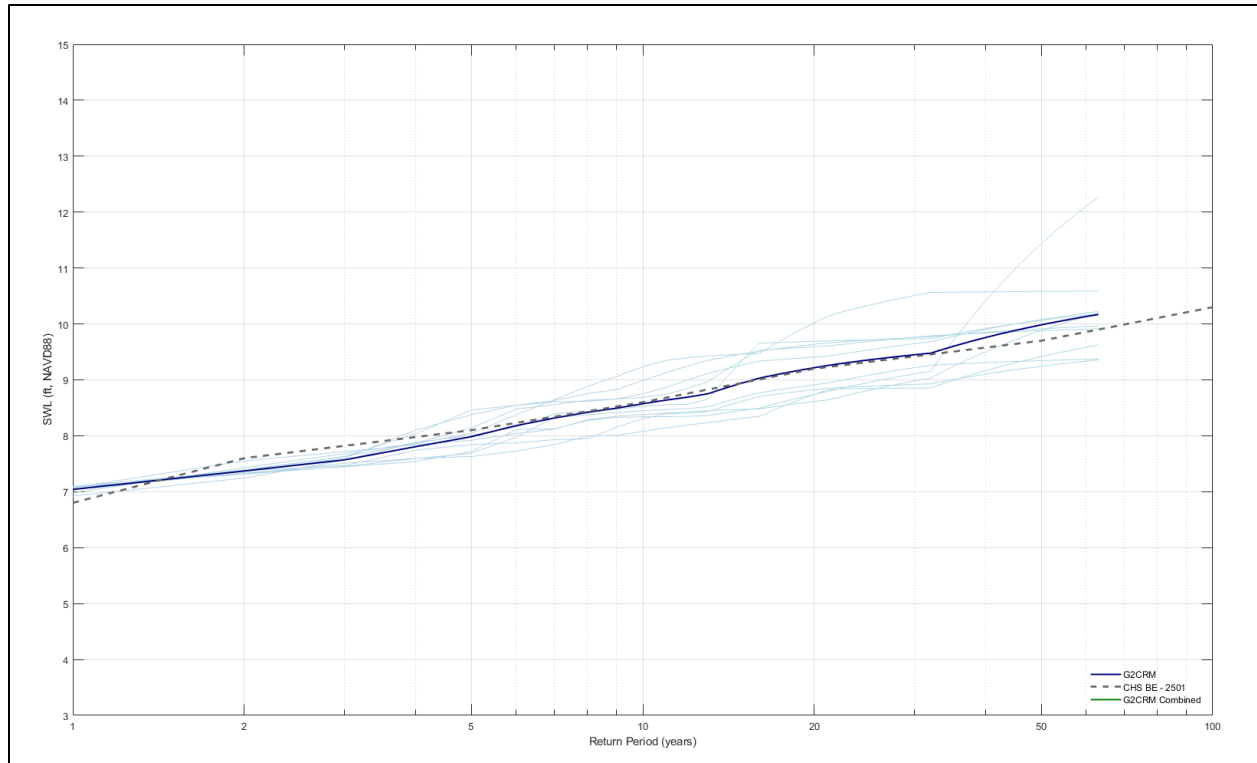


Figure 33. Comparison of G2CRM sampled water levels and CHS save point hazard curve for the Downtown-Wharves (DT_WH) model area from a 10 iteration G2CRM run.

6.4.5 Tide Station

The Boston, Massachusetts tide station was selected for application to all model areas within the study area.

6.4.6 Sea Level Change Rate and Curve

The study implemented a sea level change rate of 4.37 mm/year (0.014338 feet/year) based on the MSL trend at Boston station 8443970. This SLC rate was selected for the study in early 2024 and represents the long-term rate through 2023. Although the sea level change rate has changed slightly since 2023, it is not expected to impact the outcome of study findings.

While G2CRM requires the selection of a SLC curve, the USACE low, intermediate, or high SLC curves can be calculated with the model or a custom SLC curve can be applied. The USACE high scenario was applied for alternative formulation and evaluation within G2CRM. The selected action will be evaluated further under the low and intermediate SLC curves to evaluate the action's performance under alternate SLC scenarios.

6.4.7 Protective System Elements

Protective system elements (PSE) can be used in G2CRM to represent existing and proposed structural measures such as floodwalls, levees, bulkheads, and storm surge barriers. Table 17 lists the PSE types associated with each model area and their Future Without-Project (FWOP) elevations.

The model was configured with both flood barrier and bulkhead PSEs to represent the surge barrier. There are tradeoffs with each approach. With a bulkhead PSE, a stage-volume function can be employed to represent the time-dependent filling of a protected model area. However, the bulkhead PSE does not capture the barrier operations and assumes damages will always be reduced for water levels below the crest elevation. A flood barrier PSE on the other hand, will capture damages within the protected model area below the selected closure threshold, but does not allow a stage-volume function to be used with it. Therefore, when the flood barrier PSE crest elevation is exceeded, G2CRM transmits the exterior water level to the entire MA. Review of output from both flood barrier and bulkhead representations showed comparable damage estimates, indicating residual damage in the MAs behind the flood barrier to be appropriate. Therefore, the flood barrier PSE was ultimately selected to account for closures and capture damages below the closure threshold. This approach may overstate damages when the flood barrier crest elevation is exceeded, although there is, on average, fewer than 1 event of this magnitude per iteration. As the event is so infrequent and far out in the future, it is thought to have little impact as its damages are heavily discounted.

6.4.8 Stage-Volume Input

G2CRM has an optional data import tool for stage-volume relationships, which is used to represent internal ponding within a MA. If a stage-volume relationship is not employed, G2CRM will instantaneously transmit the stage into the MA when it exceeds the input PSE top elevation. To represent the coastal flooding more accurately within a MA with a PSE in place, G2CRM has an option to use the weir equation to calculate a time-dependent volume transmitted into the MA until the storage capacity within the MA is filled, after which G2CRM transitions back to transmitting the stage unmediated into the MA. Stage-volume relationships were created using the DEM to determine the volume within each MA in relation to various stage elevations where structural measures such as storm barriers and floodwalls were considered. By establishing these stage-volume relationships, the coastal flooding within a MA protected by a PSE could be better represented. All upland, non-tunnel model areas were represented with stage-volume functions. Use of stage-volume relationships allows PSEs, like the New Charles River Dam for example, to be overtopped in the economic modeling.

Table 17. Model area types and PSEs

Model Area	Description	Type	PSE(s)	FWOP Elevation (feet, NAVD88)
East Boston				
EB_AW	Atlantic Works	Upland	Bulkhead	8.5
EB_BI	Belle Isle	Unprotected	--	--
EB_CB	Constitution Beach	Unprotected	--	--
EB_CC	Chelsea Creek	Upland	Bulkhead	9.5
EB_CR	Car Rental	Unprotected	--	--
EB_CTP_T	Callahan Tunnel Portal	Upland	Bulkhead	9.3
EB_RY	Railyard	Upland	Bulkhead	9.5
EB_OH	Orient Heights	Upland	Bulkhead	9.5
EB_EH	Eagle Hill	Unprotected	--	--
EB_MBTA-C_T	MBTA Central Tunnel	Upland	Bulkhead	9.3
EB_STP_T	Sumner Tunnel Portal	Upland	Bulkhead	9.3
EB_WF	Waterfront	Upland	Bulkhead	8
Charlestown				
CH_AP	Auto Port	Unprotected	--	--
CH_CG	Charlestown Garage	Unprotected	--	--
CH_CW	Constitution Wharf	Unprotected	--	--
CH_LM	Little Mystic	Upland	Bulkhead	9.5
CH_NY	Navy Yard	Upland	Bulkhead	8
CH_RP	Ryan Playground	Upland	Bulkhead	9.5
Downtown				
DT_CA_T	Central Artery Tunnel	Upland	Bulkhead	10.6
DT_CG	Coast Guard	Unprotected	--	--
DT_CR	Charles River	Upland	Bulkhead	11.1
DT_CT	Chinatown	Upland	Bulkhead + Flood Barrier	14.5
DT_FPW	Fort Point West	Upland	Bulkhead + Flood Barrier	12
DT_GC	Government Center	Upland	Bulkhead	8.5
DT_LJ	Lovejoy Wharf	Upland	Bulkhead	11.5
DT_LP	Langone-Puopolo	Unprotected	--	--
DT_TA_T	Tobin Approach Tunnel	Upland	Bulkhead	11.1
DT_WH	Wharves	Upland	Bulkhead	7.5
DT_WHN	Wharves North	Upland	Bulkhead	7.5
South Boston				
SB_CC	Convention Center	Upland	Bulkhead	9.5
SB_CT	Conley Terminal	Unprotected	--	--
SB_DB	Dorchester Bay	Unprotected	--	--
SB_FPC_T	Fort Point Channel Tunnel	Upland	Bulkhead	13
SB_FPE	Fort Point East	Upland	Bulkhead +	9

Model Area	Description	Type	PSE(s)	FWOP Elevation (feet, NAVD88)
			Flood Barrier	
SB_FPS	Fort Point South	Upland	Bulkhead + Flood Barrier	10
SB_MT	Marine Terminal	Upland	Bulkhead	9.5
SB_RFP	Resilient Fort Point	Upland	Bulkhead + Flood Barrier	8
SB_SE	South End	Upland	Bulkhead + Flood Barrier	11
SB_SL_T	Silver Line Tunnel	Upland	Barrier	12.4
SB_SP	Seaport	Unprotected	--	--
SB_TW_T	Ted Williams Tunnel	Upland	Bulkhead	11.5
SB_WS	West Streets	Upland	Bulkhead	10.5
Dorchester				
DC_CP	Columbia Point	Upland	Bulkhead	9.5
DC_DB1	Dorchester Basin 1	Unprotected	--	--
DC_DB2	Dorchester Basin 2	Upland	Bulkhead	13.7
DC-SB_MP	Moakley Park	Upland	Bulkhead	10
DC_MS	Morrissey South	Upland	Bulkhead	9.5
DC_NC	Neponset Circle	Upland	Bulkhead	5.5
DC_NG	National Grid	Unprotected	--	--
DC_NR	Neponset River	Unprotected	--	--
DC_PN	Port Norfolk	Unprotected	--	--
DC_SH	Savin Hill	Unprotected	--	--
DC_TB	Tenean Beach	Upland	Bulkhead	8.5

7.0 Study Measures

The FWOP results indicate that coastal storm events, along with tides, will continue to cause socioeconomic impacts within the study area. These impacts are expected to increase in frequency due to sea level change. Therefore, measures were considered to reduce these impacts with a focus on areas previously in the Climate Ready Boston neighborhood reports. Measures were evaluated considering scale, combinability of measures, and sound engineering design and practice. Structural, nonstructural, and natural and nature-based features (NNBF) measures were initially considered to reduce impacts from coastal flooding and wave attack. However, only the following measures were considered within the final array of alternatives. See the main report for additional details on the various measures and screenings conducted prior to the final array.

7.1 Levee

Levees are embankments constructed along a waterfront to prevent flooding in relatively large areas. They are typically constructed by compacting soil into a large berm that is wide at the base and tapers toward the top, forming a trapezoidal cross section. Grass or another non-woody vegetation is usually planted on the levee to add stability to the structure. If a levee is located in an area where it may be subject to erosive forces, it may be necessary to armor the levee slope with a more protective rock face. A typical levee is shown in Figure 34. Levees may be constructed in urban areas such as Boston; however, large tracts of real estate are usually required due to the levee width and required setbacks. The height and width may limit access to the water for recreation and commercial activities, and like floodwalls, impact the viewshed of coastal properties. In some cases, levees have been incorporated into trail systems with a path on the crest. Structural measures, such as floodwalls, levees and dikes tend to trap rainfall runoff associated with storms on the landward side, and should be evaluated for residual flood risk. To reduce this residual risk, gravity outlets may be installed along the length of the structure. In cases where significant runoff may be trapped behind the structure, ponding areas and pump stations may be required. Depending on the density of development of a vulnerable area, levees and floodwalls are often constructed as a system whereby floodwalls are interspersed between levee segments as available space dictates.

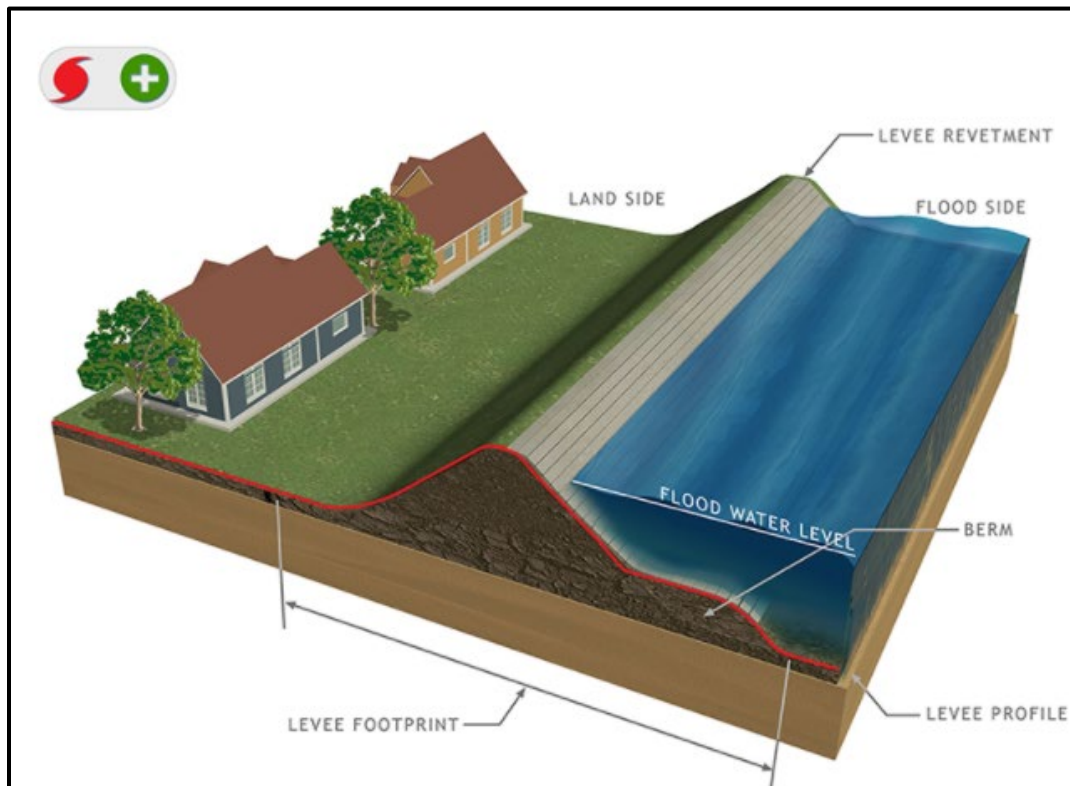


Figure 34. Levee example image

7.2 Floodwall

Floodwalls are structures used to reduce risk in relatively small areas or areas with limited space for flood risk management against lower levels of flooding. Unlike wider, more stable levees, narrow floodwalls require significant reinforcement and anchoring construction to prevent collapse from hydrostatic pressure. The significant amounts of steel sheeting and/or reinforced concrete used in constructing a typical wall make the feature extremely heavy. Because construction in a flood prone area, such as near a river or estuary, may occur on soft organic soil, pile reinforcement may be required under the base of the wall. The combination of steel sheeting, reinforcement, concrete, and pile support make a floodwall a much more costly structural risk management measure than a similar length and height levee. A typical floodwall is depicted in Figure 35. In addition to the cost of building such a structure, the real-world engineering considerations must be factored in and also the quality of life for the nearby residents. Floodwalls often block views, shade private property, separate communities, impact local hydrology, reduce wildlife mobility, etc.

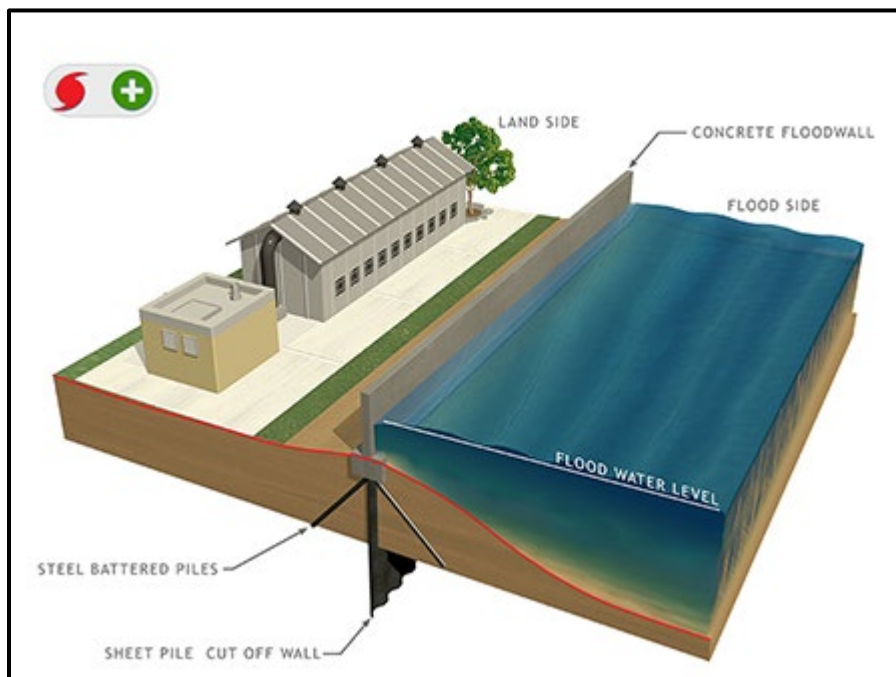


Figure 35. Floodwall example image

Three representative wave heights (1, 3, and 4 feet) were used to calculate wave forces on vertical structures using the Goda method. Wave heights were determined for each alignment based on their exposure to the expected value 2090 (USACE High SLC) 1-percent AEP wave height. Wave forces and moments were provided to structural engineering to advance the typical floodwall designs.

7.3 Surge Barrier

Storm surge barriers reduce risk to estuaries against storm surge flooding and waves. In most cases the barrier consists of a series of movable gates that stay open under normal conditions to let the flow pass but are closed when storm surges are expected to exceed a certain level. Storm surge barriers are often chosen as a preferred alternative to close off estuaries and reduce the required length of perimeter flood risk management measures behind the barriers. Another important characteristic is that they are often (partly) opened during normal conditions to allow for navigation and saltwater exchange with the estuarine areas landward of the barrier. Nonetheless, storm surge barriers can have negative effects on the ecological system and on navigation. These types of structures have been used in the US and in numerous locations around the world. Gates can vary in size from controlling the flow into small tidal creeks to massive structures blocking flow into very large rivers, navigation channels, estuaries, etc. There are many types of gates that can be used, and selection is often based on cost, predicted surge elevations, navigation, bottom type, habitat considerations, etc. An example of a surge barrier with tainter gates and pump station at Fox Point in Providence, RI is shown in Figure 36.



Figure 36. Fox Point hurricane barrier

7.4 Floodproofing

Dry floodproofing is a nonstructural technique that prevents the entry of flood waters into a structure. Dry floodproofing measures typically include the retrofit of an existing

structure and can include measures such as continuous impermeable walls, sealing openings, backflow valves, flood shields and internal drainage systems. All measures require ongoing maintenance and may require human intervention to deploy during flood events. Typically, the retrofitting of existing exterior walls is only performed up to a 3-foot flood depth.

Floodproofing was considered for only the Charlestown Community Center at the base of the Little Mystic Channel because it serves as an emergency shelter and its entrance on Medford Street remains accessible in the 2090 USACE High SLC 1% AEP event (Figure 37). The lowest ground elevation is approximately 11' NAVD88. Therefore, dry floodproofing will manage risk from coastal storms to elevation 14' NAVD88. This is equivalent to the 2090 50-year event (best estimate) or the 2040 500-year (best estimate) water level, both under the USACE high SLC scenario.



Figure 37. The Charlestown Community Center, considered for dry floodproofing, and the 2090 best estimate 1-percent AEP floodplain under the USACE High SLC scenario.

7.5 Inland Hydrology Measures

Inland hydrology measures such as pump stations, storage, and conveyance were considered where structural measures were proposed to mitigate for residual flooding due to entrapped rainfall runoff. Flap gates must be provided for all outfalls located along structural alignments to prevent backflow and flooding of the interior via the stormwater system.

8.0 Alternatives Development

Alternative development primarily focused on addressing district-scale flood pathways where inundation was far reaching and affected a large number of structures as opposed to fringe flooding which impacted a limited number of structures along the shoreline. This strategy follows the approach taken in Climate Ready Boston. In general, alternatives were developed to provide coastal risk management up to the 2090 best estimate 1-percent AEP event under the USACE High SLC scenario, based on an allowable overtopping rate of 50 l/s/m (CEM Table VI-5-6). This is generally the case for the Charlestown and Dorchester neighborhoods. In some locations, this level of performance could not be achieved due to the limited availability of high ground tie-ins. In other locations, this target elevation may have been in stark contrast to the existing condition and was not acceptable to the community. This was generally the case in East Boston, South Boston, and Downtown, where the target crest elevation was set to 14 feet NAVD88 or approximately the 2090 best estimate 1-percent AEP stillwater elevation.

8.1 East Boston

Recall that coastal flooding in East Boston occurs primarily in two areas—south of Orient Heights between Belle Isle Marsh and Chelsea Creek, and along Border Street. Most of the alternatives in East Boston are floodwalls with crest elevations of 14' NAVD88 based on the availability of high ground tie-ins.

Alternative EB1 will manage coastal storm risk to the Orient Heights Railyard along Belle Isle Marsh. This alternative consists of an upland floodwall with a crest elevation at 14 feet NAVD88. A floodwall was preferred over a living levee that would extend out into the marsh so that impacts to the marsh, an ACEC, would be minimized. With a crest elevation at 14 feet, EB1 will manage inundation within model area EB_RY to the 2090 1-percent AEP water level under the USACE high SLC scenario (Figure 38). Although flooding enters model area EB_OH first from Chelsea Creek, EB1 is considered separable because when flooding reaches the MBTA Blue Line, it will travel first along the low-lying tracks before inundating EB_RY.



Figure 38. Alternative EB1 at the Orient Heights Railyard

Alternative EB2 (Figure 39) includes the EB1 floodwall at Orient Heights Railyard and supplements it with structural measures behind Constitution Beach, along the Chelsea Creek shoreline, and hardening of the Blue Line south of Suffolk Downs Station. The crest elevation for this system is at 14 feet NAVD88, matching the EB1 floodwall crest elevation and maximizing the availability of high ground tie-ins. Alternative EB2 manages coastal storm risk within model areas EB_RY, EB_OH, and EB_CC.



Figure 39. Alternative EB2—Orient Heights Railyard Floodwall, Floodwall and Levee System behind Constitution Beach, Floodwall along Chelsea Creek, and Closure Structure near Suffolks Downs Station to harden the Blue Line.

Alternative EB2A (Figure 40) includes the EB1 floodwall at Orient Heights Railyard and supplements it with structural measures behind Constitution Beach, within the median of Route 1A, and hardening of the Blue Line south of Suffolk Downs Station. The crest elevation for this system is at 14 feet NAVD88, matching the EB1 floodwall crest elevation and maximizing the availability of high ground tie-ins. Alternative EB2A manages coastal storm risk within model areas EB_RY and EB_OH. Unlike Alternative EB2, this alternative does not manage coastal storm risk within model area EB_CC.



Figure 40. Alternative EB2A—Orient Heights Railyard Floodwall, Floodwall and Levee System behind Constitution Beach, Floodwall in the Route 1A median, and Closure Structures near Suffolk Down Station to harden the Blue Line.

Within the southern half of East Boston, Alternative EB3A (Figure 41) is a system of structural measures, managing flood risk within the Waterfront model area (EB_WF) from Wood Island Marsh and the inner harbor main channel from Jeffries Point near Logan International Airport around to Border Street, tying into high ground near Eagle Hill. To reach achievable tie-ins, crest elevations for all measures were again at elevation 14 feet NAVD88. Although it is shown as being inundated in Figure 41 due to mapping on 2021 topography, the east end of the floodwall at Lewis Mall ties into the now completed Piers Park II where grade reaches 14 feet NAVD88 at Piers Park Lane and a complete line of protection is achieved. EB3A will also provide coastal storm risk management to the three tunnel portals within model area EB_WF. While hardening the tunnel entrances themselves may have been efficient, EB3A is able to provide benefits to both the tunnels and the neighborhood.

Although the preceding alternatives are separable and independently effective in providing coastal storm risk management, Alternative 3A could be combined with Alternatives EB1, EB2, or EB2A to manage additional risk.



Figure 41. Alternative EB3A—Upland floodwall along Border Street, Floodwall from LoPresti Park to Lewis Mall (East Boston Waterfront), Road Grade Changes crossing Marginal Street and along Tomahawk Drive, and a Floodwall at Wood Island Marsh

8.2 Charlestown

Alternatives in Charlestown were again formulated to address district-scale flood pathways as opposed to fringe flooding. Alternative CH1 will manage coastal storm risk within the model area CH_RP through the Schrafft's Center property (Figure 42). This alternative consists of an upland floodwall with a crest elevation of 15.5' NAVD88 that ties into high ground on either side of the flood entry pathway. The flood pathways along the rail and Route 99 west of the Alternative CH1 alignment will be addressed through the raising of the Amelia Earhart Dam and completion of construction of Draw Seven Park in Somerville, as well as the Sullivan Square and Rutherford Avenue roadway project that will involve filling the depressed section of Route 99 that extends southeast toward City Square. Because CH_RP connects to DT_CR at elevation 12' NAVD88, model area CH_RP may remain vulnerable to flooding via flanking or overtopping of the

New Charles River Dam. At this point, that risk appears low as the Charles River model area is a large and a stage-volume function is being used to represent the existing dam.



Figure 42. Alternative CH1 is an upland floodwall at the Schrafft's Center property.

Alternative CH2 is a system of floodwalls, managing flood risk within the Little Mystic model area (CH_LM), from Chelsea Street along the Little Mystic Channel headed west until it turns inland before the Charlestown athletic fields to tie into high ground and a floodwall and road closure gate along Chelsea Street at Vine Street (. Where the floodwall is along the Little Mystic Channel and exposed to wave action, its crest elevation is 15.5' NAVD88. The floodwall at the intersection of Chelsea Street and Vine Street manages flood risk to model area CH_LM through the Navy Yard (CH_NY). Due to its inland and sheltered location, wave action was not considered in determining its crest elevation at 14' NAVD88. Flooding of CH_LM through CH_NY begins above elevation 12.3' NAVD88. Alternative CH2 also includes the nonstructural floodproofing of the Charlestown Community Center, as discussed in Section 7.4.

Alternative CH3 includes CH2's floodwall along the Little Mystic Channel and the nonstructural floodproofing of the Charlestown Community Center as well as the continuation of the Little Mystic floodwall around the perimeter of the Charlestown Navy Yard (CH_NY) to high ground at Fifth Street (Figure 44). All floodwalls in Alternative CH3 have a crest elevation at 15.5' NAVD88 and together they provide risk management to the model areas of CH_LM and CH_NY.



Figure 43. Alternative CH2 includes a pair of floodwalls—one along the Little Mystic Channel and the other inland along Chelsea Street at Vine Street—that provide coastal storm risk management to model area CH_LM.



Figure 44. Alternative CH3 includes perimeter floodwalls along the Little Mystic Channel and the Charlestown Navy Yard.

8.3 Downtown/North End

Alternatives in the Downtown and North End neighborhood focused on two flood pathways. The first was the Charles River at the New Charles River Dam. Although modifications of the dam itself were not considered within the scope of this study, measures to close flood pathways that flank the dam were used in Alternative DT1 (Figure 45). On the north side of the dam, a 1-foot berm with crest elevation at 11.7' NAVD88 runs through Paul Revere Park in Charlestown between the dam and high ground. On the south side of the Charles River, an in-water floodwall will provide coastal flood risk management to the Lovejoy Wharf model area (DT_LJ) between the Bill Russell Bridge at North Washington Street and the New Charles River Dam. A floodwall and road grade change on Commercial Street will also be used as part of Alternative

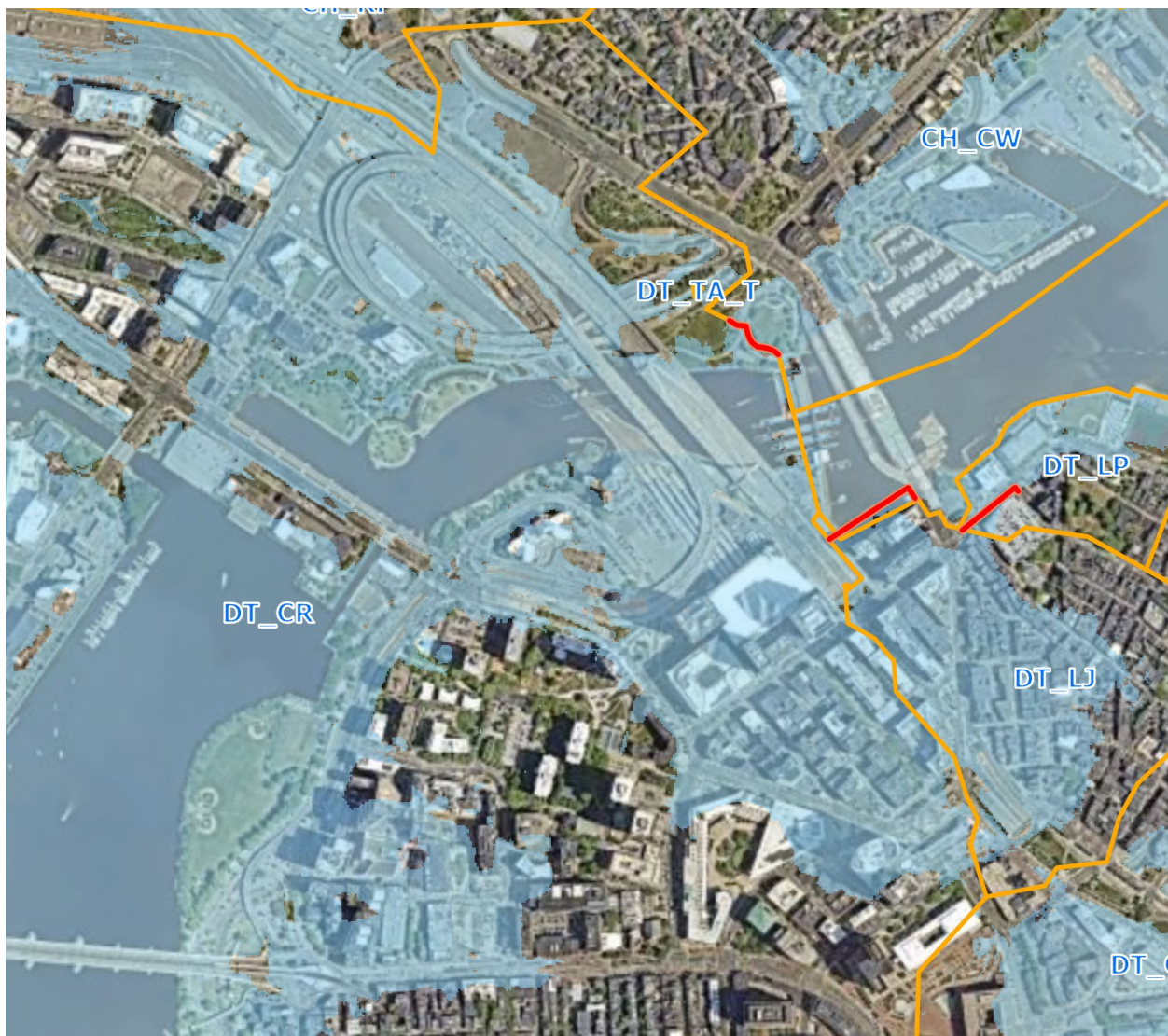


Figure 45. Alternative DT1—Resilience berm through Paul Revere Park, in-water floodwall at Lovejoy Wharf, and upland floodwall and road grade change along Commercial Street to collectively provide flood risk management to model areas DT_CR and DT_LJ.

DT1 to manage risk within DT_LJ. While there is space for levee lifts to the berm in Paul Revere Park over time in response to SLC, the floodwall measures on the Downtown side at Lovejoy Wharf and Commercial Street were assumed to be constructed once with crest elevations at 14' NAVD88, although the New Charles River Dam will still experience overtopping at elevation 11.7' NAVD88. This assumption was made based on the increased difficulty of doing work with limited space, in a densely developed and heavily trafficked area such as Downtown/North End.

Alternative DT3 is a perimeter floodwall along the eastern shore of the Downtown and North End neighborhood beginning south of U.S. Coast Guard Sector Boston to Seaport Boulevard at the mouth of Fort Point Channel (Figure 46). This alignment, with a crest of 14' NAVD88, provides coastal storm risk management to the Downtown Wharves (DT_WH and DT_WHN) and the Government Center model area (DT_GC). Within DT_GC, Alternative DT3 also provides risk management to entrances to the Central Artery Tunnel (I-93).



Figure 46. Alternative DT3 perimeter floodwall from U.S. Coast Guard Sector Boston south to Seaport Boulevard.

Alternative DT3A is similar to Alternative DT3, in that it is also a perimeter floodwall extending from Seaport Boulevard at the mouth of Fort Point Channel to the North End. However, Alternative DT3A does not provide coastal flood risk management to the DT_WHN model area and instead its alignment turns inland south of the parking lot at Sargent's Wharf and ties into high ground across Atlantic Avenue along Fleet Street as shown in Figure 47. The rationale behind this alternative is that it provides the same level of risk management within model area DT_GC more efficiently than Alternative DT3, but does not include the North End wharves between Sargent's Wharf and the Coast Guard station where flooding is primarily limited to the wharves themselves and the first row of structures landward of Atlantic Avenue before the elevation gain at Copp's Hill.



Figure 47. Alternative DT3A perimeter floodwall between Seaport Boulevard at Fort Point Channel and Fleet Street.

In addition to being shorter, Alternative DT3A also does not have to contend with crossing the Sumner and Callahan Tunnels.

8.4 South Boston

Three alternatives were developed to manage coastal flood risk within South Boston. Alternative SB1 provides coastal storm risk management to elevation 14' NAVD88 at South Boston's I-90/Ted Williams Tunnel Portal by adding elevation to the existing parapet walls and providing a vehicular gate on the wall's south side at a limited access on ramp used by the state police (Figure 48). While Alternative SB1 would limit flooding from accessing this segment of I-90, it is only independently effective to elevation 12.5'

NAVD88 at which point floodwaters can enter I-90 through the I-90 west offramp at Congress and B Streets.



Figure 48. Alternative SB1 parapet walls at South Boston's I-90/Ted Williams Tunnel Portal.

Alternative SB 2 and SB3 are neighborhood level flood risk solutions. Both begin on the north side of South Boston with a storm surge barrier across the mouth of Fort Point Channel, connecting Downtown to Fan Pier (Figure 49 and Figure 50). Both alternatives are also comprised of an in-water floodwall from Fan Pier to Commonwealth Pier, an upland floodwall from Commonwealth Pier to D Street, and an upland floodwall along the Pappas Way shoreline on Reserved Channel between Summer Street and across East 1st Street to high ground at H Street.

Alternatives SB2 and SB3 take differing routes at the D Street intersection where Seaport Boulevard becomes Northern Avenue. Alternative SB2 crosses Northern Avenue and heads south along D Street where it ties into high ground near the I-90 parapet walls. SB2 includes all of SB1 around the I-90 parapet walls. It then crosses



Figure 49. Alternative SB2 (in red), including SB1, provides a complete flood risk management solution to elevation 14' NAVD88 for model areas south and west of the alignment.



Figure 50. Alternative SB3 (in red) provides a complete flood risk management solution to elevation 14' NAVD88 for all model areas south and west of the alignment.

Haul Road where a grade change is proposed at the Summer Street and Pumphouse Road intersection. Following the road grade change, Alternative SB2 resumes as a floodwall along the southern side of Summer Street, crossing Fargo Street and Pappas Way, where it rejoins the shared alignment at the Pappas Way shoreline.

Rather than turning up D Street at the Fish Pier, Alternative SB3 continues as an upland floodwall down Northern Avenue and around the Raymond L. Flynn Marine Park. The SB3 alignment crosses the caisson at the entrance to Dry Dock #3. In order to avoid port operations at MassPort's Flynn Cruiseport Boston, the SB3 alignment runs along the center of Black Falcon Avenue, through and along the edge of several parking lots, and across Summer Street where it rejoins the shared alignment at the Pappas Way shoreline. While Alternative SB3 protects additional structures within the Marine Park, it is a much longer alignment that must also cross the Ted Williams Tunnel.

8.4.1 Fort Point Channel Surge Barrier

The surge barrier concept for Fort Point Channel was adopted as part of Alternatives SB2 and SB3 from existing studies completed for Boston Water and Sewer Commission (2023). The surge barrier concept utilizes natural storage of the Fort Point Channel, in combination with a pump station, to isolate stormwater outfalls from high sea levels and close the flood pathways through Fort Point Channel to model areas SB_FPE, SB_RFP, SB_FPS, SB_SE, and DT_FPW. The storm surge barrier and navigable gate structure, with a crest elevation at 15.5' NAVD88, would remain open under typical conditions. In the open position, normal tidal flow into and out of the channel and marine traffic are not impeded. If a large storm event with high sea levels is expected, the submerged, vertical axis flap gate structures could be closed at low tide. Fort Point Channel could then act as a storage area for stormwater, as it drains approximately 10 percent of the city's area (2,600 acres), while keeping storm surge on the harbor side of the barrier.

Usable storage within the Fort Point Channel between MLW and the approximate upper rim elevation (7' NAVD88) is presently 160 million gallons (MG). With 4.3 feet of SLC, storage would decrease to approximately 100 MG as MLW rises.

Although the surge barrier is a large and complex structure, the alternative would have been a perimeter floodwall along the Fort Point Channel shorelines. The floodwall alternative would have to contend with crossing I-90's Fort Point Channel Tunnel twice, as well as rail crossings, additional vehicular closure structures, and over fifty stormwater outfalls. Figure 51 shows the complex of outfalls which currently drain to Fort Point Channel. The storm surge barrier, therefore, also provides efficiency from an interior drainage standpoint. Rather than trying to provide many pump stations around the channel's perimeter in an area where there is generally little available real estate, the surge barrier proposes a single, larger pump station with a series of five electric

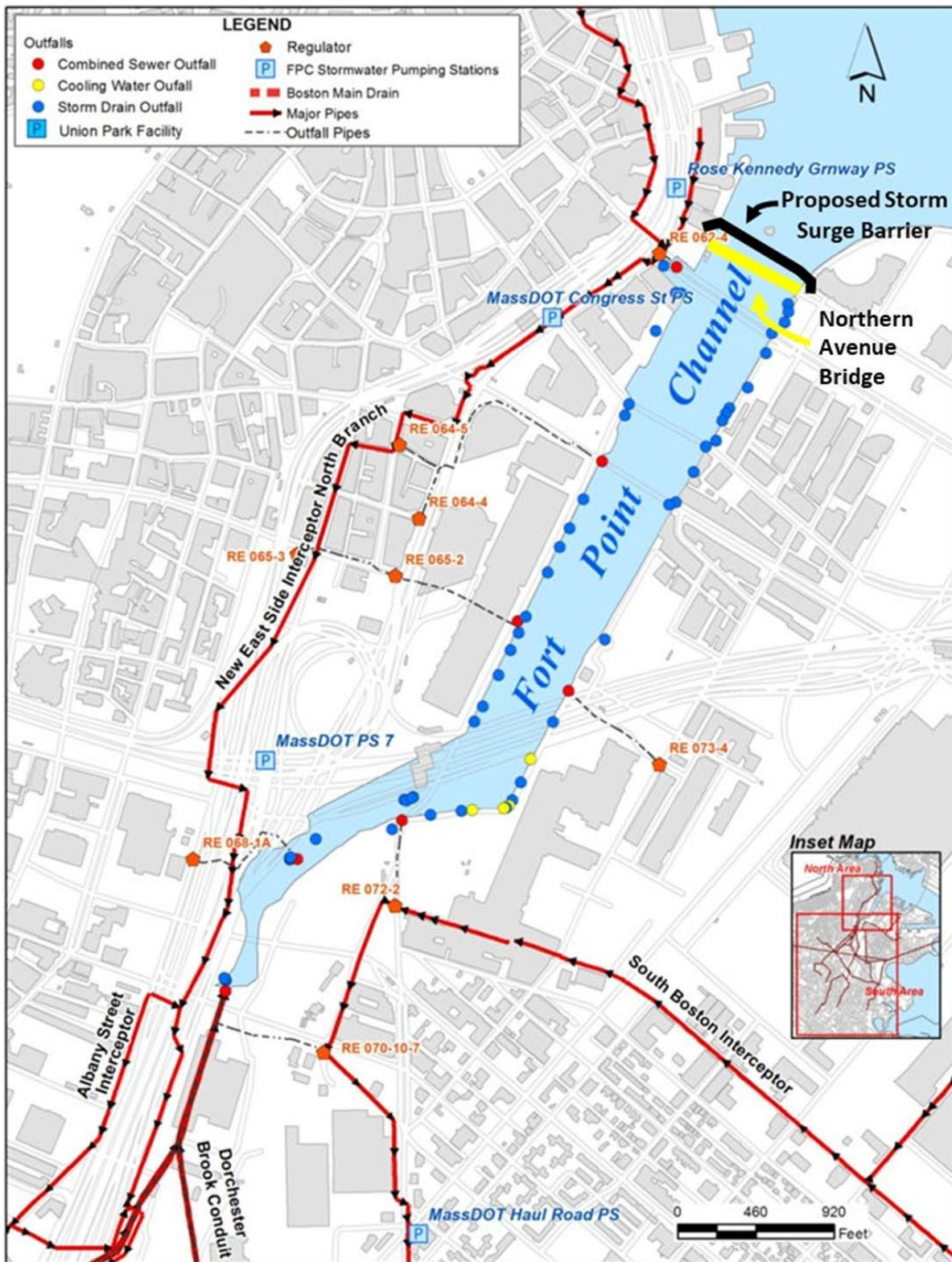


Figure 51. Fort Point Channel environs showing proposed storm surge barrier location, outfalls and major drainage infrastructure in the immediate vicinity (BWSC, 2024).

submersible pumps with a temporary offsite emergency power supply on the basis of minimized visual impacts and minimized permitting challenges.

Pumps were sized based on the surge barrier crest elevation of 15.5' NAVD88, with a discharge centerline at 17' NAVD88. The pump station utilizes 3 duty and 2 standby pumps, each with a capacity of approximately 167 CFS and static head range of 21 feet (low water level) to 4 feet (high-high water level, basin overflowing). An analysis was conducted to determine required pumping capacity by simulating the 10-year, 24-hour design storm with 100-year tropical storm surge under future SLC conditions. Based on stormwater modeling conducted by Hazen for BWSC, a pumping capacity of 500 cfs was found (Hazen/BWSC, CSDA).

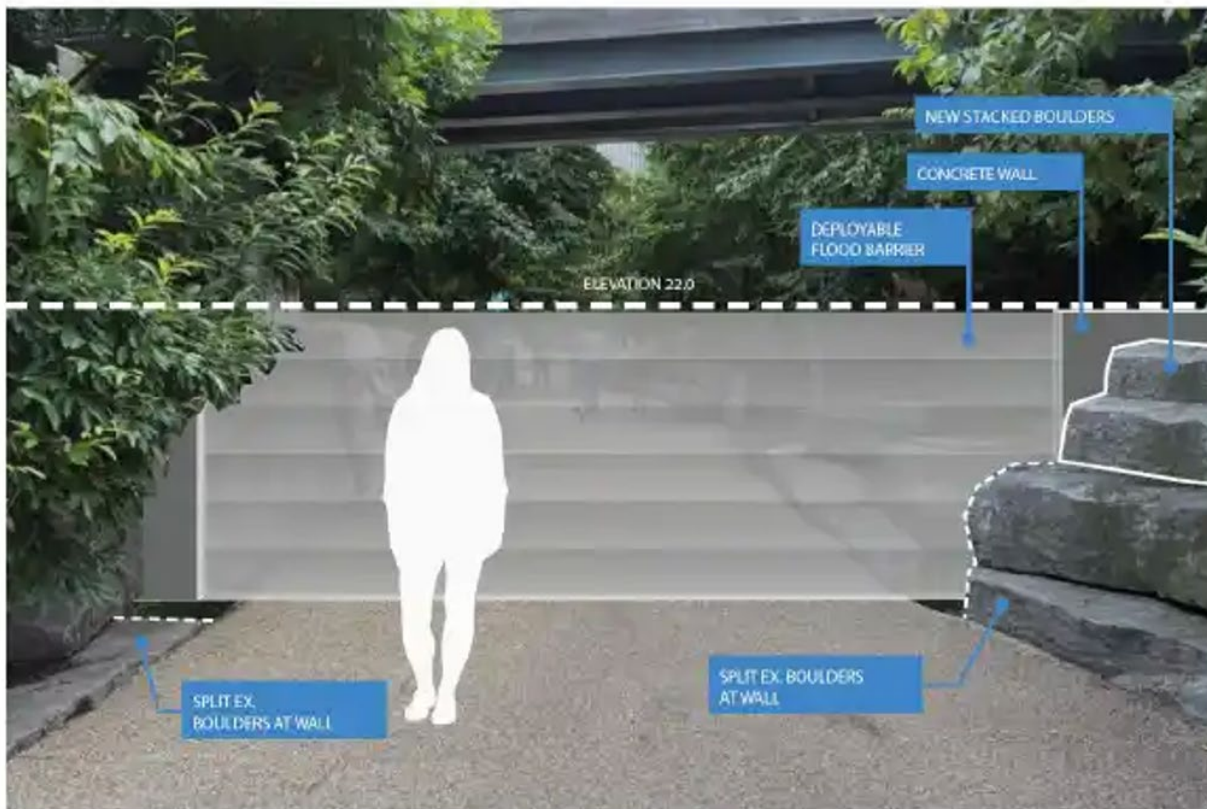
For evaluation in G2CRM, the storm surge barrier closure threshold was set to 11' NAVD88. This elevation was selected as existing elevations on the west side of the channel are above 11' NAVD88 and there are currently projects under construction or in planning and design to close the remaining flood entry pathways below 11' NAVD88 on the eastern side of the channel. The existing 11' NAVD88 contour and the locations of projects on the channel's eastern shore are shown in Figure 52. Because a timeline for completion of these projects, described below from north to south, has not yet been identified, they were not included in the FWOP modeling. Once these projects are completed, damages and benefits within model area SB_RFP below elevation 11' NAVD88 will be reduced. However, the model is still hydraulically connected to model area SB_CC along Cypher Street above elevation 10' NAVD88.

Martin's Park flood barrier, a city project, is nearing completion of construction. The deployable portion consists of two removable posts and several aluminum stop logs (Figure 53). Permanent components are two concrete pillars blended into the existing landscape and a concrete pad onto which the stop logs clamp down during a storm event. When deployed, the stop logs span the width of the walkway beneath the pedestrian bridge and stand approximately 4 feet tall. The tidal trigger for deploying the flood barrier system is currently 14.4' MLLW (8.9' NAVD88). While the deployable barrier will cut off access to the park from the Harborwalk, the park can still remain usable during a high water event. The Martin's Park deployable barrier is a critical component of cutting off flooding from Fort Point Channel between Seaport Boulevard and Congress Street.

In concert with the Martin's Park deployable, the Boston Children's Museum will use deployable barriers in front of the Fort Point Channel side of the museum to close off the flood pathway between Seaport Boulevard and Congress Street. Construction of the deployable barrier system, which will tie into high ground on both the north and south sides of the museum, is estimated to start in the fall of 2026. This is an early piece of the museum's master plan vision and phased plaza design.



Figure 52. Elevation 11' NAVD88 contours (yellow) in the vicinity of Fort Point Channel. Completed projects and projects in design are identified on the eastern shore.



Eastern Approach - Proposed Barrier Integration

Figure 53. Martin's Park flood barrier. Crest elevation is 22' Boston City Base (15.5' NAVD88).

The Sleeper Street Extension project will construct a concrete floodwall with a stoplog closure structure between two floodproofed buildings on the eastern side of Fort Point Channel (Figure 54). This project will close the flood pathway between Congress Street and Summer Street. Construction of this project is also scheduled to start in the fall of 2026.

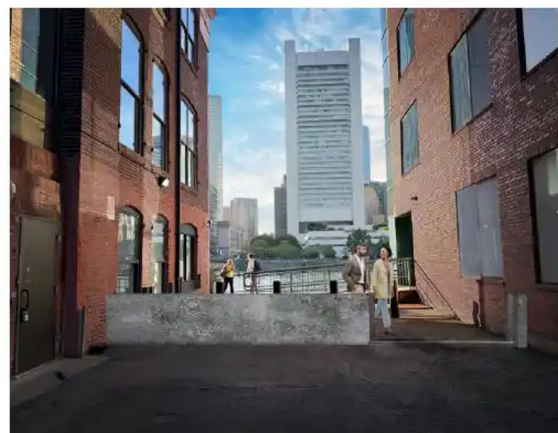
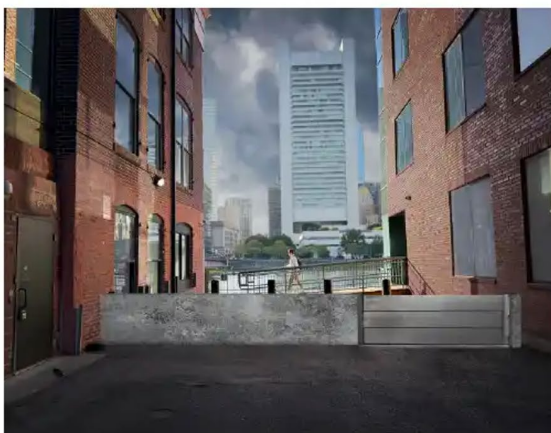


Figure 54. Sleeper Street Extension flood barrier.

South of Summer Street, the city is designing a coastal floodwall system between 15 Necco Street and the Gillette Z building. This alignment is depicted in Figure 55. In addition to the concrete floodwall, there will be deployable barriers at Binford Street and at the Gillette Z building to allow for pedestrian and vehicular access to the Harborwalk. This design is intended to be a short-term resilience project, providing coastal storm risk management to elevation 11.7' NAVD88. At this elevation, the wall will have a 2-4' stick-up height, based on existing ground elevations.



Figure 55. 15 Necco Street to the Gillette Z building floodwall and deployable barrier system.

Lastly, at the southeastern end of the channel, new pedestrian and cycling paths along the waterfront are planned as part of the Master Plan for the Planned Development Area for the Gillette Fort Point Redevelopment (Figure 56). In addition to providing recreation, the elevated paths provide for climate resiliency, managing risk to the project area and the neighborhood behind. Although Figure 56 shows the paths set back from the shoreline, the city has suggested the Harborwalk be elevated in its existing alignment

along the waterfront. This will allow for continuity along the waterfront as well as maximizing the full width of open space and its potential for active recreational use.



Figure 56. Master Plan for Planned Development Area for the Gillette Fort Point Redevelopment (2025).

While the closure threshold has been set to 11' NAVD88 for feasibility based on the aforementioned projects, it should be revisited during PED along with an adaptable closure threshold that shifts in response to SLC.

8.5 Dorchester

Alternative DOR1 is a floodwall and levee system that runs from Columbia Road south through Moakley Park and ties into high ground at Saunders Stadium (Figure 57). The DOR1 alignment has a crest elevation of 15.5' NAVD88 and can independently provide coastal flood risk management within model area DC-SB_MP to an exterior stillwater elevation of 14.1' NAVD88.

Alternative DOR2 builds on Alternative DOR1, extending the line of protection south along Columbia Point's Dorchester Bay shoreline (Figure 58). Alternative DOR2 includes a road grade change to cross Day Boulevard behind Carson Beach. On the east side of Day Boulevard, the alignment follows the existing Harborwalk as a levee, and in some narrow segments with limited available space, as a floodwall. Where the alignment approaches the Dorchester Bay shoreline and an existing revetment is present, an armored levee is proposed with a crest at elevation 17' NAVD88. An armor stone size of 800 pounds was used to develop a typical cross section for the proposed armored levee at a 1:2 (V:H) slope (see Appendix I: Civil Engineering).

On the west side of Columbia Point, a combination road grade change, levee, and floodwall system complete Alternative DOR2 north of Pattens Cove at the intersection of Morrissey Boulevard and Bianculli Boulevard. With all segment of DOR2 in place, coastal flood risk is managed within model areas DC-SB_MP, DC_CP, and SB_WS.

Alternative DOR3 provides flood risk management within model area DC_TB with a levee and road grade change at the north end of Tenean Beach that prevents coastal flooding through the flood entry pathway at the Conley Street I-93 underpass and a floodwall along the south side of the rail corridor that ties into high ground at its north



Figure 57. Alternative DOR1 manages coastal flood risk within Moakley Park and the residential neighborhoods behind it through a levee and floodwall system between Saunders Stadium and Columbia Road.



Figure 58. Alternative DOR2 builds upon Alternative DOR1, adding an armored levee along Columbia Point and a combination road grade change, floodwall and levee system at Patten's Cove where Morrissey Boulevard intersects Bianculli Boulevard.

end and the I-93 embankment at its south end. The crest elevation of the levee and road grade change behind the beach is at elevation 16' NAVD88 based on allowable overtopping limits whereas the sheltered, rail-adjacent floodwall is assumed to not be subject to wave action and has a crest elevation of 14' NAVD88. However, without additional measures described as part of Alternative DOR4, DOR3 is only independently effective or separable up to elevation 12.5' NAVD88.



Figure 59. Alternative DOR3 provides flood risk management within model area DC_TB with a levee at the north end of Tenean Beach that prevents coastal flooding through the flood entry pathway at the Conley Street underpass and a floodwall along the south side of the rail corridor that ties into high ground at its north end and the I-93 embankment at its south end.

Alternative DOR4 builds upon Alternative DOR3 and closes the flood pathways at Morrissey Boulevard and Victory Road that flank Alternative DOR3 above elevation 12.5' NAVD88. This is accomplished through the addition of a pair of floodwalls at elevation 15.5' along Morrissey Boulevard between its I-93 underpass and the Beades Bridge and a small berm at Victory Road and the I-93 North offramp to Freeport St/Dorchester. With the addition of these measures, coastal flood risk is managed within model areas DC_MS and DC_TB.

Alternative DOR6 provides coastal flood risk management to model area DC_NC with a levee through Pope John Paul and an in-water flood wall beneath the Neponset Bridge to a high ground tie-in west of the MBTA Red Line's river crossing. The crest elevation of Alternative DOR6 is 16' NAVD88 based on allowable overtopping limits.



Figure 60. Alternative DOR4 builds upon DOR3, with the addition of a pair of floodwalls alongside Morrissey Boulevard between its underpass at I-93 and the Beades Bridge and a small berm at Victory Road and the I-93 North offramp to Freeport St/Dorchester.



Figure 61. Alternative DOR6 is a levee and in-water floodwall system through Pope John Paul II Park and along the Neponset Trail on the Neponset River which manages coastal flood risk within the DC_NC model area.

9.0 Performance and Risk

ER 1105-2-101 requires risk assessment for coastal storm risk management studies. As part of the alternatives evaluation process, the PDT met to discuss Risk Informed Design (RID) and considerations for life safety with the NAE Risk Advisor. This meeting was not a risk assessment, but served as an important touchpoint to discuss preliminary assumptions, analysis, and design decisions. Collectively, the neighborhood system alignments were reviewed for completeness and to identify any flanking risks. Typical design cross sections were also evaluated.

The RID Team provided best practices from their experience on other CSRMs studies as well as design recommendations, items for further consideration, and advice on subsequent risk-related modeling and assessments.

The memorandum prepared by the RID Team is included as attachment to this appendix.

When discussing project performance, the following terms are often used:

Annual Exceedance Probability (AEP) – The probability that a certain threshold may be exceeded at a location in any given year, considering the full range of possible values, and if appropriate, the incorporation of project performance. The AEP is

expressed as a percentage. An event having a one in 100 chance of occurring in any single year would be described as the 1% AEP event.

Assurance –The probability that a target stage will not be exceeded during the occurrence of a flood of a specified exceedance probability considering the full range of uncertainties. The term selected to replace “conditional non-exceedance probability” (CNP).

Long-Term Exceedance Probability (LTEP) –The probability of capacity exceedance during a specific period. For example, 30-year exceedance probability refers to the probability of one or more exceedances of the capacity of a measure during a 30-year period; formerly long-term risk. This accounts for the repeated annual exposure to flood risk over time.

A summary of each alternative’s performance is reported for the mean AEP in Table 18 and the 90-percent confidence AEP in Table 19. Controlling stillwater levels for allowable overtopping (<50 l/s/m) are based on the 1-percent AEP wave height. Performance is reported for the start and end years of the economic period of analysis, 2040 and 2090.

For Action 2, the full system plan, the following alternatives were recommended for each neighborhood. For South Boston and Downtown/North End, a federal recommendation was not made. Rather, multiple plans are considered.

- East Boston: EB2A and EB3A
- Charlestown: CH1 and CH3
- Downtown/North End: DT1 and either DT3 or DT3A
- South Boston: SB2 or SB3
- Dorchester: DOR2, DOR4, and DOR6

For Action 3, DOR1 is recommended as the early action increment. DOR1 is separable and independently effective to an exterior stillwater elevation of 14.1’ NAVD88. This elevation is equivalent to a 0.2% AEP event in 2040 and a 1.8% AEP event in 2090 based on expected value annual exceedance probabilities. At the 90-percent confidence, a stillwater elevation of 14.1’ NAVD88 is a 0.5% AEP event in 2040 and a 50% event in 2090.

The LTEP for Action 3 is reported in Table 20 based on the mean AEPs reported for both 2040 and 2090.

Table 18. Alternative Performance by Alignment based on Mean Annual Exceedance Probabilities

Alternative (Alignment)	Crest Elevation (feet NAVD88)	Controlling SWL for Allowable Overtopping, 2040 (feet NAVD88)	Mean AEP (2040)	Controlling SWL for Allowable Overtopping, 2090 (feet, NAVD88)	Mean AEP (2090)
EB1	14	14	<0.001	14	0.009
EB2A (Constitution Beach)	14	13.9	0.003	13.5	0.071
EB3A (East Boston Waterfront)	14	13.6	0.003	13.8	0.053
CH1	15.5	15.5	<0.001	15.5	0.006
CH2 (Little Mystic Channel)	15.5	15.5	<0.001	15.2	0.007
CH2 (Chelsea Street)	14	14	0.002	14	0.04
CH3 (Navy Yard)	15.5	15.5	<0.001	14.8	0.011
DT1 (Paul Revere Park)	11.7	11.7	0.009	11.7	>0.99
DT1 (Lovejoy Wharf)	14	12	0.008	12	>0.99
DT3	14	13.3	0.004	12.8	0.33
DT3A	14	13.3	0.004	12.8	0.33
SB1	14	12.5	0.004	12.5	0.5
SB2	14	13.3	0.004	13.1	0.17
SB3	14	13.3	0.004	13.1	0.17
DOR1	15.5	14.1	0.002	14.1	0.018
DOR2 (Moakley Park)	15.5	15	<0.001	14.7	0.01
DOR2 (Columbia Point)	17	15.9	0.003	15.4	0.006
DOR3	16	12.5	0.006	12.5	>0.99
DOR4 (Morrissey Boulevard)	15.5	15.2	<0.001	14.5	0.013
DOR6	16	15.2	0.002	15.3	0.007

Table 19. Alternative Performance by Alignment based on 90% Confidence Annual Exceedance Probabilities

Alternative (Alignment)	Crest Elevation (feet NAVD88)	Controlling SWL for Allowable Overtopping, 2040 (feet NAVD88)	90% AEP (2040)	Controlling SWL for Allowable Overtopping, 2090 (feet NAVD88)	90% AEP (2090)
EB1	14	14	<0.001	13.9	>0.99
EB2A (Constitution Beach)	14	13.4	0.008	12.8	>0.99
EB3A (East Boston Waterfront)	14	13.1	0.009	13.2	>0.99
CH1	15.5	15	0.004	15	0.04
CH2 (Little Mystic Channel)	15.5	15.5	0.002	14.6	0.125
CH2 (Chelsea Street)	14	14	0.006	14	0.04
CH3 (Navy Yard)	15.5	15	0.004	14	0.5
DT1 (Paul Revere Park)	11.7	11.7	0.022	11.7	>0.99
DT1 (Lovejoy Wharf)	14	12	0.125	12	>0.99
DT3	14	12.5	0.014	11.7	>0.99
DT3A	14	12.5	0.014	11.7	>0.99
SB1	14	12.5	0.016	12.5	>0.99
SB2	14	12.5	0.01	12.2	>0.99
SB3	14	12.5	0.01	12.2	>0.99
DOR1	15.5	14.1	0.005	14.1	0.5
DOR2 (Columbia Point)	17	15.3	0.003	14.8	0.125
DOR3	16	12.5	0.019	12.5	>0.99
DOR4 (Morrissey Boulevard)	15.5	14.6	0.005	14	>0.99
DOR6	16	15	0.005	14.5	0.33

Table 20. Long Term Exceedance Probabilities for DOR1 based on the 2040 and 2090 Mean AEPs

	LTEP (2040 Mean AEP)			LTEP (2090 Mean AEP)		
	10-year	30-year	50-year	10-year	30-year	50-year
DOR1	2.0%	5.8%	9.5%	16.6%	42.0%	59.7%

10.0 Limitations

Note that at this stage only the without-project simulations have been run. The hydraulic and wave parameters utilized to evaluate alternative performance, therefore, do not account for the proposed alternatives within the project area. The physical addition of barriers may alter local hydrodynamics and result in risk transference. Without the with-project simulations, we have a limited understanding of any increases in flooding that may be caused by the addition of the project. Where with-project modeling has not been conducted, it will need to be completed as the design advances to a 35% design (level 3 cost estimate).

At this phase of study, alternative crest elevations were determined by alignment using representative water level and wave conditions from the without-project model simulations. As designs advance, alignments should be further broken down into smaller increments and site-specific water level and wave output from the with-project simulations should be used to determine final crest elevations and loads on structures.

The completeness of each alternative should be re-evaluated based on the with-project hydrodynamic model simulations to confirm there are not additional flanking risks that have not been captured from the without-project simulations.

If alternatives are constructed in phases, each alignment should also be evaluated for completeness and separability.

Finally, the modeling completed for this study assumed coastal water levels dominated any riverine contributions to total water levels. This assumption was based on a coincident frequency analysis conducted with historical records of surge and rainfall events. Because there are events beyond the historical record that have not yet occurred, further analysis of coincident coastal and riverine flooding may be needed, especially for alternatives in the vicinity of the New Charles River Dam.

11.0 Future Work

With-project coastal modeling will be needed to advance selected alternatives to a 35% design (level 3 cost estimate). This work will be similar in scope to the without-project modeling simulations in terms of the number of storms simulated and the sea level change assumptions. However, simulations will be run on the with-project mesh that has the proposed alignments and crest elevations built in. Like the without-project simulations, the with-project simulations will be conducted by ERDC-CHL. Comparisons between the with-and without-project simulations will be generated to ensure alternatives are not increasing or transferring risk.

To complete the risk assessment, simulations with and without breaches will need to be run for input to LifeSim. Output from these simulations will be needed after the 35% design.

Further storm surge barrier modeling should also be conducted, including the evaluation of additional closure thresholds and an adaptable threshold that shifts in response to SLC.

Lastly, alternatives should further be evaluated for adaptation opportunities.

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