UPCD 730
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Vulnerability of Special Needs Populations to Sea-Level Rise in Massachusetts

Calvin Anton, Xhorxho Gjoka, Hamada Hazzoum, Tina Perez, Christopher Rawson

Abstract

In this paper we will be assessing the vulnerability of the special needs population in the Boston area and what the level of vulnerability is to sea-level rise. We are characterizing special needs as the populations that are elderly or disabled and living in subsidized housing. We will then examine structural and non-structural mitigation strategies as a method of managed retreat to combat the impacts. The goal is to evaluate whether managed retreat should be considered to preserve this marginalized population. We will also identify possible new locations for affordable housing. We recently learned in a lecture that low-income households live in low quality homes in low lying areas and these combined conditions make the risk of hazards and climate change even more dangerous and impactful.

Introduction

As we are looking at the vulnerability of special needs populations to sea-level rise in Massachusetts, we will first provide an overview of the current status of housing for this population in Massachusetts and discuss the challenges that they face with housing such as accessibility, affordability and location. We will then look at how climate change might exacerbate these challenges in coastal areas prone to sea level rise.

We will then provide a summary of the National Housing Preservation Database (NHPD) which will allow us to identify federally assisted housing locations in Massachusetts and evaluate and assess the vulnerability of these properties to sea-level rise.

We will also provide a summary of the Massachusetts Coastal Flood Risk Model (MC-FRM) which shows predictive models of coastal flooding for Massachusetts in 2030, 2050 and 2070. By combining this data with an overlay of subsidized housing locations we will be able to assess which properties are at the greatest risk of flooding due to sea-level rise.

We will also be comparing FEMA'S National Risk Index (NRI) and AARP Livability Index to evaluate risks to natural hazards and community scores for livability for the elderly population. Boston has earned an Age Friendly designation and that shows the commitment the city has to supporting our aging and vulnerable populations. All of these combined resources and evaluations will help to make informed decisions on methods of managed retreat and preserving affordable housing for marginalized communities.

Lastly, we will examine the different types of managed retreat that are possible. We will first discuss structural mitigation methods like infrastructure improvements and then summarize non-structural mitigation methods like government buyout programs and relocation programs.

Methodology

Data Sources

The current status of housing for special needs populations in Massachusetts can be examined in multiple ways. For the elderly population we are choosing to focus on those aged 65 and higher. According to the US Census from 2022 , there is 0.8% of the elderly population in Massachusetts for whom poverty status is determined. This translates to just over 1.2 million people. This is slightly lower than the United States average of 11.3% of those aged 65 years or older that live below the poverty level. Most of these people would need to live in subsidized housing given their income level status.

According to the Community Economic Development Assistance Corporation (CEDAC) there are 148,780 total units of affordable housing that was produced using state and/or federal housing resources in the past 50 years. The funding programs require that the property owners commit to maintaining the affordability of these properties for an extended period of time, usually 20 to 40 years.

This specific databases tracks when the affordability restrictions will end and the properties could be converted to market rate housing. Chapter 40T law was signed into action to help preserve the privately-owned affordable housing in Mass. This legislation establishes notifications for tenants and property owners a right of first approval to provide tools for maintaining the affordable housing market.

In researching the section 202 Direct Loan program on the NHPD Preservation database it returned a listing of 18 out of 757 total records for the state of Massachusetts. This specific program provides direct Federal loans for a maximum term of 40 years 'to assist private, nonprofit corporations and consumer cooperatives in the development of new or substantially rehabilitated housing and related facilities to serve the elderly, physically handicapped, developmentally disabled or chronically mentally ill adults. This shows that there are 18 organizations that are working towards providing the appropriate housing for this marginalized community subset. There are 71 properties identified in the Boston area that are characterized as subsidized, insured, section 202, section 811 and use restriction housing.

Program: Section 202 APPLY FILTERS

Active and Inconclus DOWNLOAD COMPLETE DATABASE Xlsx EXPORT FILTERED GRID SHOW ADDITIONAL VARIABLES

Enter text to search...

#	NHPD Property ID	Property Name	Property Address	City	State	Zip Code	Total Units	Total Active Subsidies	Property Status	Earliest Start Date	Latest End Date	Latitude	Longitude	County	Congressional District	Owner Name	Owner Type	
Clear					ma													
	1022955	FIRST ASSOC PROPERTY HOMES	675 Williams St	Longmeadow	MA	01106-2055	9	2	Active	09/29/1997	02/01/2032	42.053786	-72.558721	Hampden	01	FIRST ASSOCIATION PROPERTIES, CORP.	Multiple	Details
	1022967	MENTAL HEALTH HOUSING	1030 Main St	Worcester	MA	01603-2484	20	2	Active	10/30/1998	05/01/2032	42.246656	-71.829560	Worcester	02	Mental Health Center Housing, Inc.	Multiple	Details
	1022969	NORTH SUFFOLK MENTAL HEALTH	14 Victoria St	Revere	MA	02151-3935	16	2	Active	03/10/2003	11/01/2032	42.405566	-71.007881	Suffolk	05	NORTH SUFFOLK COMMUNITY HOUSING CORP.	Multiple	Details
	1022974	SECOND ASSOC PROPERTIES	65 Price St	Springfield	MA	01104-1516	4	2	Active	09/29/1997	01/01/2032	42.146236	-72.556755	Hampden	01	SECOND ASSOCIATION PROPERTIES INC.	Multiple	Details
	1022976	UNION TOWERS II	519 Broad St	Weymouth	MA	02189-1365	75	2	Active	06/05/1987	07/31/2026	42.216563	-70.939553	Norfolk	08	UNION CONG.CHURCH HOMES, PHASE II, INC.	Multiple	Details
	1023607	MAGAZINE HOUSE	77 Magazine St	Cambridge	MA	02139-3932	11	2	Active	01/01/2001	06/01/2032	42.361454	-71.108802	Middlesex	07	77 MAGAZINE HOUSE, INC.	Multiple	Details

Figure 1. Community Economic Development Assistance Corporation (CEDAC) table of subsidized housing developments across Massachusetts.

Section 202 also provides supportive housing opportunities. These properties provide a stable living environment for elderly or disabled residents by providing on site services, community resources and social activities. There are 61 supportive housing areas across the state and they serve 8,800 residents. Public housing facilities include a variety of housing types and are managed by local housing authorities. Residents can apply for this public housing and units are available in almost every town in the state. The big concerns for all elderly or disabled residents are shared among all program and housing types as it related to accessibility, affordability and location.

In the 2021 Comprehensive Housing Market Analysis (HMA) report for Boston it highlights the fact that there is a 2.2% average increase in retirement aged residents each year. Access to healthcare services in the greater Boston area is attracting retirees from other areas and incentivizing current residents to age in place. There has been a shift seen in the percentage growth of retiree aged population compared to the 24 and younger aged population. While there are still more younger folks, there is a higher rate of increase in the

65+ year bracket than the 24 year bracket. This pretty much boils down to the fact that our older population is getting older and the younger population is not as large as it has been. This is a big reason that the Age-Friendly movement is garnering more attention.

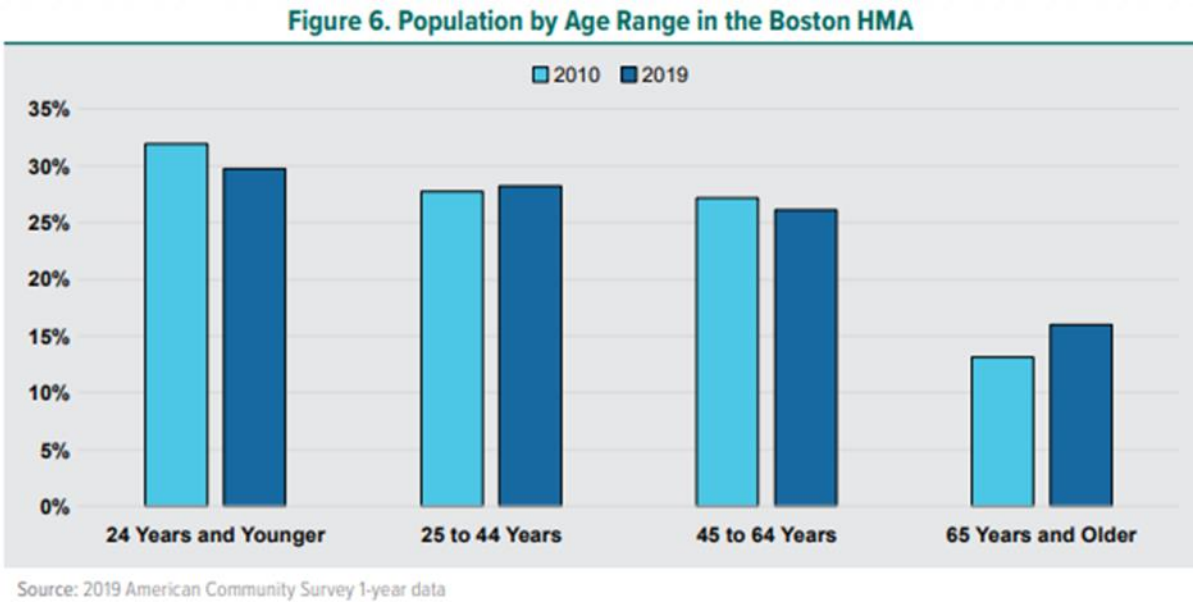


Figure 2. Boston HMA graph displaying age range and distribution for the population of Boston, Massachusetts.

In this HMA it shows that 3,500 LIHTC units were brought into service from 2010 – 2018, and 48% of these were in the Suffolk County area where Boston is. Boston currently has a goal as part of the Imagine Boston 2030 master plan to increase the number of income-restricted units in the city to 70,000, which is a jump of almost 20,000 from the current level in 2020. The city is investing almost $50 million a year towards the preservation of existing income-restricted housing as well as producing new affordable housing options.

There are quite a few challenges that this age bracket will face as they continue to age in place. There are physical barriers within the home that will make it difficult to remain mobile in your long-time home. Issues with stairs and bathrooms without grab bars can become hazardous. It is not always possible to add a ramp to the exterior of a property or install a lift to make the second level more accessible, especially in the city. Another challenge that the elderly face is access to health care. This problem is a little better in Boston than other areas, but it still is something everyone needs to be mindful of. There is an abundance of medical facilities in the city but the challenges might start to be felt when in-home care is required or someone can no longer transport themselves.

There are also social and financial issues that the aging population can suffer from. If someone is living on a fixed income from social security or some other supply source it most likely will not adjust for inflation that is being seen throughout our economy. The larger housing and tax bills will leave less money left over for groceries, medical bills and day-to-day living. As mentioned before, the lower income population tends to live in lower income housing in low lying areas. These low lying areas were generally more affordable due to the less than ideal topography, location or some other factors. And now with the ever present risk of sea level rise in coastal areas, these marginalized populations are going to be faced with some significant challenges. The risk and severity of coastal flooding and storm surges has continued to increase with each weather event. The flood risk is increasing and can create unsafe living conditions. The cost of reinforcing current homes to prevent flood damage can be very cost prohibitive to an elderly person on a fixed income.

In the case of a large weather event the resident may be forced to evacuate and ultimately relocate. In addition to being cost prohibitive it will also burden the elderly resident with social and physical challenges of losing their familiar environment and social network they are used to. This might be a positive argument for managed retreat because appropriate resources can be put in place to support the mental and physical needs of the resident without the added pressure and urgency of a recovery mission after a hazardous event. The stress and anxiety of trying to prepare for, and recover from, a weather event can be more traumatic when the vulnerable population already has to deal with health, financial or mobility issues. Managed retreat would give the resident an opportunity to find a new property further away from the coastal flooding risk and not have to deal with financial barriers or rising insurance costs from staying in the low lying areas with higher risks.

As we continue to look at the variety of risks that are posed to our vulnerable population we will also be highlighting the important risks that sea level rise and climate change are presenting our communities with. While it is nice to be on the water's edge and the coastal surroundings, this will continue to endanger the way that we live, work and play for many years to come. We as a community must recognize the dangers and work together to mitigate the risks and protect our neighbors.

National Housing Preservation Database (NHPD):

The National Housing Preservation Database (NHPD) is a comprehensive resource that tracks and stores information about any rental property with an affordable housing provision. This database stores information from various data sources, with the goal of storing and organize all the available data on affordable housing programs as an archive that would help guide policy and further improvement of these affordable housing programs around the nation.

It is of high importance to note that the NHPD has two distinct datasets:

1. Research Tool Data Grid

- This is a property-level dataset where one record corresponds to one address

2. Research Tool Data Extract

- Subsidy-level dataset that might have multiple rows/records of subsidized units in the same building and/or address

1) Research Tool Data Grid was the dataset of choice for our project. The reason behind this selection is due to our focus on the geographic location and building structures associated with the subsidized housing units for the elderly and disabled population. Using the Data Extract tool would have resulted in duplicates of the same point data when imported into ArcGIS, therefore the Data Grid helped consolidate the housing subsidy information within each property. Alternatively, the Research Tool Data Extract would have been useful for an individual subsidy approach.

Below is a brief breakdown on how the NHPD was initially used, and the variables that are vital to our study. The preliminary filtering process below provides a snapshot on the NHPD navigation. The number of properties below that are potentially at "risk" is only a preliminary estimation that served the purpose of informing us what to expect. The accurate list of target properties and risk can be found in the Results and Analysis section.

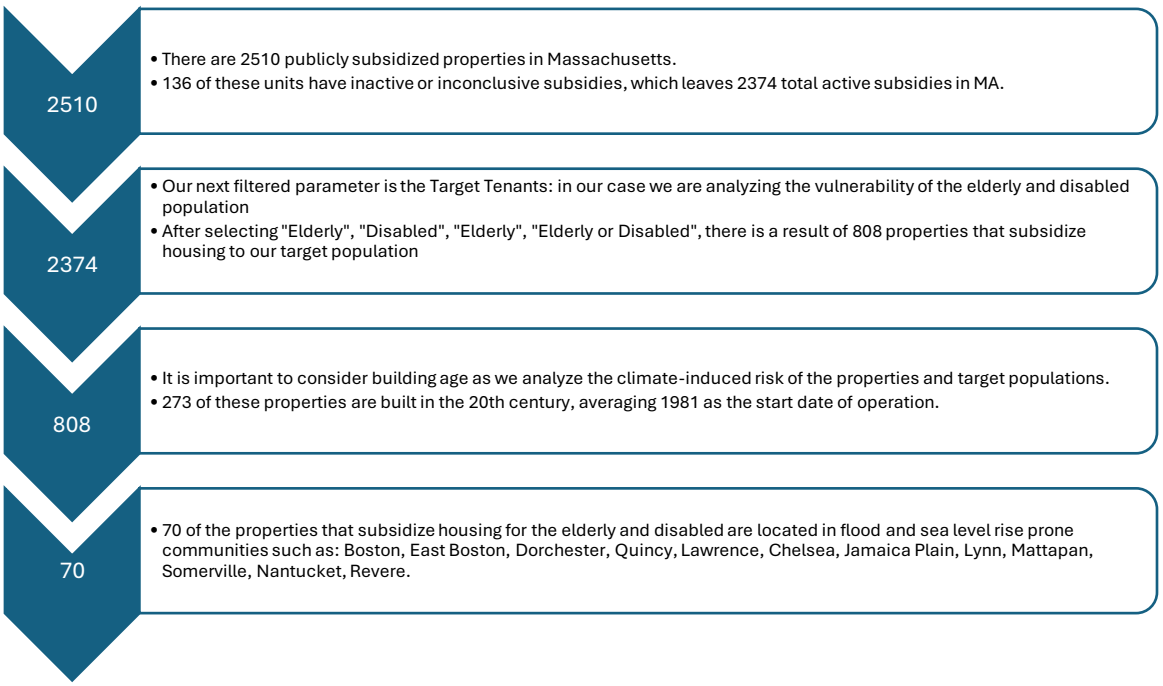


Figure 3. National Housing Preservation Database (NHPD) figure displaying their research tool data grid.

Massachusetts Coastal Flood Risk Model (MC-FRM):

The Massachusetts Coastal Flood Risk Model (MC-FRM) displays predictive models of potential coastal flooding intensity, and frequency for years 2030, 2050, and 2070. Each flooding scenario displays the full range of Annual Coastal Flood Exceedance Probabilities (ACFEP) and has output ranges from 0.001 (1000-year storm) to 1.0 (100-year storm). The model also can display flooding depth values showing the depth of water above land during a coastal flood event with 1% of ACFEP. When evaluating the predictive models, special consideration for flooding intensity, frequency and depth was given. In each of the models, those areas that are predicted to experience increasingly intense coastal flooding (i.e. 5 feet or higher), across 2030, 2050, and 2070 were noted. Additionally, coastal areas that are not directly located on the coast of the Atlantic Ocean (i.e. Merrimack, Taunton, Charles River areas, etc.), but that will be increasingly inundated during flooding events were also identified. Importance was given to these areas as it is apparent that coastal flooding events will become increasingly intense and problematic for the subsidized housing stock and those residing within it located in these areas. Consideration was also given for the temporal aspect of coastal flooding, as those properties included within the 2030 MCFRM model deserve prioritization as the impacts of flooding will be more acute than those that fall within the 2050, or 2070 MCFRM models. Overall, the MCFRM predictive models are useful in identifying areas with subsidized housing that will be increasingly vulnerable to coastal flooding, and thus where efforts to address these implications of climate change should be focused.

FEMA National Risk Index (NRI):

The FEMA National Risk Index (NRI) is an interactive mapping application that provides a holistic view of community risks to natural hazards. It uses data on 18 natural hazards, social vulnerability, community resilience, and expected yearly losses to calculate a relative measurement for every county and census tract nationwide. Coastal flooding, stated by FEMA, is when water inundates or covers normally dry coastal land due to high or rising tides or storm surges. Much of the United States is within some form of risk due to coastal flooding. Massachusetts has approximately 1,519 miles of shoreline and about 343,426 people living in some form of subsidized housing according to USAfacts.com. The FMA NRI calculates an area's risk through a simple equation where it multiplies the Expected Annual Loss by Community Risk Factor (which itself is a calculation where the Social Vulnerability is divided by the Community Resilience). The equation finally gives you the Risk Index for a community which we've used in our research

to determine the most at risk communities not only here in the city of Boston but throughout the Commonwealth. The FEMA NRI is an invaluable tool meant to give insight into key topics in planning that can get overlooked. Subsidized housing's main consideration for many developers and the public is ensuring that affordable housing is made available, when in actuality the only consideration is that what is being made available is a home that can bring together a community in which people can feel safe, valued, and protected from all risks, both man-made and natural.

AARP Livability index:

The AARP livability index is a tool that scores communities on various livability factors including housing, neighborhood, transportation, environment, health, engagement, and opportunity. According to AARP, the livability index scores are determined by drawing on multiple, interconnected points to capture the complexity of what produces a high quality of life for a diverse population across many ages. The factors that are scored are created to provide a complete and comprehensive overview of what makes certain communities better to live in over others. Scores are on a scale of 0 to 100 for each neighborhood, city, county, or state. Communities that are considered to have higher livability tend to have scores over 50. No community has a perfect score of 100 in all seven categories.

Identifying areas with high livability scores, the index helps in locating communities that offer affordable housing and necessary services, making them well-suited to accommodate populations of older adults and those with special needs, particularly those without access to a car. Understanding the balance between livability and flood risk is important when deciding on where to move if someone is at a stage of life where access to better health services and care specialists is a priority. Many older adults may no longer be able to drive and will want proximity to health services to be able to reach them via shuttles or public transportation and be near services or rideshare to allow for easy shopping and recreational activities. Many older adults may wish to age in place, however as the risk for flooding due to storm surge and sea level rise increases, many residents may wish to bear in mind these risks as they age. Populations with special needs may also wish to choose a location where they may wish to settle and not be forced to move due to rising sea levels or increased flood risk.

Massachusetts has an overall livability score of 55 out of 100 placing it into the top half of all communities in the United States with a population of 6,981,205 as of 2024 AARP determines. According to the Massachusetts Healthy Aging Collaborative, many of the communities that have a higher livability score are also communities that have a set of age and dementia friendly plans to allow residents to age in place as well as a number of additional resources and toolkits for residents that boosts the livability of these communities.

In terms of housing affordability overall, the state of Massachusetts has a score of 43 out of 10 and 59 out of 100 for Health – prevention, access and quality. Even though the state has a higher than average cost of living than most states in the country it has a large number of livable communities with robust support networks that benefit older adults. There are several communities in Massachusetts with high livability scores. The top three communities with the highest scores include Cambridge, Boston and Sommerville.

- Cambridge, Massachusetts has one of the highest livability scores at 66 out of 100. Cambridge offers excellent access to health services and a range of housing options, though it also known for high housing costs giving it a score in that area of 45 and an availability of subsidized housing of 406.5 units per 100,000. The access to health services, prevention, and quality score is 73.
- Boston, Massachusetts has a high score of 62 out of 100. Similar to Cambridge despite housing affordability challenges, Boston has excellent access to quality healthcare and services. Boston has a 16.7 percent of income spent on housing and availability 794.4 units per 100,000. The access to health services, prevention, and quality score is 62.
- Somerville, Massachusetts with a score of 65 out of 100 is a more affordable option with good access to health services and a vibrant community. The housing affordability and access score if 43, and has a housing cost burden of 19.1 per cent of income and an availability of subsidized housing of 301.4 units per 100,000. The access to health services, prevention, and quality score is 69.

How do the most affordable communities in Massachusetts compare in terms of livability and access to health services? Ayer, Massachusetts has an overall livability score of 56 but is significantly more affordable than many of the most livable towns in the state. The housing cost burden is 14.9 per cent of income and 140.3 units per 10,000. Access to health services, prevention, and quality score is 64.

Beverly, Massachusetts has a livability score of 55, is moderately affordable with a score of 41. The housing cost burden is 19.4 per cent of income with 222.6 units per 10,000. Access to health services, prevention and quality score is 56.

Lynn, Massachusetts has a livability score of 56, making it one of the most affordable communities in Massachusetts. The score for affordability and access is 46. Housing cost burden is 15.9 per cent of income and 348.4 units of subsidized housing per 10,000. Access to health services, prevention and quality score is 61.

With regard to the flood risk of the communities with the highest livability scores, according to Climate Central's Surging Sea's Risk Finder, Boston, Cambridge, and Somerville all have an 83 per cent risk of at least one flood over five feet taking place between today and 2050 in this area.

Communities at risk of flooding often face challenges like higher insurance costs and limited infrastructure resilience, which can impact their overall livability scores. Insurance can greatly increase the costs associated with living in a flood prone area, this disproportionally impacts residents in these areas.

According to Redfin roughly 14 per cent of Boston's properties are susceptible to damage from flooding over the next decade. As with most coastal areas, particularly Cape Cod and New Bedford there are substantial flood risks. Additionally, areas around Boston typically have larger populations of higher social vulnerability, making these communities priority for sea level rise mitigation initiatives or relocation efforts.

By comparing these areas, it can be determined that they are each impacted by environmental risks differently, none are immune to all environmental risks entirely. Understanding these risks is crucial for planning managed retreats and evacuations during weather events.

Understanding the balance between livability and flood risk is crucial for urban planning and development. It helps planners and policymakers make informed decisions to create resilient and sustainable communities. By identifying areas with high livability but also flood risks, resources can be allocated to mitigate these risks and ensure the safety and well-being of residents.

GIS Mapping & Analysis Methodology

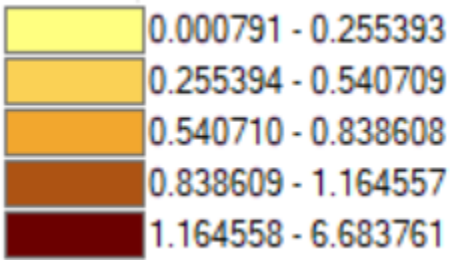
Producing our final mapping and analysis output included a few important steps which leveraged the various databases explained above. The purpose of the Mapping process is to selectively geolocate and visualize the subsidized units that were prone to flood risk according to the Massachusetts Coast Flood Risk Model. In this instance, GIS was used as an advantageous tool to merge the applicable data to visualize which subsidized housing units for our target population fall within the MCFRM zones, and which one specifically.

The active shapefiles in the GIS file that are going to be joined are: the NHPD database converted into a geodatabase, MCFRM 2030, MCFRM 2050, MCFRM 2070.

The other active shapefiles that are going to remain visible as an added layer that add context to our GIS project file are: NRI Tracts (color coded in quantiles), Massachusetts Municipalities, and City of Boston Neighborhoods.

1. Join the NHPD Data with MCFRM 2030 data
2. The output shapefile of Step 1. Is joined with MCFRM 2050 data

3. The output shapefile of Step 2. Is joined with MCFRM 2070 data
4. Filter the data output to only include properties with target tenants such as : Elderly, Disable, Elderly or Disabled, Elderly and Disabled
5. Add three (3) new field columns for the final attribute table with the joined data:
   - "Priority" = "High" for the properties that fall within 2030 zone
   - "Priority" = "Medium" for the properties that fall within 2050 zone
   - "Priority" = "Low" for the properties that fall within 2070 zone
6. To enhance the NRI context applicable to all 3 priority type properties, the Community Risk Factor (CRF) found in the NRI database was processed into quantiles to relate the data between tracts. The numerical break points of the quantiles can be found below



7. After the first six (6) steps are complete, we can see our sample of properties reduced, only including the elderly/disabled subsidized properties that fall within the 2030, 2050, 2070 MCFRM zones. We also see the NRI tracts in gradients of red.
8. The next step includes selecting the 2030 Properties which were tagged as "High Priority" and creating a new shape file from that selection, with a different symbol- the green asterisk in our case.
9. The final step was to add the MA municipalities and Boston neighborhoods to enhance the final mapping output.

Typologies

Typology #1: Subsidized housing stock located in areas where Annual Coastal Flood Exceedance Probabilities (ACFEP) in the 2030 MCFRM model are less than or equal to 2 feet.

Typology #2: Subsidized housing stock located in areas where Annual Coastal Flood Exceedance Probabilities (ACFEP) in the 2030 MCFRM model are greater than 2 feet.

Both typologies were designed taking into consideration the flood depths in the MC-FRM prediction models, along with the economic and structural (physical and policy related) constraints that may be imposed upon subsidized housing properties located in areas currently or predicted to become increasingly vulnerable to coastal flooding.

Results and Analysis

Housing at Risk

Areas located along the coast of the Atlantic Ocean, and water bodies that connect to it are predicted to experience increasingly intense coastal flooding events, which are depicted within the 2030, 2050, and 2070 MCFRM models. Subsidized housing units located within these areas, specifically, those nearest to a waterbody appear to be most at risk. Although, it is notable that certain coastal areas where subsidized housing stock is located such as the North Shore Merrimack , Boston Central, South Shore, and the Cape Cod and Islands regions of Massachusetts appear to have a higher concentration of subsidized housing properties that will be increasingly vulnerable to coastal flooding across all three MCFRM models.

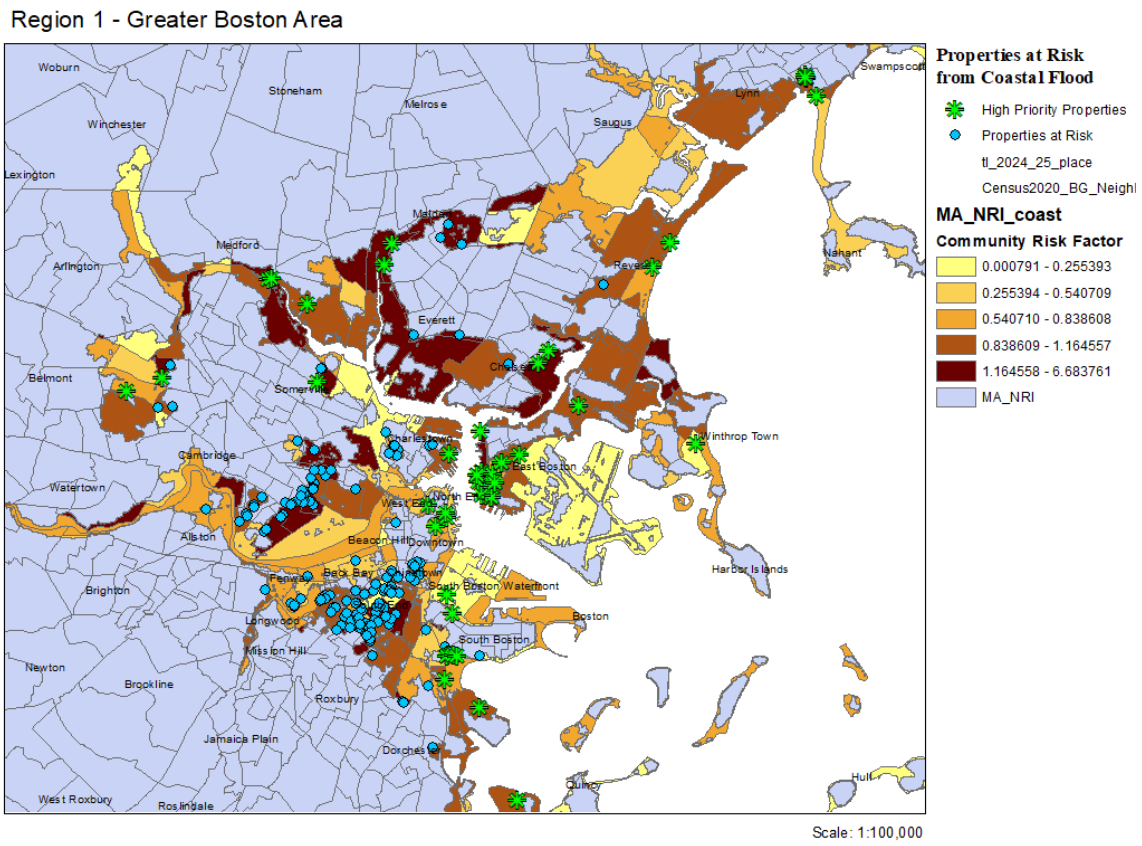


Figure 4. A Geographical Information Systems map of the "Region 1 – Greater Boston Area" region of Massachusetts. Subsidized housing properties are indicated by the blue dots. Priority subsidized housing properties are indicated by green stars. Community Risk Factor is also shown with yellow representing a community risk factor of 0.000791 - 0.255393, darker yellow represents 0.255394 - 0.540709, orange represents 0.540710 - 0.838808, darker orange represents 0.838609 - 1.164557, and darker red represents 1.164558 - 6.683761, and the gray represents the Massachusetts National Risk Index (MA_NRI). Most properties are located near the Charles River, Mystic River, Neponset River, and Boston Harbor.

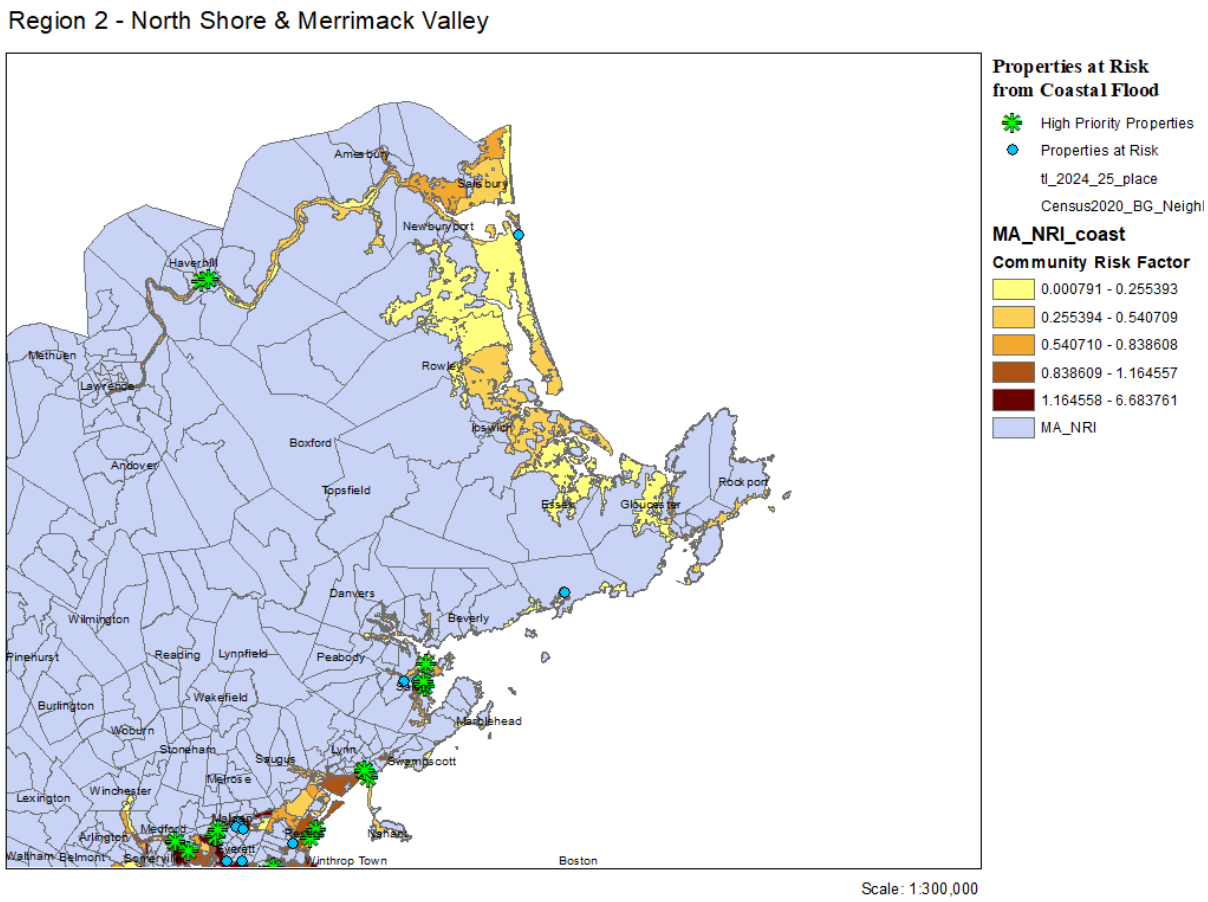


Figure 5. A Geographical Information Systems map of the "Region North Shore-Merrimack Valley" region of Massachusetts. Subsidized housing properties are indicated by the blue dots. Priority subsidized housing properties are indicated by green stars. Community Risk Factor is also shown with yellow representing a community risk factor of 0.000791 - 0.255393, darker yellow represents 0.255394 - 0.540709, orange represents 0.540710 - 0.838808, darker orange represents 0.838609 - 1.164557, and darker red represents 1.164558 - 6.683761, and the gray represents the Massachusetts National Risk Index (MA_NRI). Most properties are located near the Merrimack River, and Atlantic Ocean.

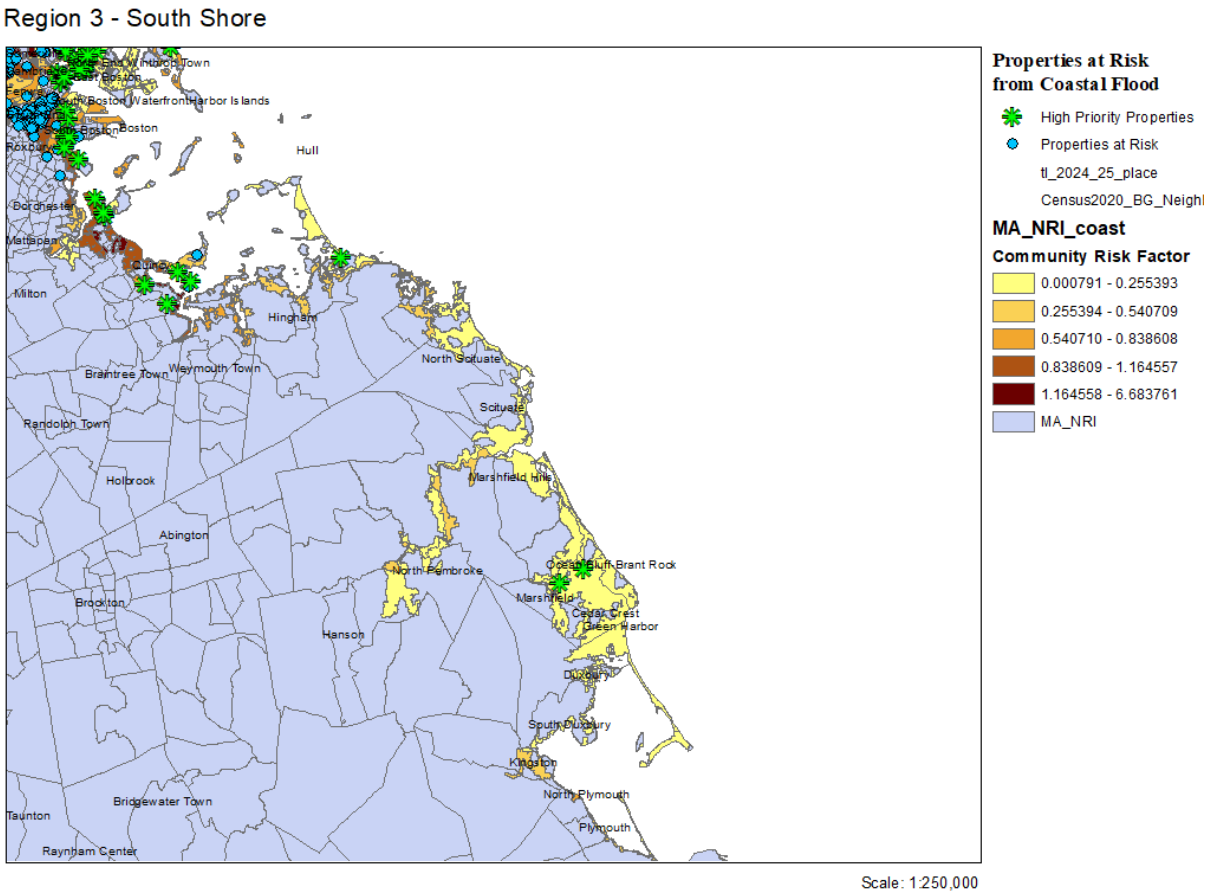


Figure 6. A Geographical Information Systems map of the "South Shore" region of Massachusetts. Subsidized housing properties are indicated by the blue dots. Priority subsidized housing properties are indicated by green stars. Community Risk Factor is also shown with yellow representing a community risk factor of 0.000791 - 0.255393, darker yellow represents 0.255394 - 0.540709, orange represents 0.540710 - 0.838808, darker orange represents 0.838609 - 1.164557, and darker red represents 1.164558 - 6.683761, and the gray represents the Massachusetts National Risk Index (MA_NRI). Most properties are located near the Atlantic Ocean.

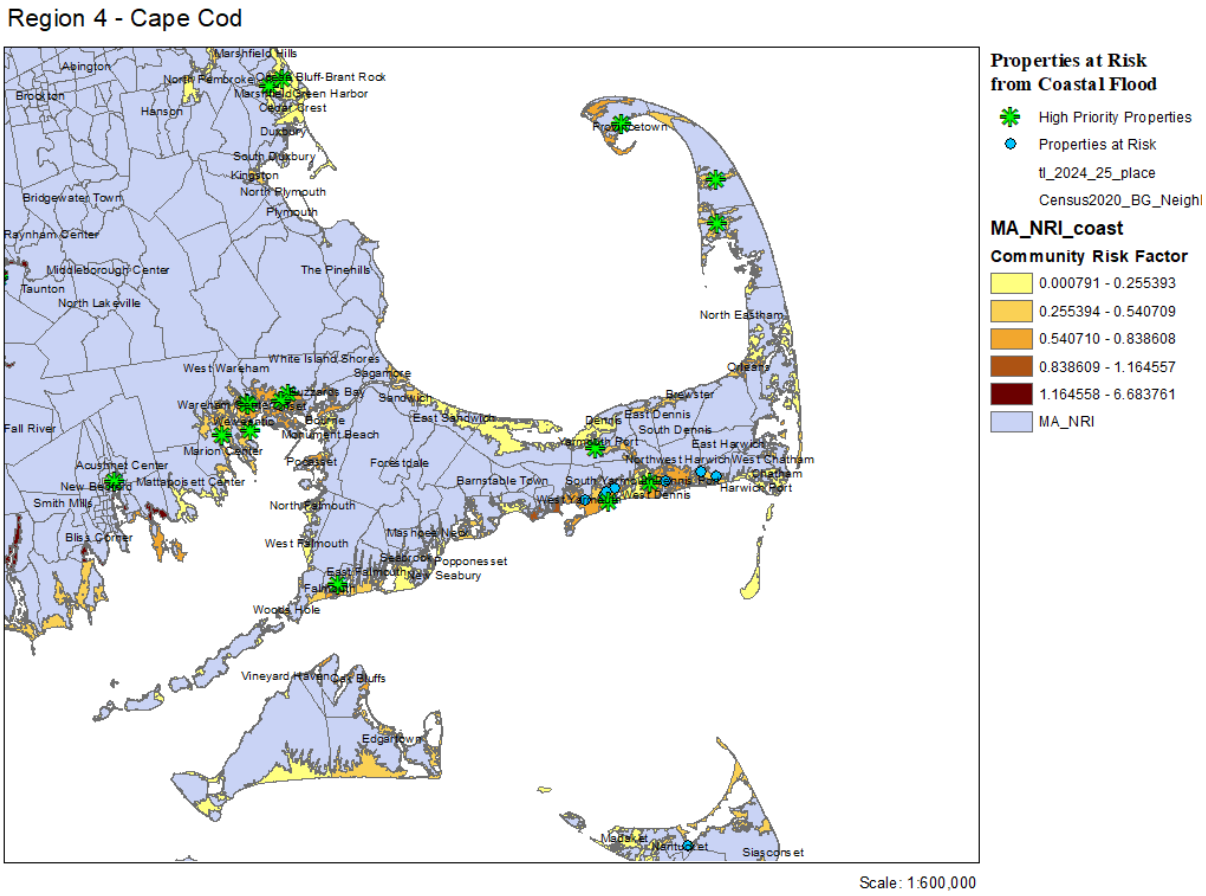


Figure 7. A Geographical Information Systems map of the "Cape Cod and Buzzards Bay" region of Massachusetts. Subsidized housing properties are indicated by the blue dots. Priority subsidized housing properties are indicated by green stars. Community Risk Factor is also shown with yellow representing a community risk factor of 0.000791 - 0.255393, darker yellow represents 0.255394 - 0.540709, orange represents 0.540710 - 0.838808, darker orange represents 0.838609 - 1.164557, and darker red represents 1.164558 - 6.683761, and the gray represents the Massachusetts National Risk Index (MA_NRI). Most properties are located near Buzzards Bay, Cape Cod Bay, and the Atlantic Ocean more broadly.

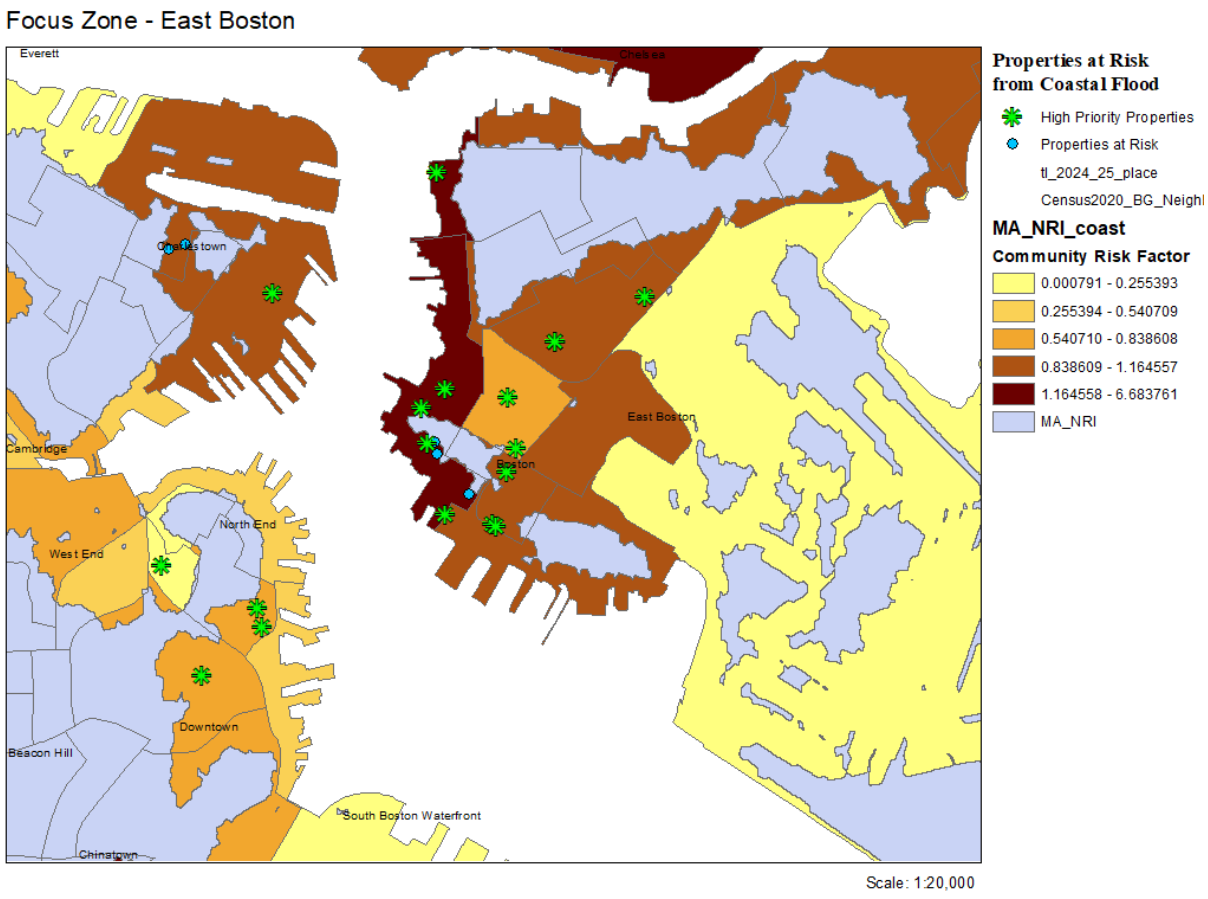


Figure 8. A Geographical Information Systems map of the "East Boston & Boston Harbor" region of Boston, Massachusetts.

We can observe that the community with the highest concentration of high risk subsidized housing for elderly and disabled is East Boston. This finding presents an opportunity to expand the vulnerability studies in this neighborhood by creating a focus group. East Boston presents a special case due to its highly diverse and immigrant population that could be prone to language isolation. We hope that our report will inform the respective institutions to craft appropriate policy for remedies that enhance the community support and quality of life that our target population is already receiving in East Boston.

Mitigation Strategies

Managed retreat is a strategic approach that involves the planned relocation of buildings, people and infrastructure away from areas that are vulnerable to the coastal risks as discussed above. It is a proactive measure that works to reduce the risks, challenges and high costs associated with disaster recovery strategies. Structural mitigation is a crucial aspect in the fight against coastal flooding and protecting those that are vulnerable to the damages it causes. "Floodplain housing is more prevalent in the most affordable and most expensive homes, emphasizing the importance of considering diverse populations…" Coastal flooding mitigation is defined as the use of structural and non-structural measures to reduce the risk of flooding in coastal areas. What we will highlight in this part of the report is the significance of structural mitigation and non-structural mitigation, with this segment emphasizing on elevating infrastructure: the costs and the benefits, the consideration of other structural mitigation methods, and finally the financial implications that go with those methods.

Structural Mitigation

Elevating infrastructure such as housing has many advantages that lead to short-term resiliency, produces economic savings overall, and ensures community protection. The process proves to be a costly yet innovative way in flood risk protection and community resiliency. According to FEMA "Several elevation techniques are available. In general, they involve (1) lifting the house and building a new, or extending the existing, foundation below it or (2) leaving the house in place and either building an elevated floor within the house or adding a new upper story". A major factor that goes into raising infrastructure is understanding flood depth and having the knowledge/ability to accurately predict future flood depths. One major source we used to better understand future flood risk and depth is the Massachusetts Coastal Flood Risk Model (MC-FRM), its purpose "helps property owners, planners and policy makers consider ways to cost-effectively build resilience and plan for the expected changes."

FEMA recommends that "Regardless of whether your house has been substantially damaged or is being substantially improved, you should consider incorporating at least 1 foot of freeboard into your Flood Protection Elevation." Our research of the MC-FRM shows that in the year 2030 the city of Boston will have an average flood risk depth of between 1.5ft to 2ft, already putting buildings which comply with FEMA recommendations at risk. By

2050, flood risk predictions in the city of Boston look to be averaging between 2.5ft to 3.5ft and by 2070 flood risk is meant to rise to 4ft to 4.5ft.

Looking through the MC-FRM flood risk model, I believe that structural mitigation techniques such as elevating infrastructure would only be beneficial for maybe the next 20 to 40 years. While elevating infrastructure is a positive mitigation technique it does not seem worthwhile as it may be obsolete in areas like the city of Boston after so many years.

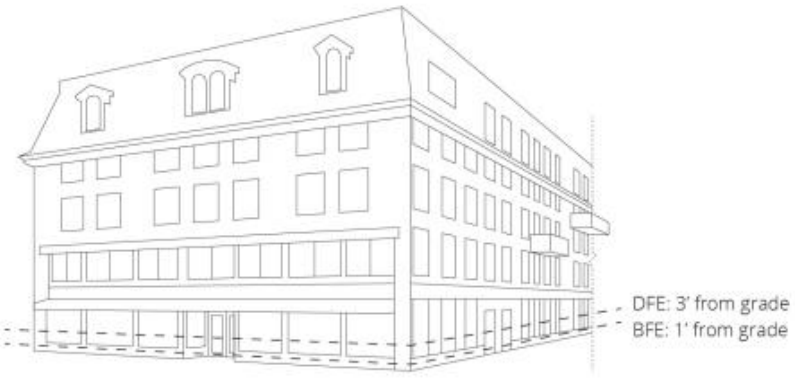
Additional measures that can be taken include insurance programs established by federal and state agencies. One measure as stated includes insurance support which can be provided in the Insurance Support funding through the "National Flood Insurance Program (NFIP). The NFIP is a federally managed program to help communities reduce flood risks via flood insurance. It is completely voluntary; however, communities and municipalities that participate in the program are required to adopt specific land-use and control measures that are aimed at managing flood risk in flood prone areas.

Furthermore, FEMA is tasked with enforcing federal regulations and standards for those participating in the program. It is recommended by FEMA that "elevating houses to the height of a flood that has a 1% chance to occur each year, also known as the 100-year flood, plus at least one foot. This is the minimum elevation for which federal funding may be available." It is important to know that there are two variations of coverage offered by FEMA, one covers the physical building while the other covers the tenant's possessions, however, neither covers the land which the property is one.

The cost-benefit analysis of the NFIP is very much two-sided. While the benefits that stem from the NFIP are helpful as they encourage floodplain management and provide financial protection to homeowners but there are some questions that have arisen regarding the long-term viability due to the incurring debt the program continues to take. In an article titled *"The National Flood Insurance Program: Why Government-Back Flood Insurance Is Drowning in Debt"* by Louis Masi the author states "As of January 5, 2021, the NFIP is over twenty billion dollars in debt." ... "The NFIP's indebtedness is due to a combination of natural disasters and a lack of private flood insurers." Masi also states that due to the incessant natural disasters and that the seemingly inevitability of increasing sea level around the world and frequency and strength of weather storms the debt of the NFIP is going to continuously rise highlighting a potential fault and chink in the armor of the long-term viability of the program.

Case Study #1

Adaptive Re-Use Mixed Use Devlopment



18th / 19th Century Wharf Building

SFHA Zone: AE
BFE: 1' from grade
Freeboard: 2'
DFE: 3' from grade

Existing Conditions: first floor retail, apartments above, mechanical equipment on the first floor

Figure 9. Adaptive re-use mixed use development located within an increasingly flood prone area where flood depths are predicted to be 1 – 2 feet. | Source: Boston Planning and Development Agency Retrofitting Report, 2016

Option #1 | Infilling First Floor

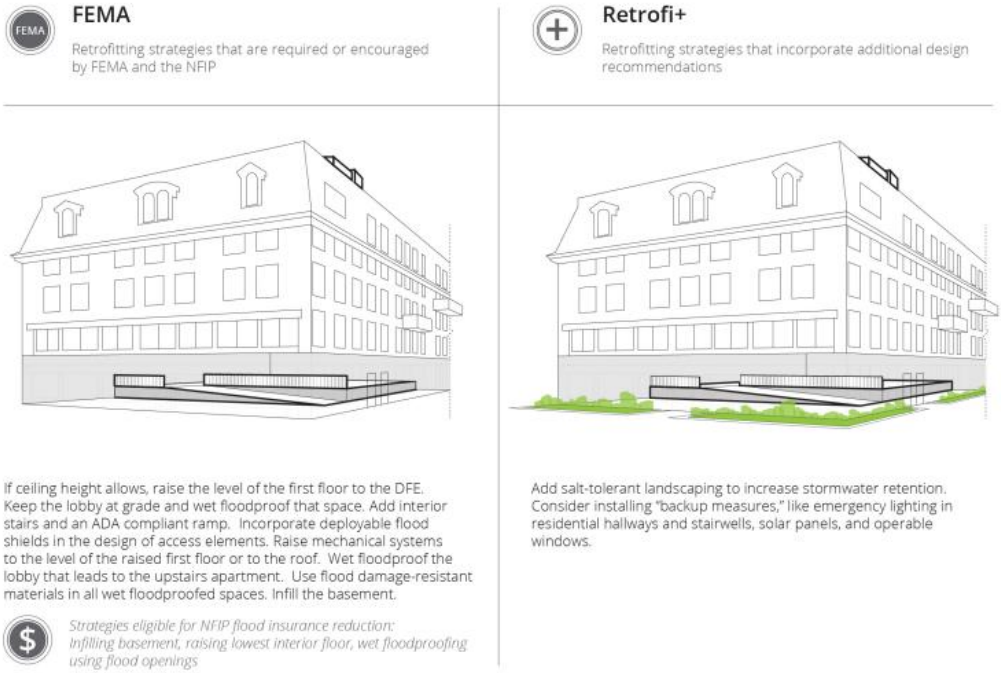


Figure 10. Adaptive re-use mixed use development located within an increasingly flood prone area where flood depths are predicted to be 1 – 2 feet but containing solutions that could be employed to address flood depths by ***infilling*** the first floor among other options | Source: Boston Planning and Development Agency Retrofitting Report, 2016

In Figure 10, the adaptive re-use mixed use development located with an increasingly flood prone area includes structural modifications that will retrofit this building into a more resilient version that could withstand the adverse impacts of coastal flooding.

The structural mitigation modifications that FEMA and NFIP proposes include:

- Infill the first floor to effectively raise the first floor a story
- Build a ramp to access the newly raised first floor
- Add deployable flood shields
- Relocate mechanical infrastructure onto the top of the roof
- Use flood damage resistant materials
- Wet floodproof basements

The structural mitigation modifications that Retrofi+ proposes in addition to those made by FEMA and NFIP include:

- Include salt tolerant landscaping for retention
- Additional lighting
- Operable windows
- Stairwells

Option #2 | Abandoning First Floor

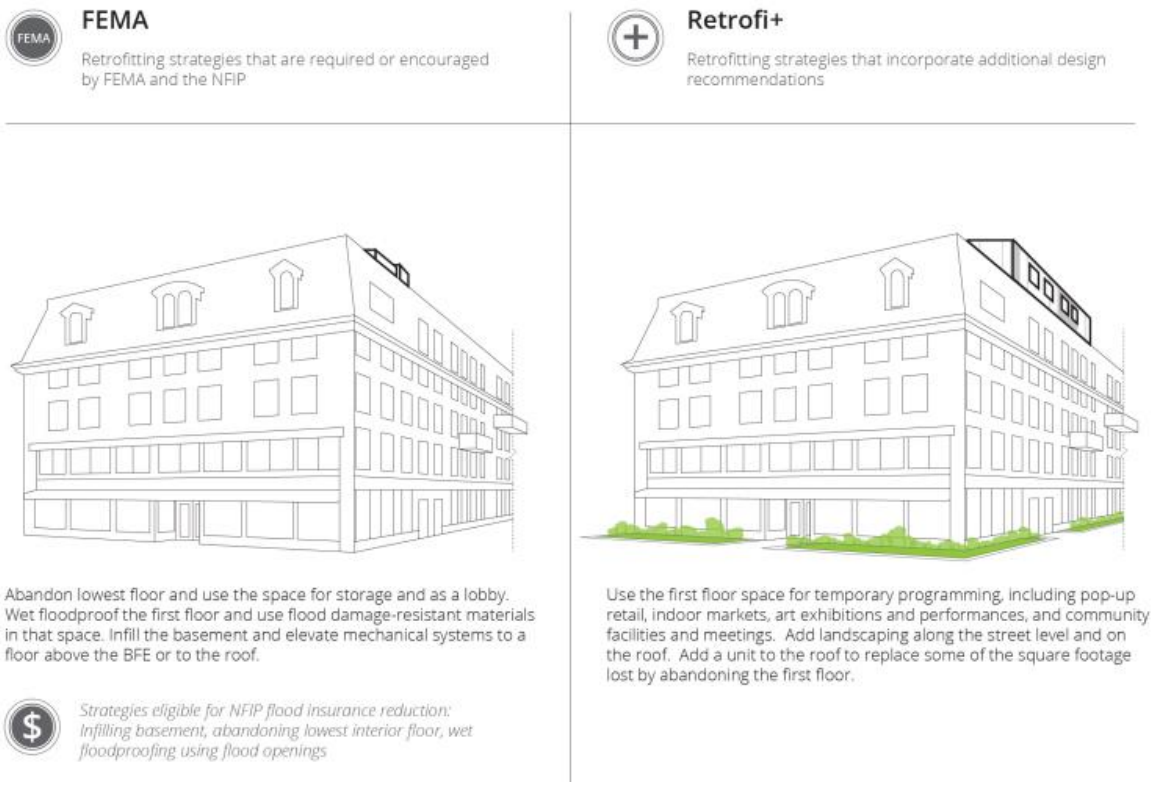


Figure 11. Adaptive re-use mixed use development located within an increasingly flood prone area where flood depths are predicted to be 1 – 2 feet but containing solutions that could be employed to address flood depths by ***abandoning*** the first floor among other options | Source: Boston Planning and Development Agency Retrofitting Report, 2016

In Figure 11, the adaptive re-use mixed use development located with an increasingly flood prone area includes structural modifications that will retrofit this building into a more resilient version that could withstand the adverse impacts of coastal flooding.

The structural mitigation modifications that FEMA and NFIP proposes include:

- Abandoning the first floor
- Use first floor as storage or a lobby
- Infill the basement
- Relocate mechanical infrastructure to the roof
- Use flood damage resistant materials
- Wet floodproof first new lobby or storage area

The structural mitigation modifications that Retrofi+ proposes in addition to those made by FEMA and NFIP include:

- Use first floor space for programming or pop-up events
- Add salt water tolerant landscaping around the building for retention
- Add additional unit on roof to make up for abandoned space on the first floor

Option #3: I Dry Floodproof First Floor

Figure 12. Adaptive re-use mixed use development located within an increasingly flood prone area where flood depths are predicted to be 1 – 2 feet but containing solutions that could be employed to address flood depths by **dry floodproofing** the first floor among other options | Source: Boston Planning and Development Agency Retrofitting Report, 2016

In Figure 12, the adaptive re-use mixed use development located with an increasingly flood prone area includes structural modifications that will retrofit this building into a more resilient version that could withstand the adverse impacts of coastal flooding.

The structural mitigation modifications that FEMA and NFIP proposes include:

- Dry floodproofing the first floor

- Dry floodproof mechanical room
- Relocate easily movable mechanical infrastructure to roof
- Infill the basement
- Reinforce structural systems

The structural mitigation modifications that Retrofi+ proposes in addition to those made by FEMA and NFIP include:

- Add salt water tolerant landscaping around the building for retention
- Install backup generators
- Stairwells
- Additional lighting

Overall, these three options include a series of modifications that can be employed to retrofit this adaptive reuse mixed use development project serving as viable solution models that could be applicable to larger subsidized housing projects that will be adversely impacted by coastal flooding in a low flood depth scenario similar to Typology 1 (subsidized housing project projected to experience 2 feet or less of flood depth).

Case Study #2

Triple Decker Units

Case studies regarding structural mitigation methods we've looked at that impact areas in the most vulnerable spots in Boston can be found in the report "Retrofitting Boston Buildings for Flooding: Potential Strategies" by Adria Boynton. Boynton details structural mitigation methods that can be done in East Boston, an area we've identified through the MC-FRM report as extremely vulnerable. Multi-family units such as "Triple Deckers" are a very common sight in New England, and they are ways structural mitigation can be implemented within them to ensure families can remain safe against rising storm water events.

A structural mitigation solution shown by Boynton shows how to fill the basement level of a unit and retrofit the roof by placing mechanical systems there. Additionally, building on the roof using the space as storage or implementing a potential roof top deck is a way the property owner can reclaim any lost square footage lost below due to the infilling. Boynton also details if multi-family units have walkouts that are on grade flood vents that implement flood damage resistant material can be implemented too. What is beneficial about these two solutions, Boynton details, is how these measures are eligible for NFIP Insurance reductions which may greatly increase the sense of appeal for homeowners and landlords who offer affordable rent rates.

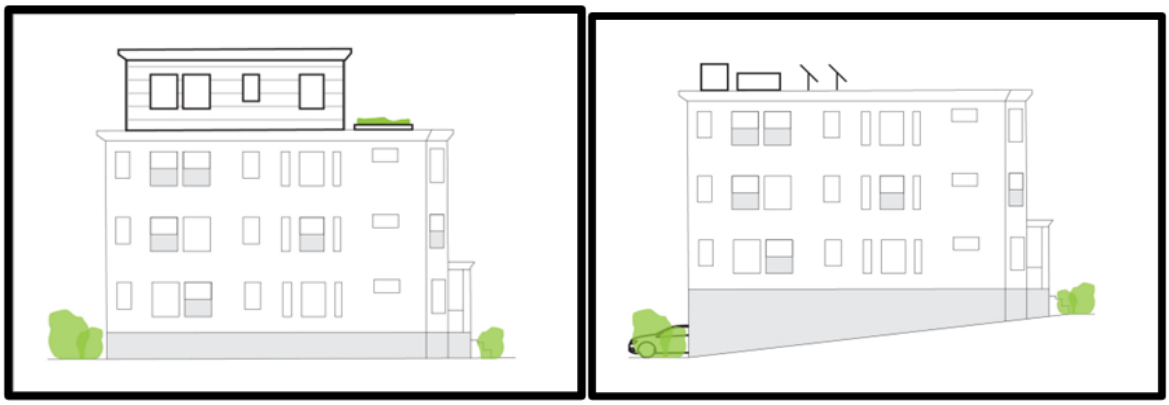


Figure 13. Triple Decker located within an increasingly flood prone area where flood depths are predicted to exceed 2 feet but containing solutions that could be employed to address flood depths | Source: Boston Planning and Development Agency Retrofitting Report, 2016

The two examples shown in the renders in Figure 13, above by the author show various ways in which structural mitigation methods can be employed in multiunit properties for areas in our Typology 2. Retrofitting the roof is an advantageous way to create space from a once unused portion of the property while maintaining the aesthetic of a neighborhood. The implementation of flood vents to reduce stress on structures is again a very good solution that can be applied to not only multifamily properties but housing developments in vulnerable location similarly in Typology 2 (subsidized housing project projected to experience 2 feet or more of flood depth).

Non-Structural Mitigation

- **Managed Retreat:** Analyze the viability of relocation programs, including buyouts and community counseling.
- **Site Selection:** Use the AARP Livability Index to recommend new locations for affordable housing that offer good access to services and healthcare while maintaining social capital.
- **Implementation Challenges:** Identify barriers to relocation, such as community resistance and legal considerations, and suggest ways to overcome them.

There are a variety of non-structural mitigation strategies such as government buyouts, zoning and land use policies, setback ordinances and permitting restrictions. By

using these methods humans are essentially 'moved out' of harm's way and natural areas are restored to enhance their ecosystem services. The research outlined above highlighted the areas at the highest risk of coastal flooding in the Boston area and through proactive measures the city can use coastal planning strategies and habitat restoration efforts to try to combat the effects that are predicted. By relocating communities away from the high risk areas, the efforts can then be focused on protecting the shoreline and trying to reduce the overall risks.

There are many challenges associated with managed retreat and it is often accompanied by controversial and lengthy debates. One of the biggest struggles the elderly population would face with managed retreat would be the strong attachment to place that they feel. Elderly people have often lived in their homes for many years and they have strong emotional and cultural ties to their communities. There are also economic concerns in regards to relocating and establishing the same quality of life in a more resilient area. Elderly people are typically on a fixed income from Social Security and retirement benefit checks and they do not necessarily have the required capital to pack up and relocate in a manner that is equitable to their current living situation.

Government buyout programs are one way of managing retreat. These programs require voluntary participation of the homeowners that are in the high risk areas and this becomes exponentially more difficult in rental housing units. The landlord must first agree to sell their properties for a fair market value and then tenant relocation assistance is required to provide the tenants with financial support for moving services, temporary housing and new rental accommodations. These programs are usually funded by federal agencies like FEMA and administered by local authorities. This requires high levels of coordination for successful implementation of the programs. Major challenges seen are ensuring fair compensation for the landlord as well as the tenants and adequate relocation support. These buyout programs will then allow for the areas of high risk to undergo habitat restoration efforts and potentially even create open and usable spaces for the public.

A major issue in Boston for these buyout programs would be the challenge of finding suitable land for relocation that is comparable to the properties that are being left behind and that is affordable. Densely populated cities do not have vast quantities of open land to build new properties on. Thorough assessments are required to find land that is accessible and has sufficient infrastructure and is environmentally sustainable. The high cost of housing in Boston makes the buyouts expensive and can limit the number of properties that can be acquired. There are social equity concerns because low income

and minority communities are typically disproportionally affected by these programs, and the elderly population would fall into that category as well.

Alternate methods of non-structural mitigation are zoning and land use policies which would restrict development in high risk areas. This would help to reduce the number of people and properties that are at risk in the first place. There can also be policies requiring elevated structures to be built in areas with known high risks for coastal flooding. There are also green infrastructure methods that can be implemented to manage floodwaters and protect coastal areas.

Setback ordinances are also an effective way to mitigate the coastal flood risks in high-risk areas. These ordinances help create buffers away from shorelines and reduce the exposure to coastal flood risks and preserves natural barriers which can help reduce the impact of flooding. Permitting restrictions would also help to enforce the above methods by making sure that building in high risk areas are carefully monitored and managed.

Case Study #1

Government Buyout Programs

There is a case study by Rice University Kinder Institute for Urban Research which examines the use of buyouts in Harris County, Texas and Charlotte-Mecklenburg, North Carolina. These programs involve the purchasing of, and ultimately the demolition of, properties in flood prone areas which will work to prevent future flood damage. This non-structural mitigation strategy is viewed as a cost-effective way of dealing with flooding and mitigation as compared to repeatedly repairing and rebuilding structures in these high-risk areas. The case study highlights the Hazard Mitigation Assistance (HMA) program and its subprograms which are run by FEMA. In a time period ranging from 1985 to 2017 Harris County has received and used $342 million in federal funds to acquire over 3,100 properties. This high number of properties acquired is due in part to the low cost of land in the area, but that still correlates to thousands of properties and homeowners that have benefited from this mitigation strategy. The Harris County Flood Control District buyout program targeted low and moderate income neighborhoods and there were lots of issues related to financial compensation and finding affordable housing locations in nearby regions. FEMA'S NRI would be able to provide valuable insight into additional areas that would benefit from this type of mitigation strategy. The buyout programs are gaining popularity but there still remains the issues of getting residents to buy in to the concept as well as the amount of time it takes to complete the process. Only once a disaster is

declared then the grant and approval process can only begin. Once FEMA has allocated federal funds the process can take more than two years later than the event occurred. In this time period the homeowner most likely has performed the repairs to their damaged home and no longer considers the buyout. This type of buyout program is seen most commonly in single family homes, up to 90% of the cases, so the likelihood that this could be used in a densely populated urban context such as Boston is less plausible.

Case Study #2

Zoning and Setback Ordinance

Another case study in Marshfield, Massachusetts is considering managed retreat as part of their coastal resiliency plans. This involves working with homeowners to gradually relocate and convert vulnerable properties into natural buffers. The town hired a consultant to study the options for managing sea level rise and storm damage. The Wood Hole Group determined that there were 15 properties that were in high-risk areas and would be vulnerable to flooding each year. A managed retreat strategy could be to buy out these properties and also create setback ordinances and create natural buffers like green spaces along the coast. The strategy would cost an estimated $7.6 million to acquire the affected properties. There are different ways that managed retreat can look like in terms of what can be done with the land once a homeowner leaves following a buyout. One such way is using the land once occupied by the structure as open beach front space that can be used by the public, allowing for more waterfront access for everyone.

These case studies have implemented successful flood mitigation strategies, and they highlight the effectiveness of proactive measures. With carefully planned managed retreat strategies the communities can reduce future coastal vulnerability and improve their resiliency to rising sea levels and storm surges. These strategies might be hard to implement in densely populated urban areas, but the problems warrant evaluating it further as time goes on, especially in multifamily housing structures.

Recommendations

Taking into account all of the current projections of sea level rise over the next several decades, managed retreat appears to be a more appropriate strategy for the most

vulnerable properties in high-risk areas in contrast with adaptation measures. As mentioned, structural mitigation techniques such as elevating infrastructure can be effective short-term but not long–term. Flood insurance can also be ineffective due to the bureaucracy, expense, and long wait times other recommendations need to consider. Additionally, the increasing frequency and severity of coastal flooding events make it challenging to ensure the safety and well-being of special needs populations through on-site adaptation alone.

Managed retreat offers a proactive approach by relocating residents to safer areas, thereby reducing their exposure to flood risks and the associated physical, social, and financial challenges. On-site adaptation, such as retrofitting homes with flood-resistant features, can be cost-prohibitive and may not fully mitigate the risks for elderly and disabled residents. Additionally, the stress and anxiety of preparing for and recovering from weather events can be particularly traumatic for these populations. Managed retreat provides a more sustainable and comprehensive solution by addressing both immediate and long-term needs. However, the question of where these populations should go is posed. When comparing the ArcGis maps with the predicative flood maps from MC-FRM we've identified are Watertown, MA, the Jamacia Plain neighborhood and Chestnut Hill neighborhood of the of the city of Boston. While areas here have a high price in terms of value, we believe that land use laws and Chapter 40B here in Massachusetts could be advantageous in securing housing for elderly and special needs populations.

In terms of making recommendations for policy to aid on the process of managed retreat; there are a number of suggested proposals. The first can be a number of incentives for populations to retreat. Creating financial assistance programs, such as grants and subsidies, to support the relocation of vulnerable populations from high-risk areas as well as the implementation of tax incentives for property owners who choose to relocate from flood-prone zones to safer areas on higher ground.

Potential policy or program changes in the state of Massachusetts may be easiser to implement due to how progressive many municipalities and the legislature are. While the city of Boston is an already high-risk area implementation of new developments utilizing the flood resistant design requirements in areas not yet prone to flooding can be advantageous, the method could also be used in already flood prone areas or potential places that may suffer in the future. Establishing these into building codes can reduce the need to retrofit adding more in terms of labor cost. Other incentives could be provided to developers to build more affordable housing in safer, higher-elevation areas and prioritize the construction of accessible housing units that are designed to best accommodate the elderly and those with special needs.

The expansion of emergency preparedness and response by establishing emergency services in greater numbers that specifically handle these populations during emergencies and evacuations. It will be important to have ways to reach these populations with important updates and alerts on conditions that are affecting their area in a timely manner. Engaging the community around the impacts of sea level rise and its impact on their area is also of high importance. There is a high importance of social networks of these populations so it should be a priority to promote disaster awareness and preparedness when these events strike.

Conclusion

It is apparent that coastal flooding events across the Commonwealth's expansive coastline (bordering the Atlantic Ocean and waterbodies connected to it) will become increasingly intense and problematic for the subsidized housing stock and those residing within it located in these areas. Thus, it will be important to understand the effects of relocation of these populations, as the resilience of these communities will depend on how well their social networks have endured to relocation processes and whether they have been re-established in their new areas of residence. "Moving communities away from these danger zones in a planned and anticipatory way can prevent future forced displacement but has been considered an option of last resort because of its potential to lead to unemployment, food insecurity, heritage loss, and other damages". Additionally, it is important that while relocating people of these populations we need to ensure that again they have social networks and that we are moving them to areas that have access to the right amenities they need. Relocating them away to aid in avoiding one issue to have another issue arise is something that planners must actively consider and avoid.

The vulnerability of the special need's population in the Boston metropolitan area to sea-level rise is a critical issue that requires immediate and comprehensive action. By focusing on non-structural mitigation strategies, such as managed retreat, this study highlights the importance of proactive measures to protect elderly and disabled residents living in subsidized housing. The Massachusetts Coastal Flood Risk Model (MC-FRM) provides valuable predictive data that can guide decision making based on identifying areas of high-risk properties and inform policy decisions as well as impacting the character of affected areas.

Managed retreat offers a viable solution to reduce the risks associated with coastal flooding and ensure the safety and well-being of vulnerable populations. By implementing

supportive policies and programs, increasing affordable housing options in safer areas, and enhancing community resilience, we can create a more secure and sustainable future for these marginalized communities. Further research is essential to understand the long-term impacts of climate change on special needs populations and to develop effective strategies for their protection and adaptation.

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