Coastal Flood Resilience Design Guidelines

boston planning & development agency

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Cover photo: Landslides Aerial Photography / Alex MacLean

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Contents

Executive Summary

The Coastal Flood Resilience Design Guidelines document is a resource to help Boston property owners and developers make informed, forward-looking decisions about flood protection for existing buildings and new construction.

This effort directly builds on Climate Ready Boston's initiatives on coastal flood resilience, which recommends a zoning overlay district and resilience design guidelines to advance building adaptation and protection from future flood risk—specifically, the 1 percent annual chance flood risk in the year 2070 with 40" of sea level rise. The role of the design guidelines is to raise awareness of future coastal flooding risks for residents and businesses, to describe and illustrate a range of strategies to reduce flood damage and disruption, and to provide consistent standards for official review for projects within the proposed Zoning Overlay District.

Resilient Design Principles

The Fort Point Channel is a major inundation point for the 1 percent annual chance flood risk in the year 2070. *Photo: Landslides Aerial Photography / Alex MacLean*

The strategies within this document center on four overarching resilient design principles guiding the design of building retrofits and new construction projects within the Zoning Overlay District.

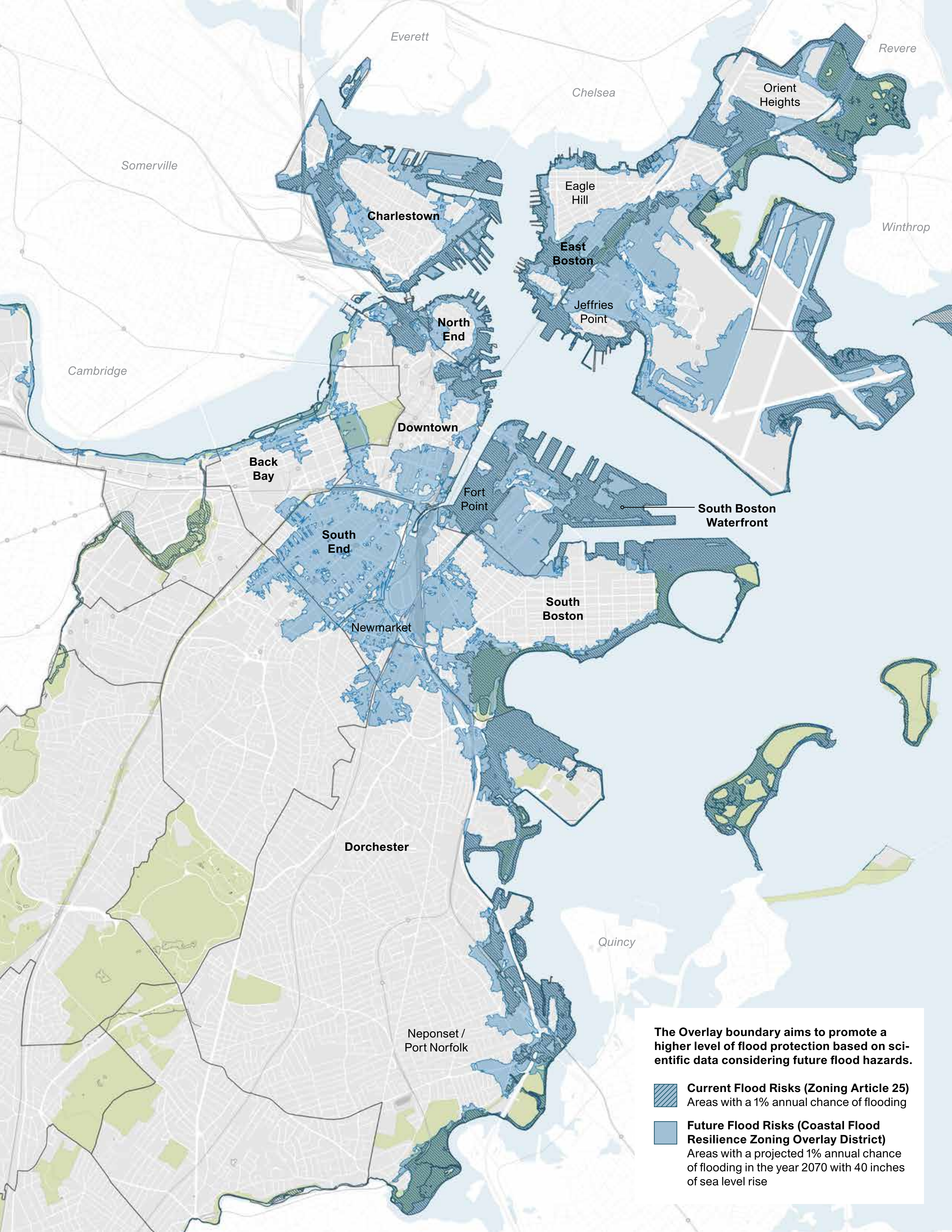
- Adaptation strategies should be future-looking and draw on best resiliency practices that also respond to the unique condition of Boston's building types.
- Building-scale resilience solutions should contribute to an overall enhancement of the public realm.
- Flood resilience strategies should play a beneficial role in overall building sustainability such as enhancing surrounding landscapes, and improving stormwater management and energy efficiency.
- Individual building upgrades should, wherever possible, relate to adjacent district-scale flood prevention infrastructure investments.

Additionally, because resilience improvements may increase property values and thereby potentially affect affordability for residents, including Boston's large population of renters and students, resources will be needed to prevent preparedness investments from negatively impacting socially vulnerable populations.

Using the Guidelines

Before using the design guidelines, building owners and project proponents should first identify future coastal flood risk and understand the underlying regulations applicable to any proposed project. The BPDA Zoning Viewer will indicate whether a property is within the future floodplain along with base flood elevations for the year 2070. Owners and proponents should consult City, State, and Federal regulations, other local jurisdictions such as Historic Districts, and local regulations such as Article 80 of the zoning code to determine if additional requirements apply to a particular parcel, existing building, or proposed project. Once risk and jurisdictional regulations are identified, the strategies presented in this document can be evaluated and selected in consultation with a professional architect or structural engineer.

Resilience Tooklit

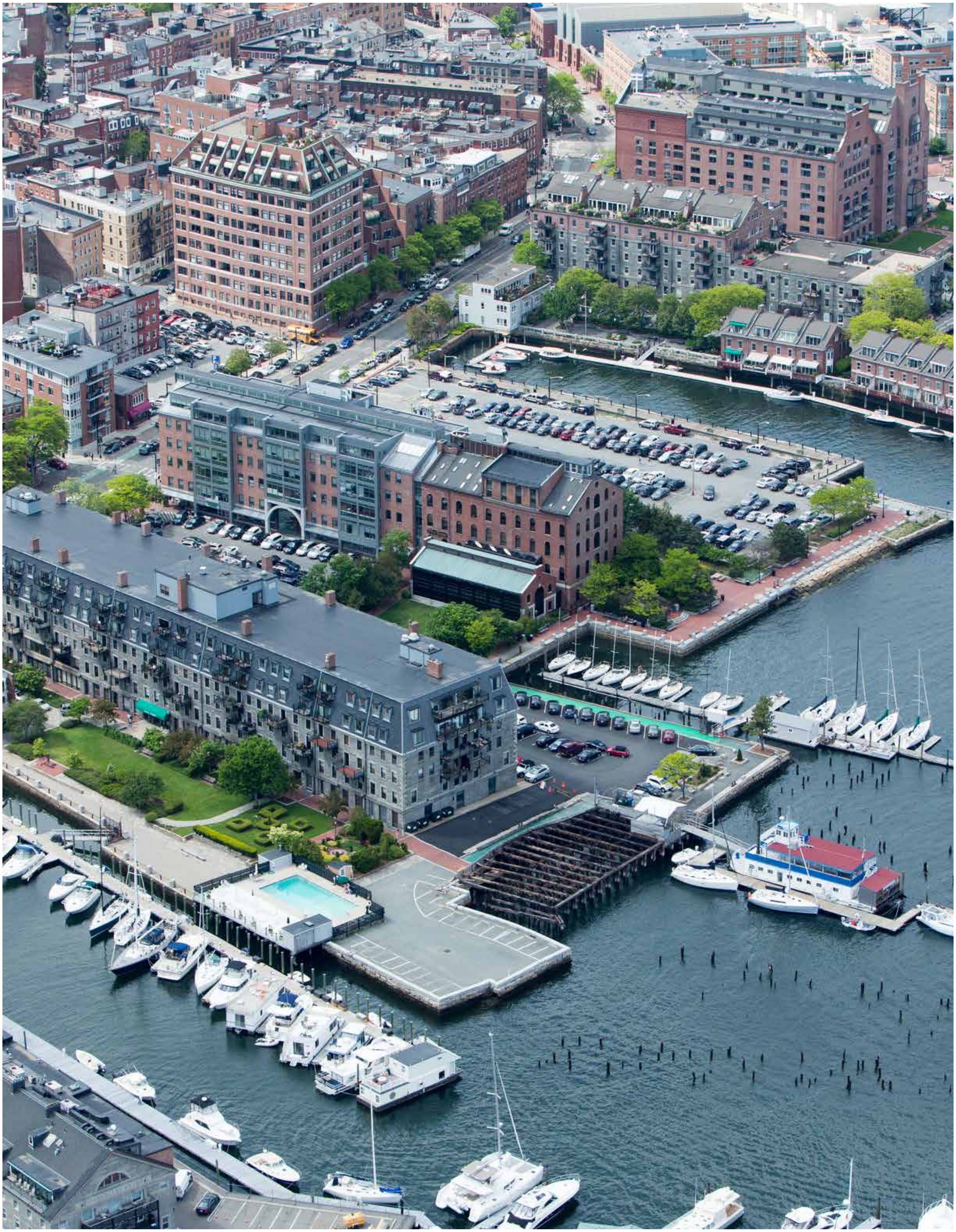


Everett
Revere
Chelsea
Orient Heights
Somerville
Eagle Hill
Charlestown
East Boston
Winthrop
Jeffries Point
North End
Cambridge
Downtown
Back Bay
Fort Point
South Boston Waterfront
South End
South Boston
Newmarket
Dorchester
Quincy
Neponset / Port Norfolk
The Overlay boundary aims to promote a higher level of flood protection based on scientific data considering future flood hazards.
Current Flood Risks (Zoning Article 25)
Areas with a 1% annual chance of flooding
Future Flood Risks (Coastal Flood Resilience Zoning Overlay District)
Areas with a projected 1% annual chance of flooding in the year 2070 with 40 inches of sea level rise

The toolkit of building-scale flood resilience strategies is divided into three categories: building form, building envelope and access, and building systems. Each strategy includes a description along with supporting information including technical considerations, relative cost and insurance factors, public realm considerations, sustainability co-benefits, and further resources. District-scale strategies applicable to larger projects are included with reference to other City resilience resources including Boston Public Works Department's Climate Resilient Design Guidelines, and the Climate Ready Boston neighborhood Coastal Resilience Solutions reports. Additionally, the document presents supporting site and building strategies that promote resilience from other risks besides coastal flooding, such as extreme heat and precipitation, and address urban design and accessibility considerations.

Case Studies

The Design Guidelines document concludes with case studies illustrating how strategies can combine to enhance the coastal flood resilience of retrofits and new construction at a range of scales and in different neighborhoods. These case studies feature six prevalent building types with varying levels of vulnerability, and each one highlights long-term and incremental resilience strategies appropriate to the building's use and construction type. While these examples are not intended to be exhaustive, they illustrate pathways specific to the Boston context for making our buildings and residents safer and better prepared for future coastal flooding.



The North End contains a range of building types that are susceptible to various levels of coastal flood risk. *Photo: Landslides Aerial Photography / Alex MacLean*

Glossary of Key Terms

1% Annual Chance Flood
Also known as the 100-Year Flood and the Base Flood, this is defined by FEMA as a flood with a 1% annual chance of occurring or being exceeded. FEMA Flood Insurance Rate Maps delineate the extent of the Base Flood, along with its corresponding Base Flood Elevations.

100-Year Floodplain
This is the extent of a flood that has a 1% annual chance of occurring or being exceeded. Also referred to as Special Flood Hazard Areas (SFHA) on FEMA Flood Insurance Rate Maps.

Adaptation
Adaptation refers to changes that respond to anticipated environmental risks.

Base Flood Elevation (BFE)
This is defined by FEMA as the top of water elevation projected for a specified flooding scenario. BFEs listed on FEMA Flood Insurance Rate Maps are based on the 1% Annual Chance Flood.

Article 25: Flood Hazard Districts
Article 25 is the section of the Boston zoning ordinance establishing a flood hazard district as defined by FEMA Flood Insurance Rate Maps (FIRMs). Note that this is different from the Sea Level Rise—Flood Hazard Area (SLR-FHA) which delineates the extent of flooding projected in 2070.

Article 37: Green Buildings and Climate Resiliency Review Procedures
This section of the Boston Zoning Code states that all projects subject to Article 80 Large Project Review are planned, designed, constructed, and managed to minimize adverse environmental impacts; conserve natural resources; are resilient to climate change; promote a more sustainable city; and enhance the quality of life in Boston.

Article 80: Development Review and Appproval
Article 80 is the section of the Boston Zoning Code that defines the development review process for large projects (more than 50,000 square feet), small projects (greater than 20,000 square feet with some exceptions), planned development areas and institutional master plans. The review process may include, but is not limited to, review of a project's impacts on transportation, public realm, the environment, and historic resources.

Boston City Base (BCB)
BCB is a city-wide datum that can be converted to NAVD88 by using a conversion factor of BCB-6.46 feet.

Boston Harbor Flood Risk Model (BH-FRM)
This is a flood risk model which was created as part of the Massachusetts Department of Transportation (MassDOT) and Federal Highway Administration (FHWA) Resilience Pilot Project. It was developed by UMass-Boston, Woods Hole Group, Inc. and the University of New Hampshire. It uses climate projections to simulate flooding from extreme weather and sea level rise, in order to plan for future resilience.

Building Floodproof Elevation
A BPDA term for the height below which water will not enter the building, including above- and below-grade building conditions and openings.

Coastal Flood Exceedance Probability (CFEP)
This is the likelihood that a location will experience a flood during a given year. The MassDOT BH-FRM uses the 1% CFEP and the 0.1% CFEP to estimate flood depths in 2013, 2030 and 2070.

Critical Facilities and Infrastructure
This is defined by FEMA as a facility where even a low risk of disruption would constitute a severe threat. FEMA includes hospitals, fire

stations, police stations, critical record storage facilities, and similar structures within this scope. The American Society of Civil Engineers also includes facilities related to energy, water, transportation, communication systems, and natural and virtual resources within their definition of critical facilities.

Design Flood Elevation (DFE)
This is defined by FEMA as the height of the lowest occupiable floor (when wet floodproofing), or the height of the lowest structural member of an inhabitable floor (when elevating a building). The DFE is separated from the BFE by freeboard.

Dry Floodproofing
Dry floodproofing is the practice of sealing a space or a building up to the level of the DFE or higher, in order to keep water from entering. When dry floodproofing, property owners must strengthen structural members in anticipation of the hydrostatic and hydrodynamic pressure caused by floodwaters. In post-FIRM buildings, dry floodproofing can only be used for non-residential spaces in A Zones.

Federal Emergency Management Agency (FEMA)
FEMA manages the federal government's response to natural and manmade disasters. FEMA also manages the NFIP and produces Flood Insurance Rate Maps (FIRM).

FEMA Flood Zone
This is the geographic area that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area. Note that this is different from the Sea Level Rise—Flood Hazard Area (SLR-FHA) which delineates the extent of flooding projected in 2070.

FEMA Zones A, AE
Defined by FEMA as areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage based on Flood Insurance Rate Maps (FIRM). These zones are included in Boston's Article 25. Note that this is different from the Sea Level Rise—Flood Hazard Area (SLR-FHA) which delineates the extent of flooding projected in 2070.

FEMA Zones V, VE
Defined by FEMA as coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These zones are included in Boston's Article 25. Note that this is different from the Sea Level Rise—Flood Hazard Area (SLR-FHA) which delineates the extent of flooding projected in 2070.

Flood Insurance Rate Map (FIRM)
Maps produced by FEMA that delineate the borders of the 100-year floodplain and corresponding Base Flood Elevations. The flood projections shown on FIRMs are based on historic data, and do not include factors related to future sea level rise.

Floodproofing
Floodproofing is defined by FEMA as structural or non-structural interventions that reduce flood damage to a space or a building.

Freeboard
Freebord is defined as the distance between the SLR-BFE and the SLR-DFE. It is defined by FEMA as a factor of safety, or a buffer between predicted flood levels and a building's lowest occupiable floor.

National Flood Insurance Program (NFIP)
NFIP is an insurance program managed by the FEMA. Communities that agree to participate in the NFIP also agree to enforce floodplain regulations that meet FEMA requirements. Property owners in participating communities are able to purchase two types of flood insurance from

the NFIP: building coverage (which includes the building, foundation, appliances and essential systems), and contents coverage (which includes belongings damaged during a flood).

North American Vertical Datum of 1988 (NAVD88)
A base measurement created by the National Geodetic Survey and used to calculate or compare elevations. NAVD88 can be converted to BCB by using a conversion factor of NAVD88+6.46 feet.

Resilience
Resilience is the ability of a system to prepare for, withstand, and recover quickly from a disaster. Ideally, resilient systems should recover from an event by becoming stronger than they were prior to the stress.

Sea Level Rise—Base Flood Elevation (SLR-BFE)
A BPDA term for the top of water elevation predicted by the BH-FRM's 1% CFEP in 2070 scenario. This includes 3.2' of sea level rise above 2013 tide levels, an additional 2.5" to account for subsidence, and the 1% Annual Chance Flood. The SLR-BFE is separated from the SLR-DFE by freeboard.

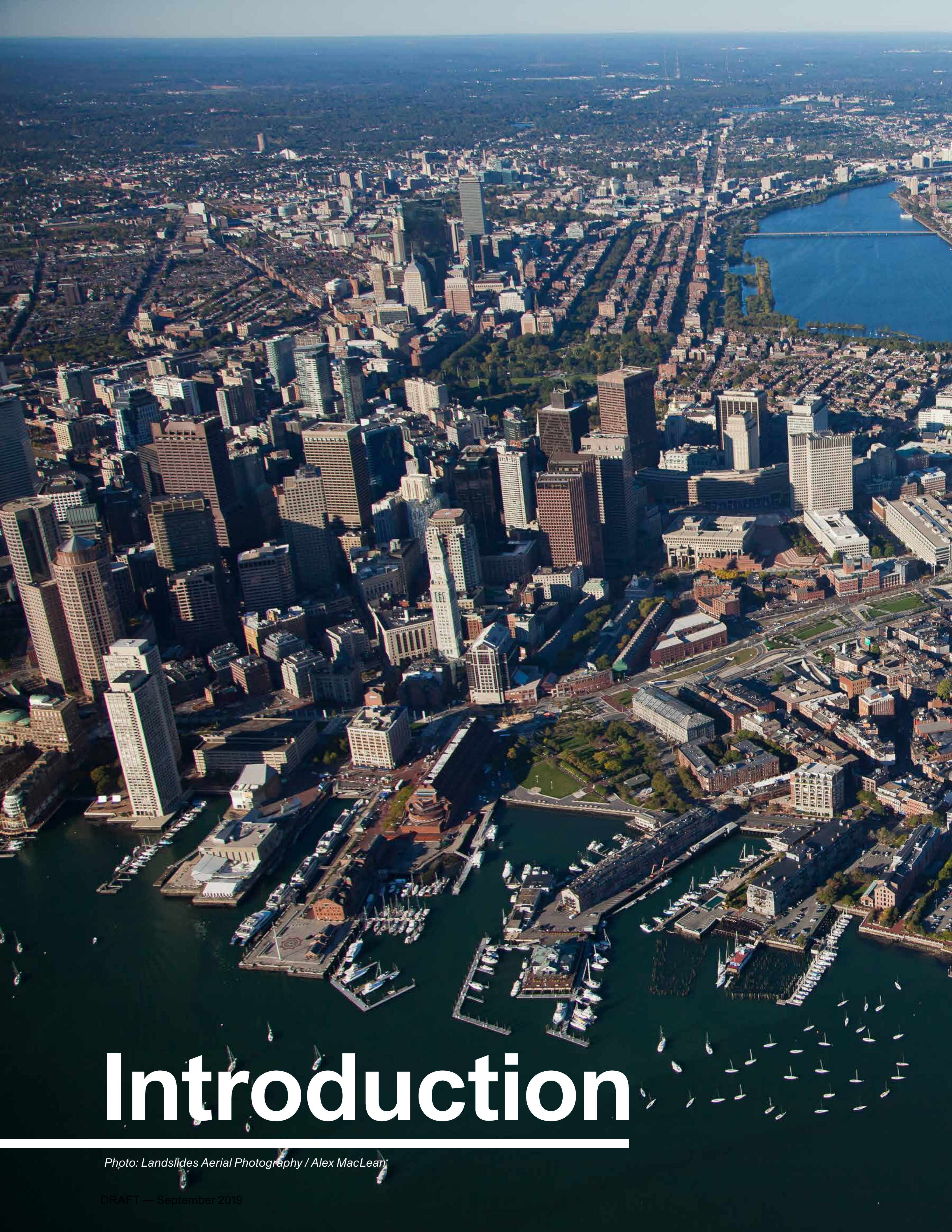
Sea Level Rise—Design Flood Elevation (SLR-DFE)
A BPDA term for the height of the lowest occupiable floor. This elevation is separated from the SLR-BFE by freeboard.

Sea Level Rise—Flood Hazard Area (SLR-FHA)
A BPDA term that delineates the extent of flooding projected in the BH-FRM for the 1% annual chance coastal flood event in 2070 with 40 inches of sea level rise (SLR).

Sustainability
Practices that protect the health of people and the environment.

Wet Floodproofing
Designing for the movement of water through a space or a building, which equalizes hydrostatic pressure and helps prevent structural failure. Wet floodproofing is only allowed for parking, access, crawl space, and storage.

Photo: Landslides Aerial Photography / Alex MacLean



Introduction

Photo: Landslides Aerial Photography / Alex MacLean

Overview

The Coastal Flood Resilience Design Guidelines and recommendations for a Zoning Overlay District are part of the City's ongoing efforts to implement the Resilience Initiatives of Climate Ready Boston, the City's 2016 climate resilience and adaptation plan, by promoting buildings that are resilient to climate change. These are intended to guide private development—both new construction and alterations to existing buildings—to become more resilient to current and future coastal flooding.

This document is envisioned as a resource to help developers and property owners implement measures that better protect buildings from coastal flood damage, and simultaneously ensure that the zoning regulations that control building use and dimensions are aligned to facilitate the implementation of flood protection and preparedness strategies presented here.

Planning Context

The Coastal Flood Resilience Zoning Overlay District (the Overlay) and Resilience Design Guidelines (the Guidelines) directly build on the City of Boston's recent planning efforts, notably the Climate Ready Boston (CRB) initiative and recommendations developed in 2016. CRB is aimed at generating resilient solutions for neighborhoods, infrastructure, and governance that help the city and region prosper and grow in the face of long-term climate change.

The report provides the first comprehensive climate vulnerability assessment for the City of Boston. It identifies critical infrastructure, facilities, natural resources, and neighborhood populations, that are vulnerable to impacts from increased extreme heat and coastal, riverine, and stormwater flooding. Through the assessment, sea level rise and coastal flooding emerged as the most significant risks for the City to address through further resilience planning and implementation.

As cited in Climate Ready Boston and other city reports, studies show that investments in flood hazard mitigation and other resilience measures can be highly cost-effective. The 2017 report by the National Institute of Building Sciences estimated that, on average, every $1 invested in mitigation prevents $6 in damage.

CRB promotes resilience strategies at different scales to reinforcing layers of protection. These include measures developed through district-scale analysis to protect broad reaches of the City's waterfront neighborhoods, as well as changes to zoning and building standards that provide greater resilience at the site and building level. The report recommended the City implement the following initiatives, which are of direct relevance to the Overlay and Guidelines:

- Establish Flood Protection Overlay Districts and require potential integration with flood protection systems
- Establish a planning flood elevation to support zoning regulations in the future floodplain
- Revise the zoning code to support climate-ready mechanical systems
- Promote climate readiness for projects in the development pipeline
- Pursue state building code amendments to promote climate readiness
- Incorporate future climate conditions into area plans

The development of the CRB report ran in parallel with the development of Imagine Boston 2030, which was issued in 2017 as the first citywide plan in more than 50 years. One of the primary goals of Imagine Boston 2030 is to prepare for climate change. To support this objective, key findings and recommendations of CRB were incorporated into Imagine Boston 2030 as well.

Taken as a whole, these planning efforts and the CRB initiatives aim to promote a city that is resilient to climate change impacts, that is environmentally sustainable, inclusive and accessible to all, that advances strong stewardship to ensure its financial sustainability, and that is planned collaboratively through broad and open public discussion.

How the Design Guidelines and Zoning Overlay Advance Resilience

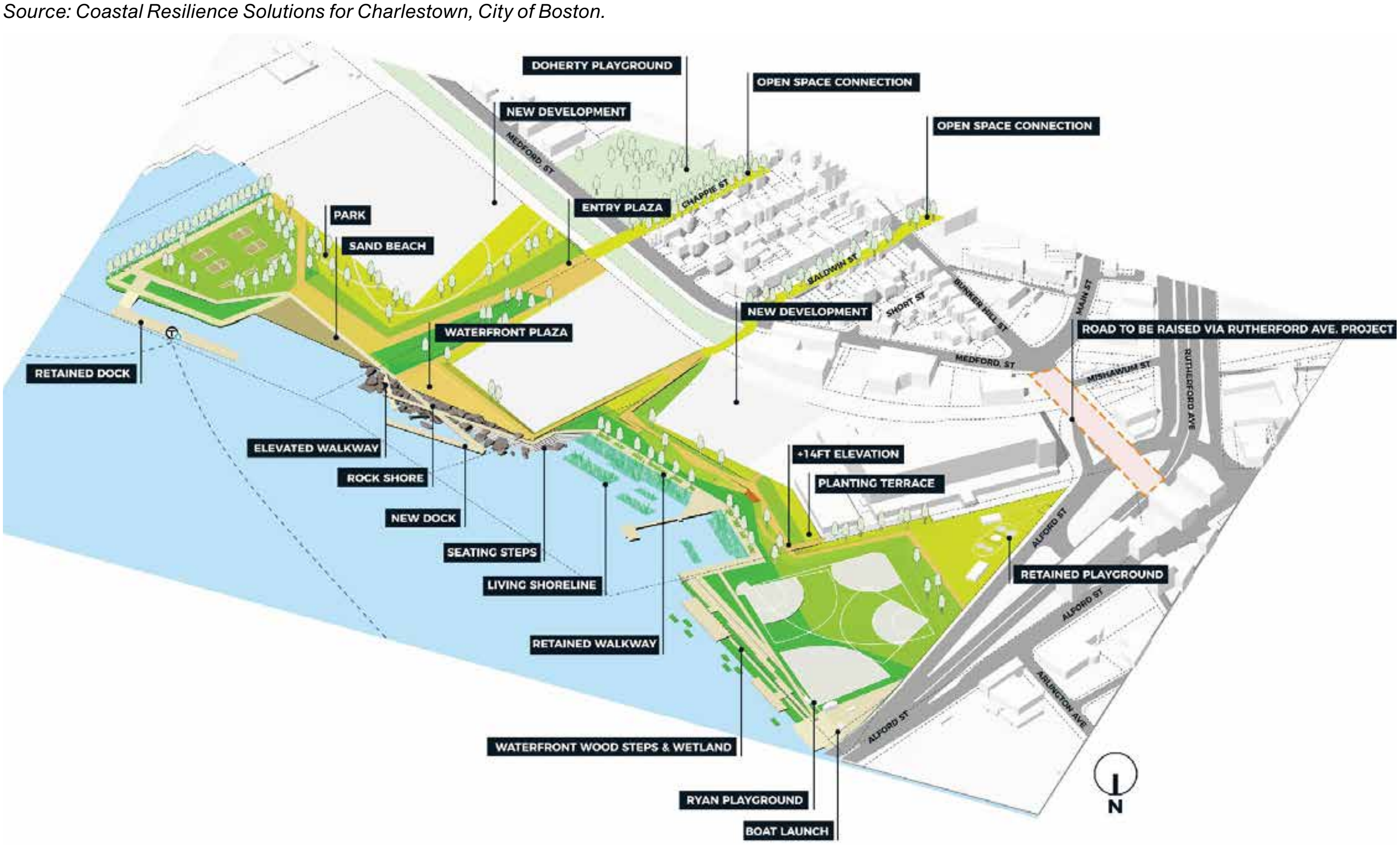
The development of flood resilience design guidelines and recommendations for a zoning overlay district is a critical next step in advancing preparedness for Boston's vulnerable neighborhoods. This design guidelines document informs residents and businesses of risks from coastal flooding and measures they can implement to reduce such risks. In parallel, the zoning overlay district will provide the City with an important regulatory tool to better influence, guide, and streamline resilient actions and eliminate regulatory barriers faced in implementing resilient measures identified in the Guidelines.

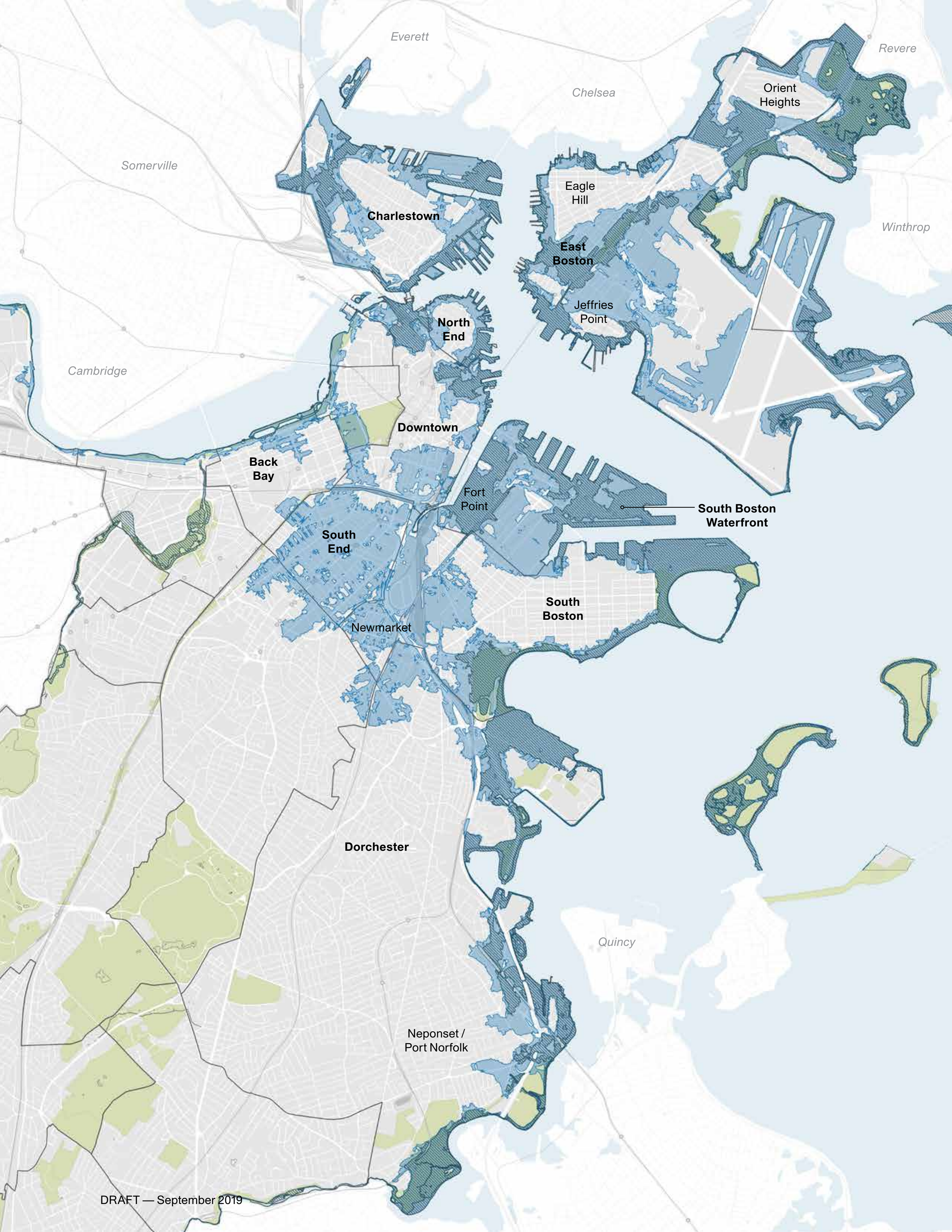
While the Design Guidelines and Zoning Overlay are important tools for moving the City's resilience agenda forward, they are still only one part of a multi-layered approach to resilience, as more fully described in the CRB report. In waterfront areas in particular, alignment of proposed development activities with the Zoning Overlay, design guidelines, and district-scale protection plans will require special coordination to maximize the benefits of long-lived investments in coastal resilience. The City is also engaged in state-level initiatives to update the State Building Code and state environmental regulations that may provide additional levels of resilience.

Coastal flooding is just one of many risks that climate change is intensifying and making more frequent. Even within the Zoning Overlay area, inhabitants and structures may also be at significant risk of stormwater flooding or extreme heat. In addition to adapting to these risks, the City is working towards a goal to make Boston carbon-neutral by the year 2050, doing its part to mitigate the effects of human activity on climate change. The Overlay recommendations and the Design Guidelines are therefore structured to promote the co-benefits of sustainable design that address these additional climate concerns.

Because resilience improvements may increase property values and thereby potentially affect affordability for residents, including Boston's large population of renters and students, resources will be needed to ensure that flood preparedness efforts also advance social equity and protect socially vulnerable populations.

Multiple layers of protection: Climate Ready Boston's resilience strategy involves multiple layers of protection at various scales. Zoning is just one of these layers. This image illustrates a series of interventions to make Charlestown more resilient. While the Overlay and Guidelines cannot implement all these recommendations, they will play a role in regulating private development.
Source: Coastal Resilience Solutions for Charlestown, City of Boston.




Everett
Revere
Chelsea
Orient Heights
Somerville
Eagle Hill
Charlestown
Winthrop
East Boston
Jeffries Point
North End
Cambridge
Downtown
Back Bay
Fort Point
South Boston Waterfront
South End
South Boston
Newmarket
Dorchester
Quincy
Neponset / Port Norfolk

Extents of the Overlay

The spatial boundary of the coastal flood resilience zoning overlay district (i.e., areas with a projected 1% annual chance of flooding in the year 2070 with 40 inches of sea level rise) was determined by utilizing projections from the best-available tool (the Boston Harbor Flood Risk Model, or BH-FRM) for which data was available citywide. This tool, developed by The Woods Hole Group, projects future flooding risks that are not accounted for in Federal Emergency Management Agency (FEMA) flood maps, which are based on historical data. These projections are helpful in that they form a consistent baseline for which to base planning and design criteria across the city. Similarly, the 1 percent annual flood chance event is used for consistency purposes in that it reflects a relatively rare event for which to base flood risk management.

In the context of the Zoning Overlay & Design Guidelines, year 2070 1 percent annual chance flood elevations and extents are used in place of historical data, reflecting sea level rise and the intensification of storms with shifting climate conditions. The 2070 time horizon was selected to account for the long-lived nature of the city's building stock and the hazards these building assets experience during their useful life. The 40 inches of sea level rise, which incorporates 2 inches of land subsidence, is a projection that fits within the range of scenarios identified by the Boston Research Advisory Group's 2016 Climate Ready Boston—Climate Projections Consensus report. It is the basis for the city's neighborhood coastal resilience plans and used by regional partners—including state agencies and neighboring municipal communities.

Zoning Article 25
(Areas with a 1% annual chance of flooding)

Coastal Flood Resilience Zoning Overlay
(Areas with a projected 1% annual chance of flooding in the year 2070 with 40 inches of sea level rise)

Key Definitions

(A full list of terms used in this document is included in the glossary)

1 Percent Annual Chance Flood

A "1 percent annual chance flood" is a flood event that has a 1 in 100 chance of occurring in any given year. Another name for this flood is the "100-year flood." Experts prefer not to use the "100-year" term since it gives the impression that a certain level of flooding will only occur once every 100 years. In fact, it has a one percent chance of occurring in any given year and can even occur multiple times in a single year or decade. Over a 30-year period, there is almost a one in three chance that a 1 percent annual chance flood will occur at least once.

Sea Level Rise—Base Flood Elevation (SLR-BFE)

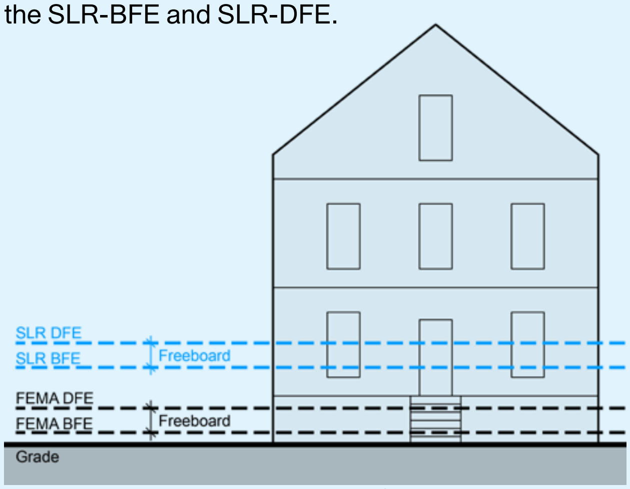
The term used in the Overlay and the Design Guidelines for the top of the water elevation projected for the 1 percent annual chance coastal flood in the 2070 scenario under the Boston Harbor - Flood Risk Model. This includes 40 inches of sea level rise (including 2 inches to account for subsidence.) The SLR-BFE is separated from the SLR-DFE by the freeboard.

Sea Level Rise—Design Flood Elevation (SLR-DFE)

The term used in the Overlay zoning and the Design Guidelines for the minimum elevation of the lowest occupiable floor for residential uses, or dry floodproofing for non-residential uses. This elevation is separated from the SLR-BFE by the freeboard.

Freeboard

Defined by FEMA as a factor of safety or a buffer between the predicted flood elevation levels and a building's lowest occupiable floor for residential uses, or dry floodproofing for non-residential uses. For purposes of the Overlay zoning and the Design Guidelines, the freeboard is the distance between the SLR-BFE and SLR-DFE.



Role of the Design Guidelines and Overlay in Addressing Coastal Flood Risks

The proposed Coastal Flood Resilience Zoning Overlay District will incorporate the extent and elevation of future flooding, provide regulations on the use, height, performance standards, and incentives for the design of new construction and retrofitted buildings to promote resilience to coastal flooding.

As noted previously, Climate Ready Boston recommended the development of zoning and other building and land use controls that facilitate adaptation to climate change. The BPDA has already started to integrate resilience into its planning and development review processes. Community planning efforts initiated by Imagine Boston 2030 are now integrating the CRB vulnerability assessment and resilience recommendations into district plans, to promote climate preparedness. Projects that undergo Large Project Review under Article 80 of the Zoning Code are required to provide planning responses to sea level rise and other climate change hazards, as defined by BPDA's Climate Resilience Checklist in Article 37.

To assist developers with assessing future flood risks on their properties, the BPDA has integrated a Boston Sea Level Rise—Flood Hazard Area layer, based upon the BH-FRM, in the existing BPDA Zoning Viewer mapping tool (see http://maps.bostonredevelopmentauthority.org/zoningviewer.) The layer provides a Sea Level Rise—Base Flood Elevation (SLR-BFE) for each flood hazard area, which is a future flood elevation based upon a 1 percent annual chance storm event with 40 inches of sea level rise in 2070. The City has determined 40 inches of sea level rise to be a reasonable standard for preparedness, based on the best currently available scientific data. The same zoning viewer will be used as the basis for mapping the proposed Overlay district.

The Design Guidelines provide detailed and consistent standards for project reviews by the staff of BPDA and other City agencies, to encourage a quality streetscape and building that is pedestrian-friendly and flood-proofed. The Design Guidelines also inform residents and businesses how to assess their coastal flooding hazards and identify measures they can implement to reduce risks from those hazards. The City's goal is for the Overlay and the Design Guidelines to become part of standard development practice for project owners, designers, and builders.

Neighborhoods and Existing Building Types Affected by Coastal Flooding Risks

Crafting adaptation solutions for the city's vulnerable building stock requires understanding the range of building types that occur in the coastal floodplain and how they are distributed in neighborhoods at-risk.

In general, buildings in Boston are dominated by small- and mid-scale housing. One- to three-story housing, which include single-family houses, two-family houses, and triple-deckers, make up more than 30% of the total square footage of built space in Boston. The next biggest category of buildings is mid-scale residential buildings—residential buildings with fewer than 30 units or less than 7 stories in height. Together, low- and mid-rise residential buildings make up almost half of the built square footage in Boston and are also highly prevalent in the Overlay. These building types pose one of the biggest challenges for retrofitting and adaptation, because most of this building stock is older. In addition, owners of smaller buildings often have limited access to capital and limited capacity to undertake resilience improvements themselves. Many of these neighborhoods have existing building stock that is non-conforming with existing zoning. Any changes made to the massing of these buildings could trigger other requirements for zoning compliance.

Building attributes such as material configuration, construction type, lot condition, and size and form are important factors when considering resilience retrofit strategies. Each of these factors presents different opportunities or constraints that will affect the feasibility, effectiveness, and cost of adaptation. For example, townhouses in the South End have larger lot coverage ratios, this can limit the ability to implement on-site landscape strategies. Triple-deckers in East Boston often have the first floor elevated two to three feet above grade, this may minimize flood risk to the first floor, compared to other building types in the same area, but these buildings may have basement apartments that are at risk.

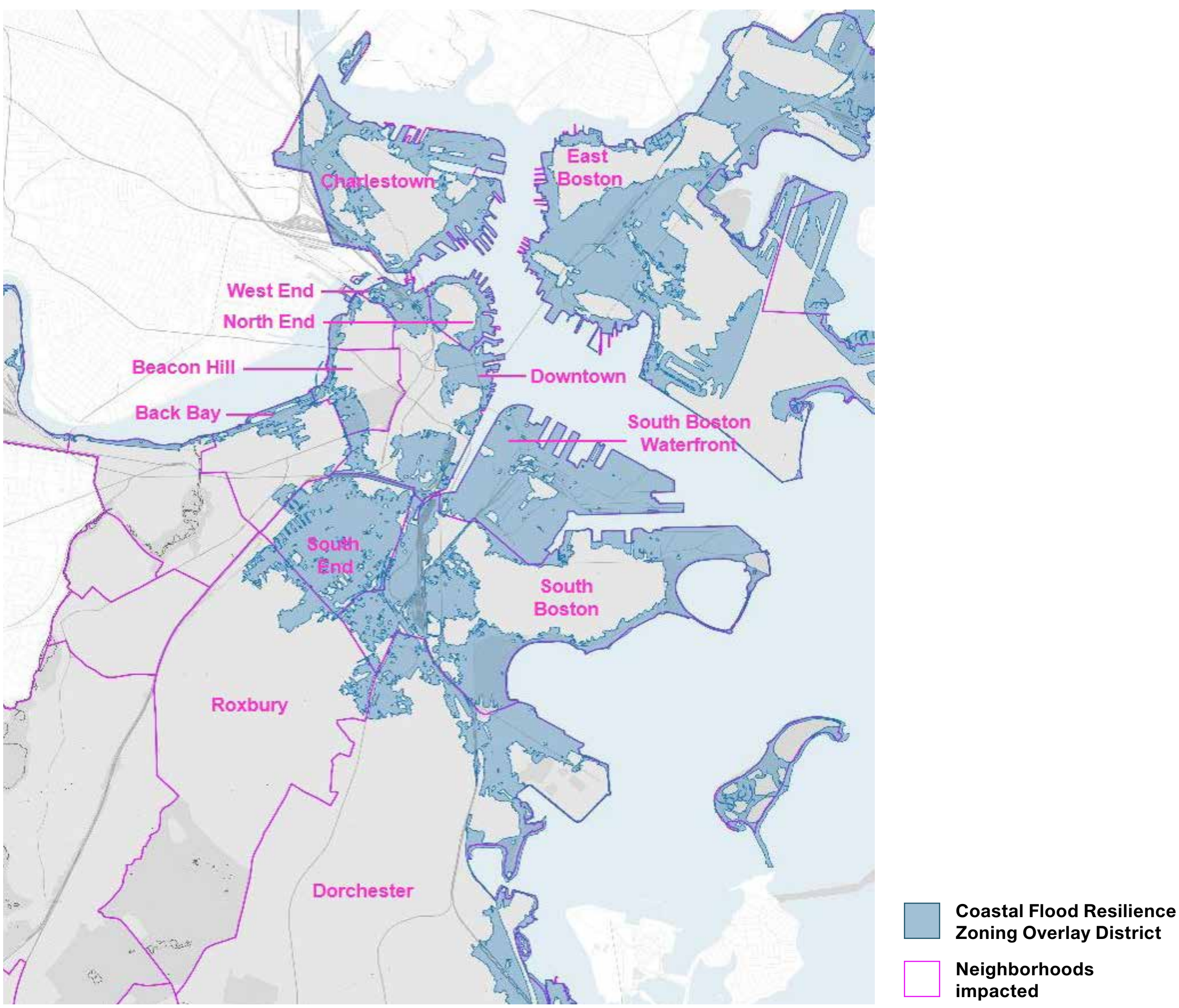
In order to develop guidance on more readily applicable adaptation strategies within the Overlay, the six most prevalent building types in neighborhood areas vulnerable to coastal flooding were identified. This analysis was conducted using the City of Boston Tax Assessors' Parcel Data and Building Data used in the Climate Ready Boston vulnerability assessment. Attributes from parcel and building data were inventoried and matched to each of the six building types presented here. They are:

- One- and Two-Family Residential
- Triple Decker
- Attached Townhouse
- Pre-war Mixed-use
- General Industrial
- Three-family Residential (New Construction)
- Multi-family Mixed-use (New Construction)

(Note that this is not a comprehensive list. These types cover the range of buildings most commonly found in the floodplain. There may be others that are unique or a combination of types and not listed here.)

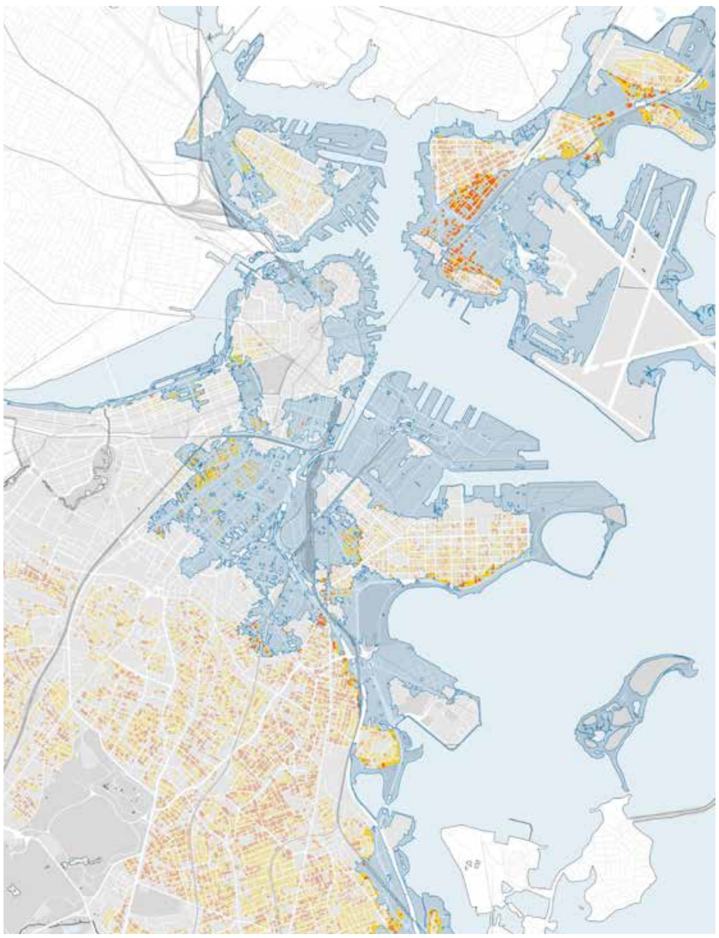
The case studies presented in Section III of the accompanying Design Guidelines are based on these six building types within the Overlay, showing how they vary in their vulnerability to damage and in their applicable retrofitting options. Primarily, the retrofitting case studies provide best practice recommendations for smaller residential and mixed-use buildings that contain residential units, and that fall below the review thresholds for Article 80 Large or Small Project Review, i.e., buildings with a gross floor area (GFA) less than 20,000 SF.

Neighborhoods Impacted by the Overlay



The maps below are an illustration of locations where these types tend to cluster. They have been derived from the City of Boston's Tax Assessors' database using the best available attributes to identify the building types. Because of limitations with the data, these maps are not comprehensive or mutually exclusive. There may be instances where all buildings of a certain type are not represented on the map, or buildings are identified in more than one map.

One- and Two-family Residential, and Triple-deckers



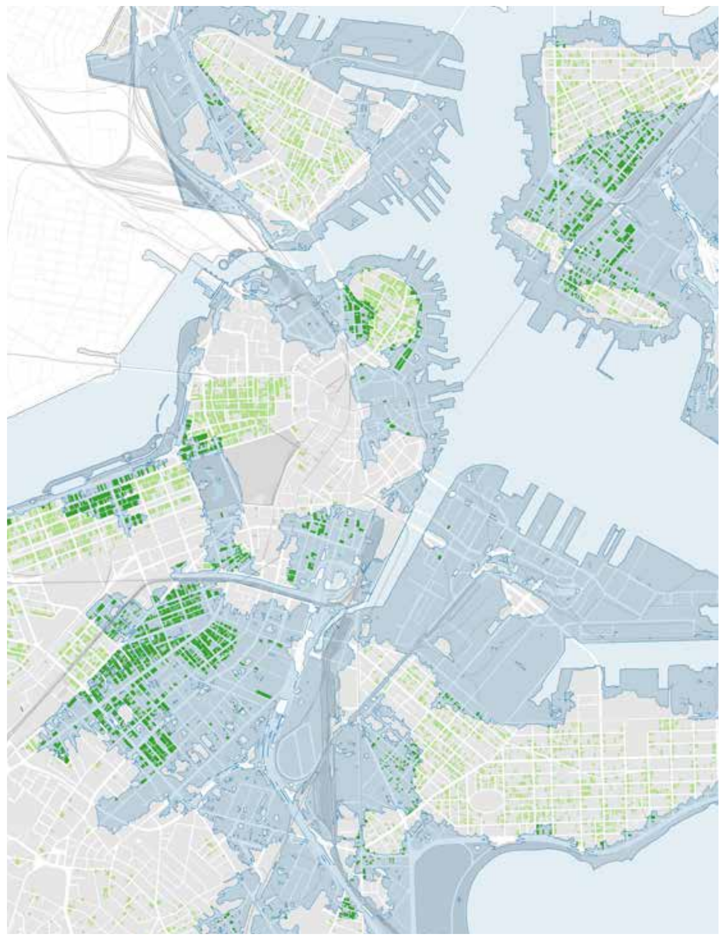
One- and two-family detached residential in the Overlay

Triple-deckers in the Overlay

Other one- and two-family detached residential

Other triple-deckers

Attached Townhouses



Attached townhouses in the Overlay

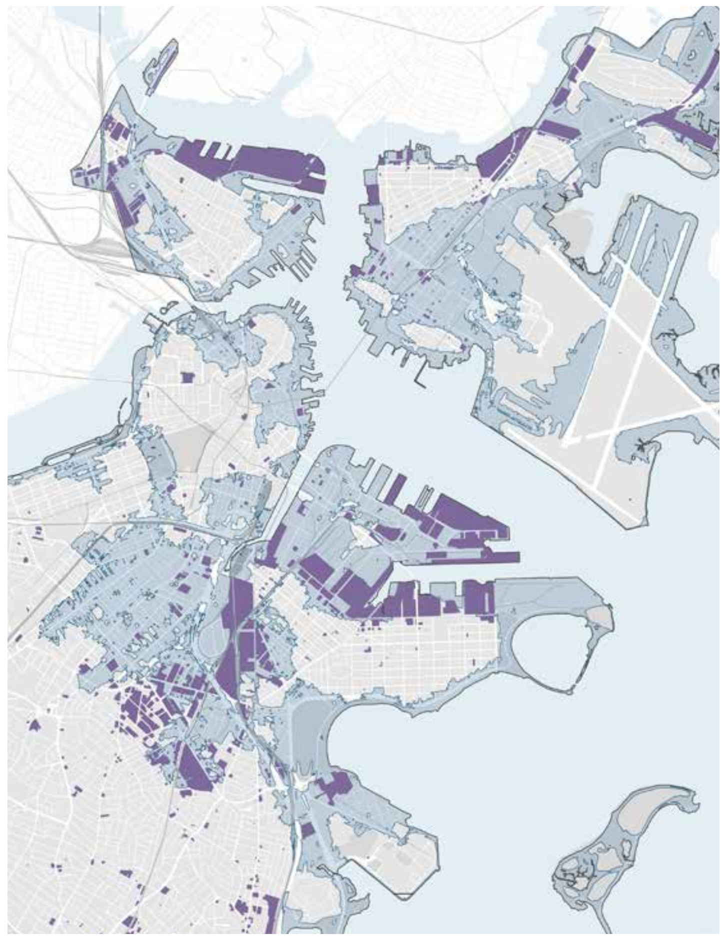
Other townhouses

Pre-war Commercial or Mixed Use Buildings

Pre-war commercial or mixed-use buildings in the Overlay

Other pre-war commercial or mixed-use buildings in the Overlay

General Industrial Buildings



General industrial buildings in the Overlay

Other general industrial buildings

Resilient Design Principles

The strategies presented in this report draw on the four principles below that should guide the construction or retrofit of projects in the Overlay.

Resilience Standards

Proposed designs / renovations should incorporate best practices and standards to reduce or eliminate coastal flood risk or damage resulting from future climate conditions.

Urban Design and the Public Realm

Resilient measures should be seamlessly integrated into the public realm and building design. Resilient design should support pedestrian connections and accessibility and enhance the character of the streetscape, and they should not diminish the public realm to the greatest extent possible.

Sustainability Co-benefits

Wherever feasible, implementation of flood resilience measures should also enhance a building's energy efficiency, carbon footprint, and passive survivability.

Relationship to District Solutions

Enhancements at a parcel level should not worsen risk at adjacent parcels or restrict future implementation of district coastal resilience plans, and, to the extent feasible, should support the resilience goals and implementation of district coastal resilience plans.

Resilience Standards

Boston is choosing to adopt a higher standard than the minimum set by state and federal regulations to make new and existing and future construction resilient to future climate change impacts. Precedents from other municipalities that are implementing similar forward-looking strategies have informed the City's approach. The strategies presented in this document are drawn from a number of local and national sources and adapted to suit the Boston context and respond to prevalent building and construction types in the city.

Urban Design and Public Realm

Integration of flood-resilient design strategies will have a significant impact on the ground-level condition of new and existing buildings, and subsequently, the public realm. In adapting best practices to each individual project, it will be critical to address the interface between the private and public realm in a manner that ensures that access is maintained for people of all abilities, and solutions contribute to an overall enhancement of the street wall at the ground level rather than detracting from it. This document identifies measures to achieve this principle for applicable strategies.

Sustainability Co-benefits

Potential areas where resilient design strategies can also achieve other sustainability co-benefits such as increasing building efficiency or creating new public space. The Design Guidelines provide examples, including: upgrading to more efficient heating and cooling systems in addition to floodproofing when replacing equipment, simultaneously considering the resilience and operational benefits of an on-site renewable energy system, designing and selecting operable windows for both passive ventilation and energy efficiency benefit, and incorporating landscaped flood protection systems that also provide recreational open space and ecosystem services.

Relationship to District Solutions

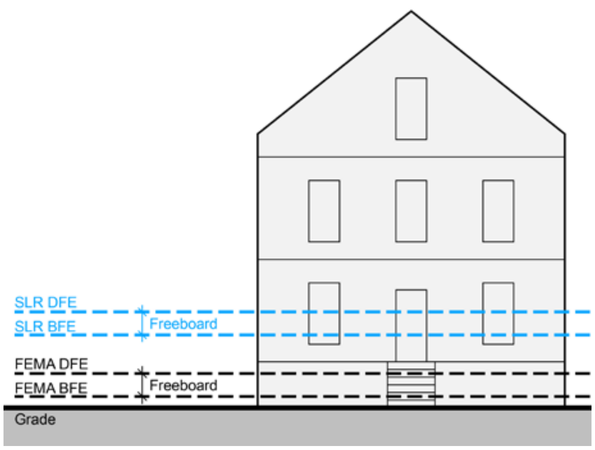
Climate Ready Boston emphasizes solutions that are independently effective can also work together to provide mutual support and reduce the risk of a catastrophic failure associated with a single line of defense. District-scale coastal flood protection infrastructure investments have been planned as the first line of defense. The Design Guidelines provide a framework for coordinating parcel-level development activities with these district-scale plans. Additional details and guidance on proposed district-scale strategies can be found in Climate Ready Boston, the Boston Public Works Department's Climate Resilient Design Guidelines, and the neighborhood coastal resilience solutions reports.

How to Use the Guidelines

Identify Your Risk

First, determine whether your parcel is exposed to coastal flooding risks by opening the BPDA Zoning Viewer, turning on the Sea Level Rise—Base Flood Elevation (SLR-BFE) layer, and click on your parcel. The parcel information box will list the SLR-BFE number in feet, Boston City Base datum. If no information is listed, your parcel is not in the Overlay.

Next, take the SLR-BFE number and add either 1' or 2' of freeboard to it, depending on the existing (for retrofits) or planned (for new construction) uses. For most uses, 1' of freeboard is required. Residential uses, and uses which are conditional within the overlay (these may include essential facilities and services necessary for emergency response as determined by the zoning), the required freeboar dis higher at 2'. If there are multiple uses with different freeboards, the higher freeboard should be used. The SLR-BFE plus the freeboard equals the



SLR-DFE.

Understand the Regulations

The design and construction of buildings and structures in areas at risk from coastal flooding is regulated by FEMA's FIRMs, State building code as well as City zoning regulations and other local laws.

Federal, state, and city regulations

FEMA requires local governments to adopt minimum zoning standards in order for property owners to participate in the National Flood Insurance Program (NFIP). These standards must be applied to areas that FEMA has mapped as having a 1 percent annual chance of flooding. Article 25 of the Boston Zoning Code was established to meet this requirement, giving property owners in Boston access to federally subsidized flood insurance. NFIP also has specific regulations governing how buildings in flood zones should be designed and constructed. Those are addressed by the Massachusetts State Building Code, 780 CMR (State Building Code), which is included by reference in Article 25.

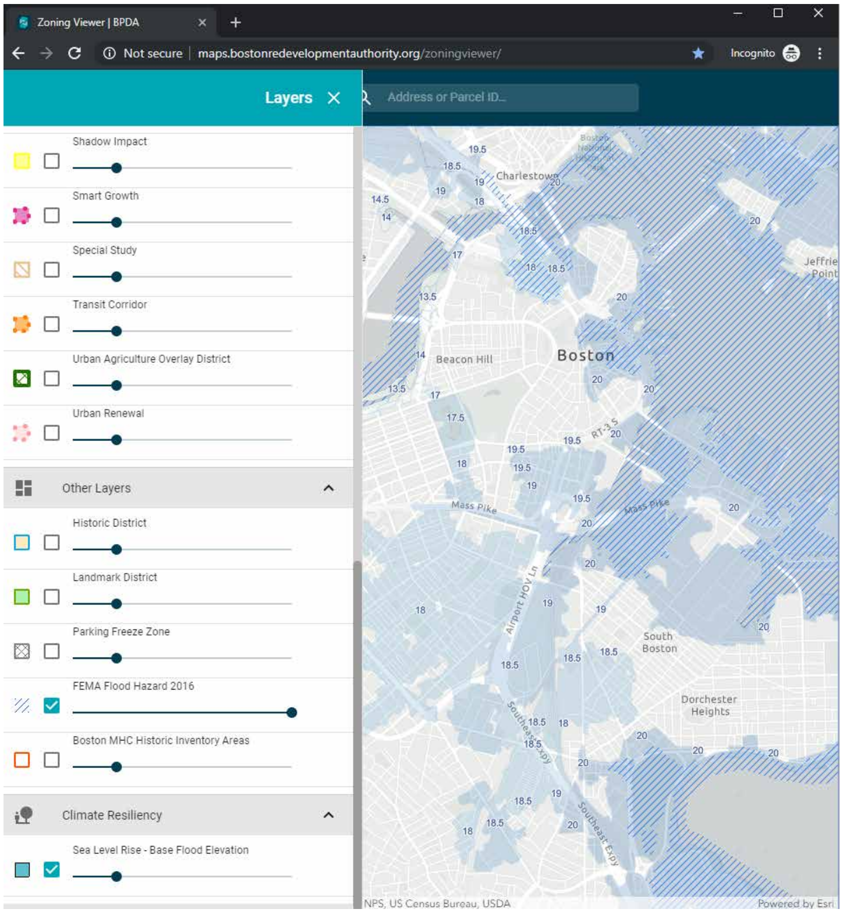
Article 25 states that structures within the Article 25 overlay, whether permitted by-right or requiring zoning relief, must comply with the flood hazard requirements of the State Building Code. The State Building Code is enforced at the local level by the Boston Inspectional Services Department when it processes building permit applications. The State Building Code provides minimum standards for flood-resistant buildings within FEMA's flood zones that satisfy the requirements of the NFIP. The current 9th edition of the State Building Code, which came into effect on January 1, 2018, includes provisions of ASCE 24-14, Flood Resistant Design and Construction.

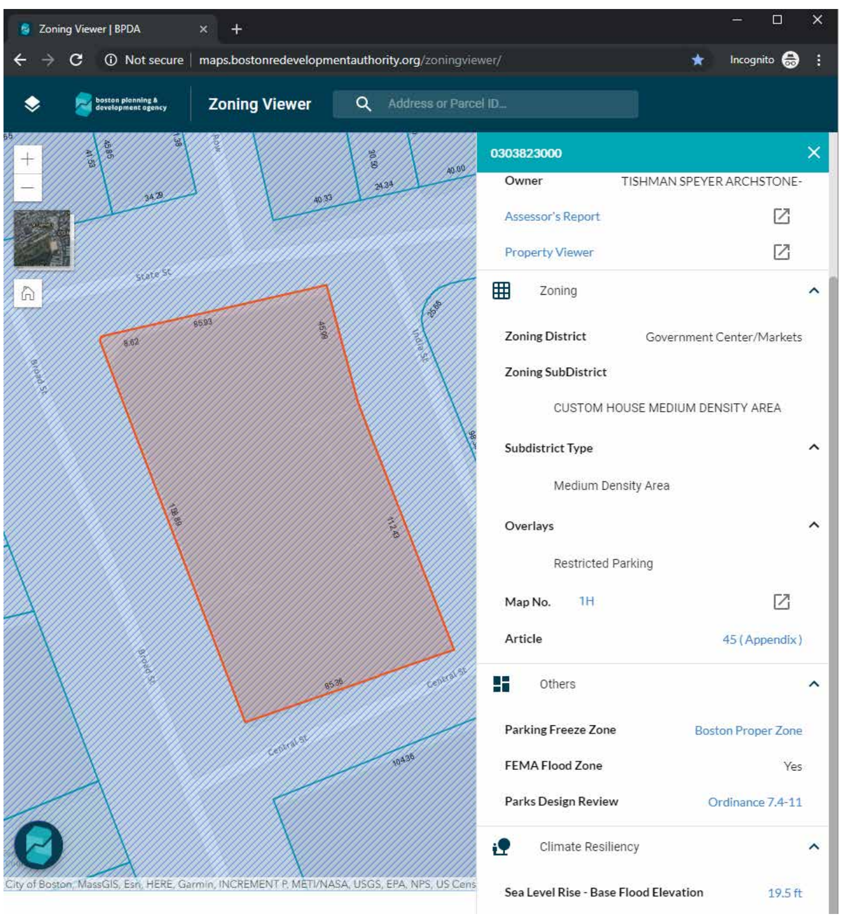
Proposed Overlay District

The current zoning for Flood Hazard Districts (Article 25), and the State Building Code (SBC) do not consider future climate conditions; Article 25 and the SBC standards for flooding refer to FEMA's FIRMs, which are based on historical information. Although a building constructed to these standards may be climate-ready today, the building and its occupants will face continuously increasing risk as sea levels continue to rise over the building's design life. Many of the areas at risk of flooding identified by BH-FRM also lie outside the boundary of Article 25 and are not required to meet the resilience standards outlined above. The City's proposed Resilience Zoning Overlay District will determine the new standard for resilient construction and retrofits within the BH-FRM extents.

Threshold for compliance

The proposed zoning is assumed to build on existing provisions in the Zoning Code, including the structure of code articles and sections,





defined terms, and standards and procedures for project reviews, to the extent possible. Therefore, Resilience requirements from the new Overlay will be integrated into the existing Article 80 Large and Small Review procedures. The resilient design principles will primarily be implemented through the application of the Design Guidelines, which will provide examples of best practices and design intent that could be implemented to meet the requirements of the Overlay. For renovation projects within the Overlay, resilience review by a committee will be required only if the alteration exceeds 50% of the building value (or, alternatively, 50% of the building area). These recommendations are subject to further study and evaluation by the City.

Other considerations

Depending on the location of the project and retrofitting strategy, other agencies with relevant jurisdiction may need to be involved in permitting, as well. For example, if the property is within an Historic District or is a designated landmark, the Boston Landmarks Commission would need to review the proposed project. Since a majority of the vulnerable neighborhoods are located on or close to the waterfront, they will likely be subject to statewide waterfront regulations as well. A project may be subject to regulations of a Designated Port Area (DPA) or Chapter 91 if it falls within either of those jurisdictions or is within the boundary of a Municipal Harbor Plan.

The BPDA zoning viewer can be used to view the extent of Zoning Article 25 and the proposed Overlay, and identify flood risk at the parcel-scale for each property in the city. *Source: BPDA Zoning Viewer*

Evaluate and Choose a Strategy

Guidance on resilient retrofits and new construction strategies are presented as a toolkit, divided into four categories: Building Form, Building Envelope and Access, Building Systems, District Scale Strategies, and Supporting Strategies. These strategies address designing for resilience through location and use of structural systems (the superstructure and the foundation), critical systems (mechanical, electrical, and plumbing systems), materials, and landscape.

Building Form
- These strategies include resilience measures that affect building height.

Building Envelope and Access
- These include resilience measures affecting circulation and access as well as the building envelope.

Building Systems
- These include protecting critical mechanical, electrical, and plumbing systems; conveyance systems; as well as back-up measures such as drainage.

District-scale Strategies
- These include large-scale measures integrating various forms of flood defenses into district-scale coastal flood protection systems.

Supporting Strategies (Building and Landscape Scale)
- These include building and landscape strategies that address climate risks not directly related to coastal flooding, such as on-site power generation and site material treatments to manage stormwater and extreme heat.

Building use is an important criteria for determining the most appropriate resilience measures. For example, current federal standards limit wet floodproofing to parking, access, and storage uses, and limit dry floodproofing to non-residential spaces. Under current federal standards, residential buildings are not allowed to dry or wet floodproof habitable spaces. Commercial uses are not allowed to be wet floodproofed. And even though much of the Overlay is outside the areas governed by federal regulations, Boston is proposing to adopt the same federal standard for the protection of life and safety. Besides use, other considerations such as code requirements, cost, structural characteristics, urban design, and accessibility influence the determination of appropriate adaptation strategies. Because coastal flooding and associated protection measures may impose significant structural loads on a building, owners should consult licensed professionals such as professional engineers to verify the suitability of resilience measures for their particular project.

The following criteria is provided for each of the guidelines in the document to inform the decision-making process.

Applicable scales
- Article 80 new construction or renovation (> 20,000 SF)
- Non-Article 80 new construction or renovation (< 20,000 SF)

Applicable building types (existing types for retrofits)
- Townhouse, Triple decker, Pre-war mixed use, Contemporary commercial, 1-2 family detached residential, Contemporary mixed use

Applicability by locations
- Exceptions or special circumstances

Description
- Description of the design strategy

Technical Considerations
- Detailed information to consider to help the reader properly plan and implement each strategy.

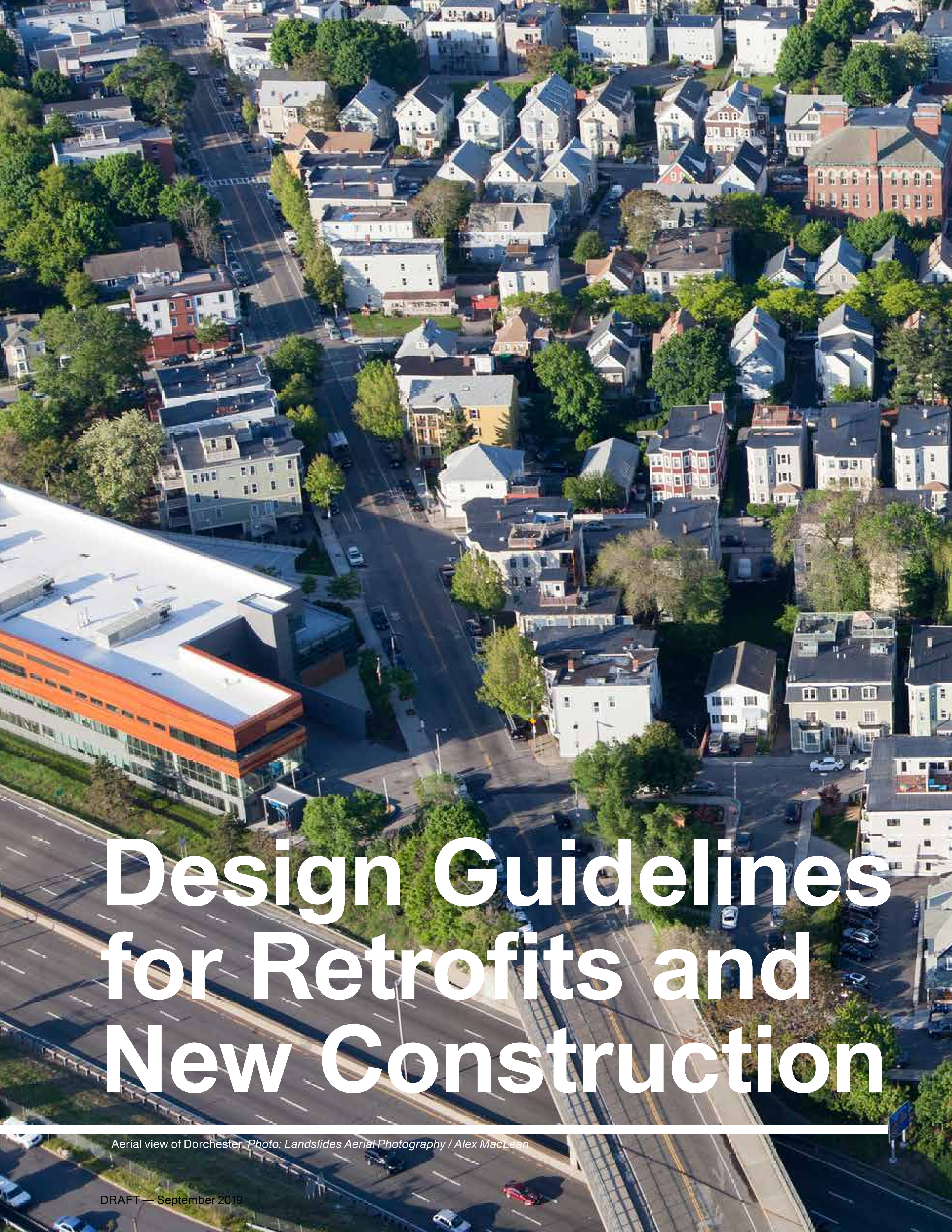
Cost and Insurance Considerations
- Orders of magnitude:
  $ = 100s
  $$ = 1,000s
  $$$ = 10,000s
  $$$$ = 100,000's

Public Realm and Urban Design Considerations
- Considerations that highlight the impact of individual strategies on the urban design and public realm.

Sustainability Co-Benefits
- Potential areas where resilience improvements can also achieve other sustainability co-benefits such as upgrading the building envelope.

Additional Resources
- A listing of reference material for further information on the indicated strategy.

Design Guidelines for Retrofits and New Construction



Aerial view of Dorchester. *Photo: Landslides Aerial Photography / Alex MacLean*

Elevate on Open Foundation

In this flood resilient strategy, a building is elevated on piles, piers, or posts with open foundations so that its first occupiable floor is at or above the SLR-DFE.

In areas subject to wave action, this strategy protects a building from high and moderate-height waves which would otherwise erode fill material placed below a structure or cause structural damage to solid foundation walls.

Applicability

Project Scale	Non-Art. 80 renovations and new construction
Building Type	Detached 1–2 family
Locations	Required in FEMA V Zones, recommended in FEMA Coastal A Zones (see Section 1 for explanation about relationship of FEMA zones within the Overlay).

Elevated home in the Arverne neighborhood of Queens, New York.
Photo source: NYC Housing Recovery Operations

Cost and Insurance Considerations

$ | $$ | **$$$** | **$$$$**

- Elevation of structures insured under the NFIP may be eligible for FEMA Hazard Mitigation Assistance grants and flood insurance premium reductions.
- The design of enclosures below the lowest floor will affect insurance rates. All else being equal, the lowest rates are available for buildings rated as "free of obstruction," which have no enclosure below the lowest floor other than insect screening or open wood latticework (i.e., at least 50% of the lattice construction is open, such as shown in photo).

Public Realm Considerations

- Access from grade to the lowest floor should be carefully considered for design integration into both the building and the public realm. The sidewalk-facing side of an open foundation level should incorporate streetscape mitigation measures (screening, plantings, front porch, etc.).

Sustainability Co-benefits

- When elevating a building on an open foundation, ensure that adequate under-floor insulation is provided to prevent heat loss.

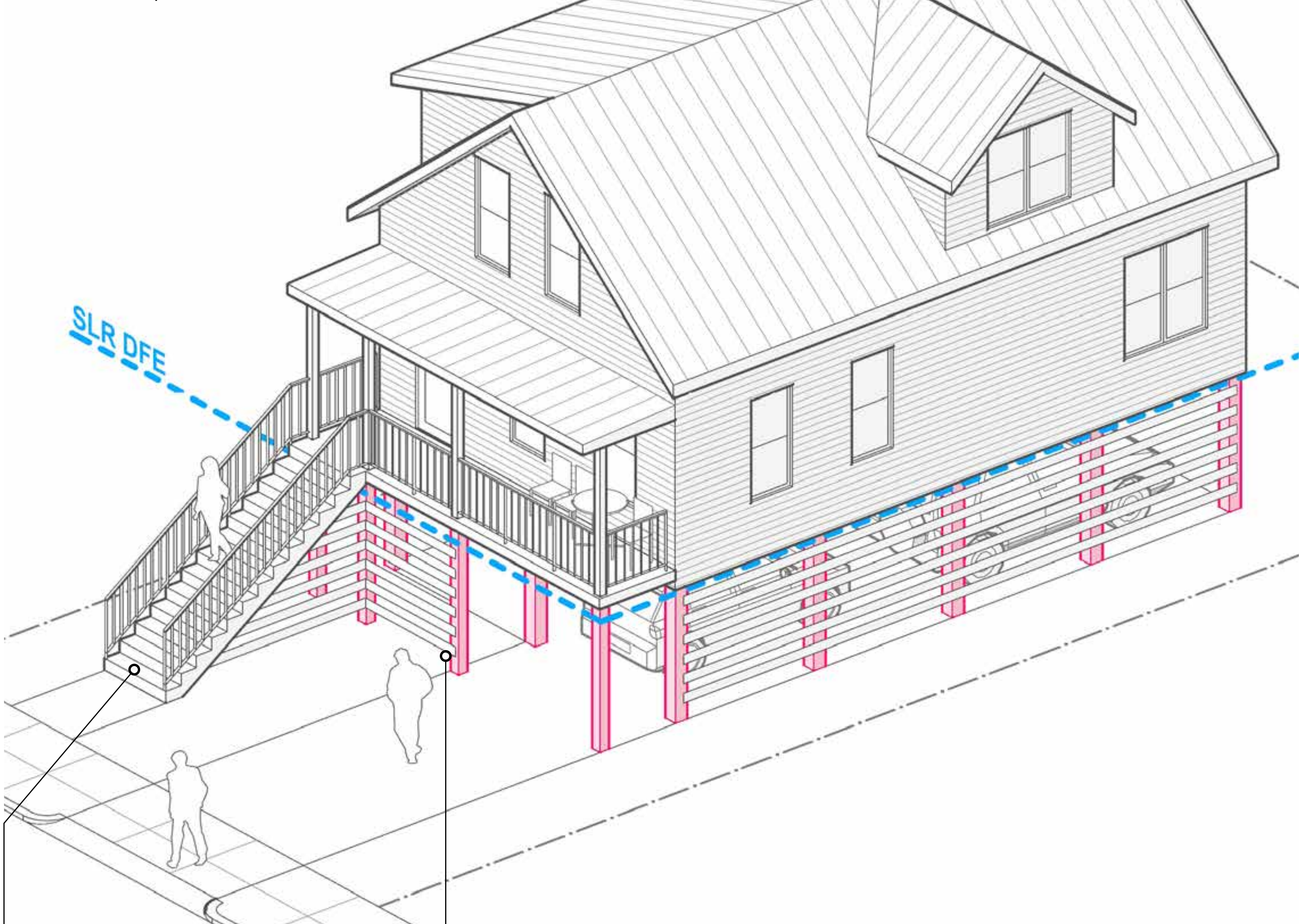
Additional Resources

- FEMA P-312, Homeowner's Guide to Retrofitting
- FEMA P-55, Coastal Construction Manual
- FEMA Technical Bulletin 5, Free-of-Obstruction Requirements
- FEMA Hurricane Sandy Recovery Fact Sheet No. 2, Foundation Requirements and Recommendations for Elevated Homes
- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions

Technical Considerations

Suitability

Inside FEMA V Zones, new, substantially damaged, and substantially improved buildings must be elevated on piles, piers, or posts with open foundations in these zones, the use of fill to elevate a structure is prohibited. In FEMA Coastal A Zones, the same practices are recommended.



Stairs, Decks, Porches

Appurtenant structures (e.g., stairs, decks, porches) must be designed either to structurally resist design flood loads or break-away without damaging the building or its foundation. Decks and porches must be designed to allow flooding to pass through them, so as to not adversely affect adjacent or nearby structures by diverting harmful floodwaters and waves.

Materials

Building materials below the DFE should be resistant to water damage.

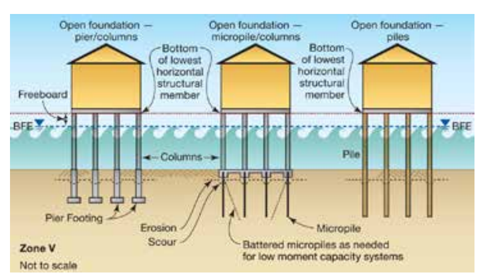
Structural stability

Elevated open pile, pier, or post foundations must be designed to structurally resist site-specific design flood loads, be geotechnically stable, and be protected from scour and erosion. The diagram below illustrates NFIP-compliant foundations.

Below-grade Enclosures

Existing below-grade enclosures (basements, crawlspaces, etc.) should be filled to match the adjacent grade. The fill must be compacted and designed to resist scour and erosion.

Enclosures below the lowest floor should be designed either to be free of obstruction or with breakaway walls and flood openings.



Examples of NFIP-compliant foundations: piers / columns on pier footings, columns on micropiles, and piles.

Source: FEMA. May 2013. Foundation Requirements and Recommendations for Elevated Homes.

Elevate on Solid Foundation Walls and Filled Subgrade Space

In areas not subject to wave action, a building may be elevated by raising the lowest occupiable floor on solid foundation walls to meet the SLR-DFE.

When retrofitting an existing building using this strategy, existing solid foundation walls should be extended to meet the newly-elevated lowest floor. Existing foundations and footings may need to be modified or reinforced to ensure structural stability. See the complementary strategy, Wet Floodproofing, for additional information on protecting the structure.

Applicability

Project Scale	Non-Art. 80 renovations
Building Type	1–2 family detached, triple decker
Locations	Elevation on solid foundation walls is prohibited in FEMA V Zones and not recommended in Coastal A Zones, seaward of the LiMWA.

Cost and Insurance Considerations

$ | $$ | **$$$** | **$$$$**

- Elevation of structures insured under the NFIP may be eligible for FEMA Hazard Mitigation Assistance grants and flood insurance premium reductions.

Public Realm Considerations

- The sidewalk-facing side of an elevated solid foundation wall should incorporate streetscape mitigation measures (plantings, contextual materials, lighting, color, art, see p42 for more details.)

Additional Resources

- FEMA P-312, Homeowner's Guide to Retrofitting
- FEMA Hurricane Sandy Recovery Fact Sheet No. 2, Foundation Requirements and Recommendations for Elevated Homes

House in Meyerland, Houston before elevating.

Construction photo showing house elevating on extended foundations. Spaces below SLR-DFE are not habitable.

Offcite / "Mid-Century Elevated: How an Architecturally Significant House Was Lifted Above the Floodplain" / All photos by Raj Mankad

House after elevating. Note that the condenser is also elevated at left. Flood vents are not pictured.

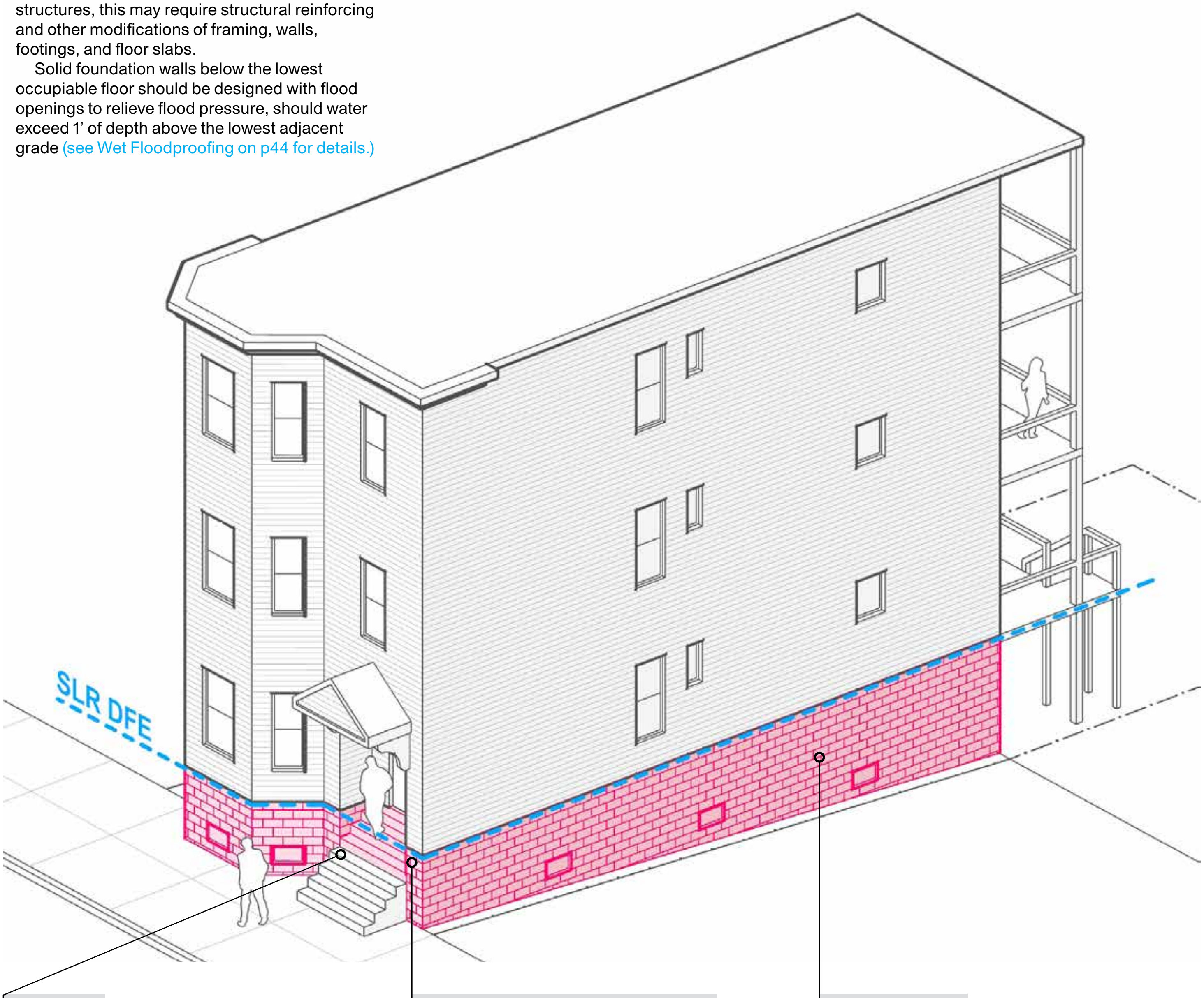
Technical Considerations

Foundations

Elevated solid wall foundations must be designed to structurally resist site-specific design flood loads, be geotechnically stable, and be protected from scour and erosion. For retrofits of existing structures, this may require structural reinforcing and other modifications of framing, walls, footings, and floor slabs.

Solid foundation walls below the lowest occupiable floor should be designed with flood openings to relieve flood pressure, should water exceed 1' of depth above the lowest adjacent grade (see Wet Floodproofing on p44 for details.)

Scour and erosion depths and the need for structural fill should be considered to ensure that the foundation will not be undermined in design flood conditions.



Access

Access from grade to the lowest floor should be carefully considered for design integration into both the building and the public realm. The modification of building access and height may trigger building, accessibility, and other applicable code requirements, and therefore should be coordinated.

Stairs, Decks, and Porches

Appurtenant structures (e.g., stairs, decks, porches) must be designed either to structurally resist design flood loads or break away without damaging the building or its foundation.

Decks and porches must be designed to allow flooding to pass through them, so as to not adversely affect adjacent or nearby structures by diverting harmful floodwaters and waves.

Basements

Existing below-grade enclosures (basements, crawlspaces, etc.) should be filled to match the lowest adjacent grade. The fill must be compacted and designed to resist scour and erosion.

Materials that can be used for fill include compacted soil, crushed stone encased with a concrete slab, and controlled low strength material ("flowable fill"). Consult with a contractor or engineer to determine the most suitable material depending on project requirements.

Building materials below the DFE should be resistant to water damage. (see p48 for details)

Elevate on Fill

Elevate the lowest occupiable floor of a new building on structural fill to meet the design flood elevation (DFE).

Applicability

Project Scale	Non-Art. 80 and Art 80 new construction
Building Type	All new construction
Locations	Elevation on fill is prohibited in FEMA V Zones and not recommended in Coastal A Zones, seaward of the LiMWA.

Sunset Park Material Recovery Facility, Brooklyn, New York. *Photo by Field Condition / "SIMS Sunset Park Material Recovery Facility"*

Cost and Insurance Considerations

$ | $$ | **$$$** | **$$$$**

- Elevation of structures insured under the NFIP may be eligible for FEMA Hazard Mitigation Assistance grants and flood insurance premium reductions.
- Within areas subject to Article 25 and FEMA FIRM's, a building elevated on fill that exceeds the FEMA BFE may be eligible for a Letter of Map Revision based on fill (LOMR-F), which, if approved by FEMA, would eliminate the NFIP requirement for the building to comply with flood resistance standards and to carry flood insurance. However, the elimination of these requirements does not mean the building is not at risk of flooding.

Public Realm Considerations

- Elevation of a building on fill should try to create a positive co-benefit of creating or preserving open space in the form of fill slope with vegetation and other public amenities.
- On the waterfront, elevating a site on structural fill is encouraged where doing so will also serve to prevent flooding from crossing through the site from the waterfront to other properties or public rights-of-way landward of the site. In so doing, elevation of an entire waterfront site, as opposed to just the portion of a site immediately surrounding a building, can support the incremental implementation of district-scale coastal flood protection.

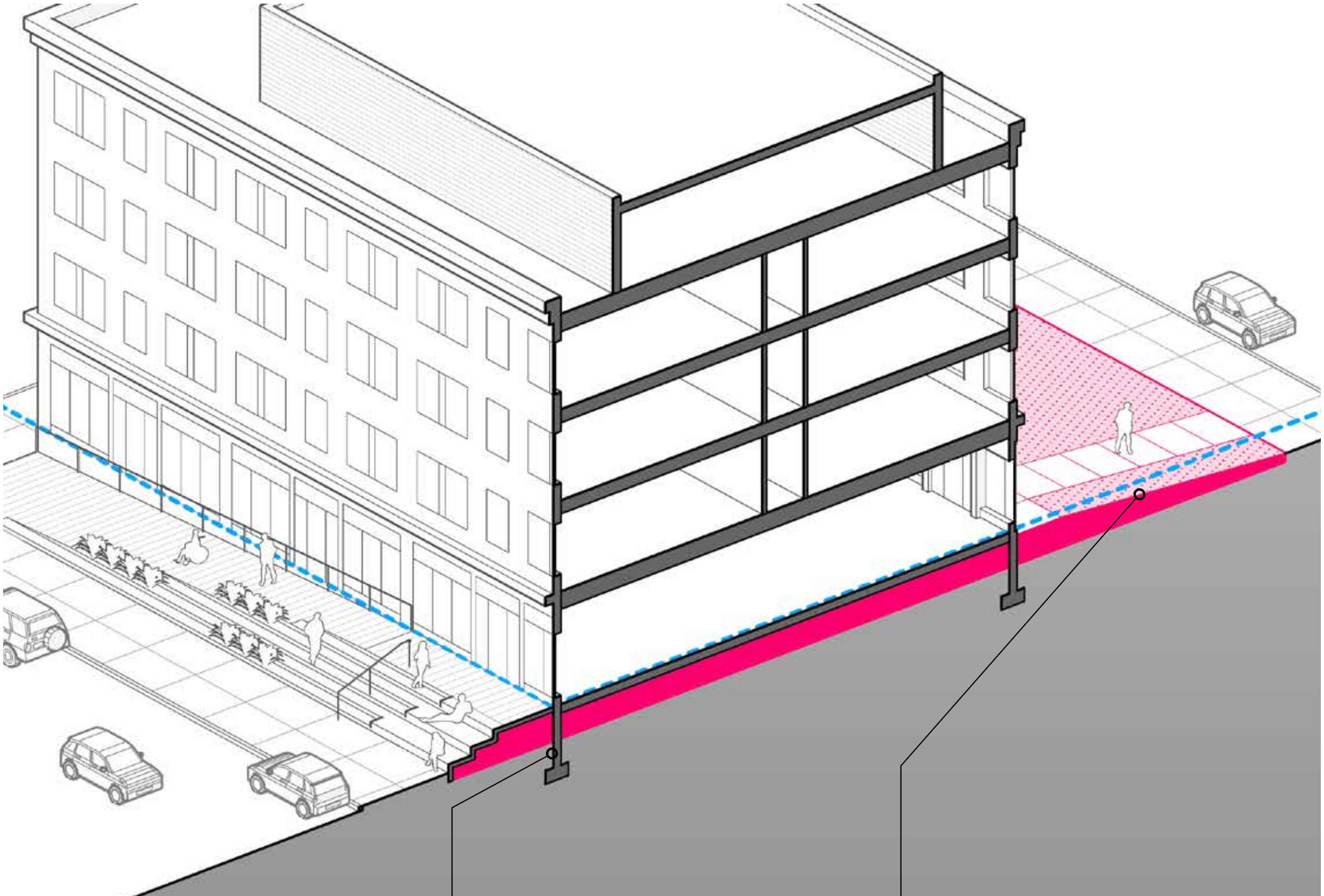
Sustainability Co-benefits

- For large sites, this strategy has the potential to incorporate landscape features into existing or new ground space areas that can provide resilience for additional climate risks such as extreme precipitation and rising temperatures.

Additional Resources

- NYC Planning, Urban Waterfront Adaptive Strategies
- FEMA Hurricane Sandy Recovery Fact Sheet No. 2, Foundation Requirements and Recommendations for Elevated Homes
- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions

Technical Considerations



Structural stability

Buildings and sites elevated on fill must be designed to structurally resist site-specific design flood loads, be geotechnically stable, and be protected from scour and erosion.

Use Restrictions

Use of this strategy should not result in habitable spaces below the SLR-DFE, such as basement units.

Foundations

Solid foundation walls below the lowest occupiable floor should be designed with flood openings to relieve flood pressure, should water exceed 1' of depth above the lowest adjacent grade.

Materials

Building materials below the SLR-DFE should be resistant to water damage.

Sloping to Adjacent Grade

Fill may be graded to slope up from adjacent ground level or be held in place by retaining structures. The toe and surface of fill slopes must be protected from erosion and scour under design flood conditions, and maximum fill slopes must not be exceeded.

Fill must be designed so as not to adversely affect nearby structures by diverting harmful floodwaters and waves or increasing flow velocity.

Repurpose or Relocate Ground Floor Use

Existing enclosures below the SLR-DFE can be repurposed from residential or utility uses to parking, access, or storage, and then the enclosures can be wet floodproofed to protect the structure.

Depending on the base zoning, certain spaces can be converted to commercial use and dry floodproofed. In coordination with zoning requirements, the displaced program can be recouped in the form of a building expansion.

Applicability

Project Scale	Non-Art. 80 renovations
Building Type	Triple decker, Townhouse, pre-war mixed use
Locations	Appropriate for buildings located outside of FEMA AE zones

Rooftop addition to an existing pre-war mixed-use building in the Fort Point neighborhood.
Source: Hacin and Associates / FP3

Cost and Insurance Considerations
Cost varies

- Costs will vary greatly depending on the extent of addition/expansion
- Upgrades required to meet current codes may add significant cost to the base flood protection improvements.
- Conversion to commercial or parking uses may require substantial capital investment but also generate revenue.
- A building addition may trigger a Substantial Improvement declaration.
- Converting a ground floor use in combination with floodproofing may contribute to insurance premium reductions.

Public Realm Considerations

- Consider strategies to mitigate for an unoccupied lower level through screening, plantings, and front porch design, as well as potential for temporary programming in the abandoned space.
- If allowable, converting lower levels to commercial uses can contribute to an active urban streetscape.
- Additions will need to observe design guidelines within landmark districts.

Sustainability Co-benefits

- Rooftop additions or other building expansions are good opportunities to incorporate green/blue/white roofs for stormwater management and/or energy co-benefits, or solar panels to supplement power supply (see p57 for more details.)

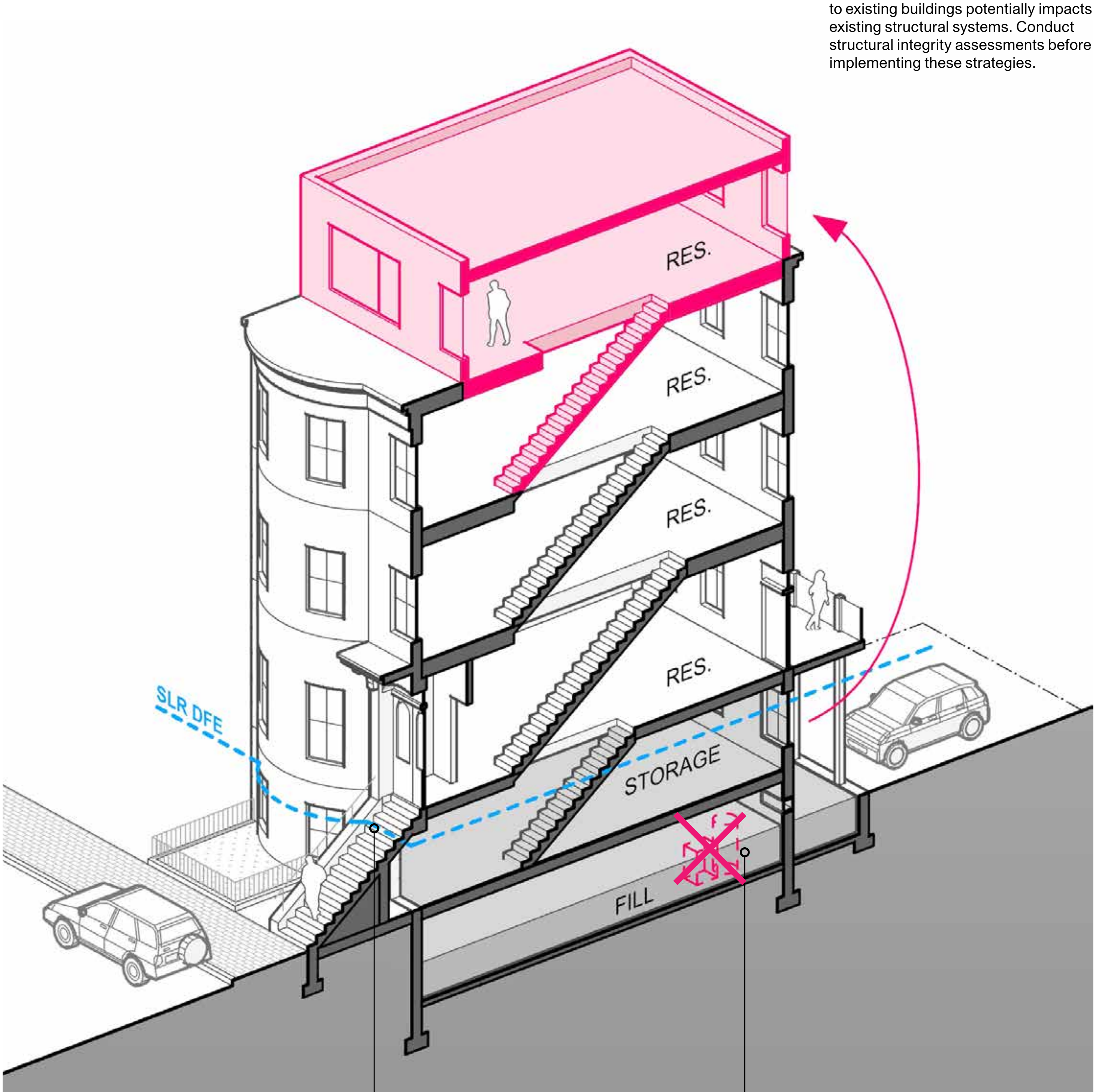
Additional Resources

- FEMA P-1037, Reducing Flood Risk to Residential Buildings That Cannot Be Elevated
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience

Technical Considerations

Structural Integrity

Additions above or extensions adjacent to existing buildings potentially impacts existing structural systems. Conduct structural integrity assessments before implementing these strategies.



Regulatory Triggers

Additions or extensions may trigger requirements for other improvements to meet current codes (fire protection, accessibility, landmarks, energy conservation, etc.).

Wet Floodproof Areas below DFE

Wet floodproof below the SLR-DFE by filling the basement to the nearest adjacent grade, installing flood vents on at least two walls, and restricting all use below the SLR-DFE to storage, access, and/ or parking.

Note that filling in basement may negatively impact structural materials like brick, which need to breathe.

Locate Critical Systems above DFE

Locate water heater, electrical panels, and other critical systems above the SLR-DFE.

Elevate Lowest Interior Floor with Interior Circulation to DFE

For buildings that have high first floor ceilings, a portion of the first floor may be elevated or reconstructed at or above the SLR-DFE to protect that floor from flood risk. Circulation to reach the elevated first floor level from an at-grade entry area may be provided by internal ramps and stairs.

Elevating a new or existing building's ground floor above the DFE can protect against flood damage; however, a change in ground plane may lead to the unintended consequence of disrupting the visual connectivity between pedestrians and building interiors. One way to avoid this disruption is by providing a carefully designed interior circulation area that mediates an at-grade entry area with an elevated main floor.

Cost and Insurance Considerations

$ | $$ | $$$ | **$$$$**

- For projects within Article 25 (FEMA zone), the elevation of structures insured under the NFIP may be eligible for FEMA Hazard Mitigation Assistance grants and flood insurance premium reductions.
- Similarly, if the building is located within a FEMA zone, elevating the lowest floor may trigger a Substantial Improvement declaration.

Applicability

Project Scale	Non-Art. 80 renovations
Building Type	Triple decker, Townhouse, Post-war mixed use, Contemporary mixed use
Locations	Appropriate for buildings located outside of FEMA AE zones

Public Realm Considerations

- In new construction, to maintain visual connection at the sidewalk and an active streetscape, circulation from at-grade lobbies (wet or dry floodproofed) can lead to elevated areas above the DFE.
- This strategy may be an advantageous technique for maintaining the front facade of an historic building while enhancing the resilience of the structure.

Additional Resources

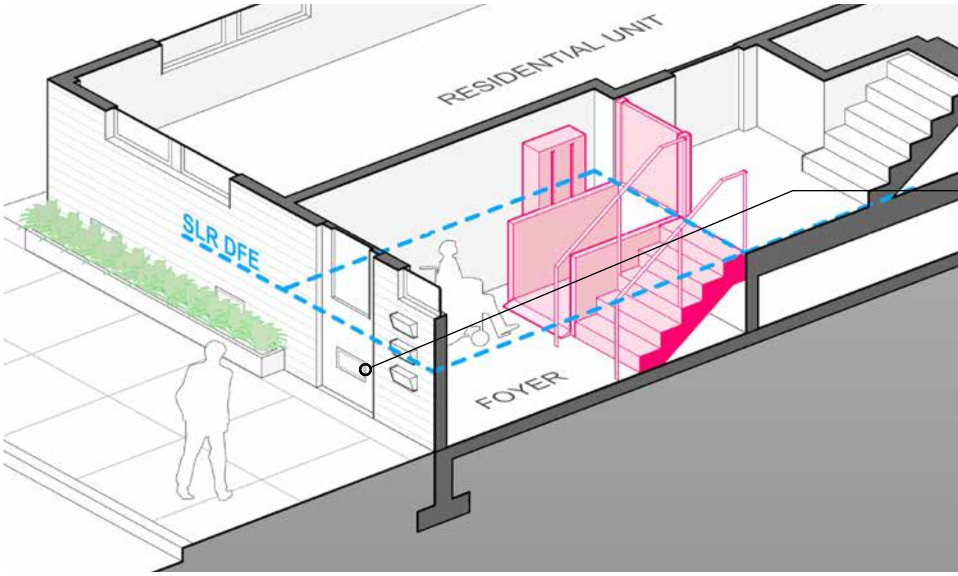
- FEMA P-1037, Reducing Flood Risk to Residential Buildings That Cannot Be Elevated
- FEMA P-467-2, Floodplain Management Bulletin - Historic Structures

Retrofitted stairs lead to an elevated first floor in a retail shop in Darlington, Wisconsin. *Photo: FEMA. 2013. Floodproofing Non-Residential Buildings.*

Floodable entryway with stairs that lead to an elevated lobby at the Querini Stampalia in Venice, Italy. *Photo: Architectours / "The renovation of the Fondazione Querini Stampalia is a great example of how Master Carlo Scarpa integrated the new with the old"*

Technical Considerations

Small Building Strategy



Openings

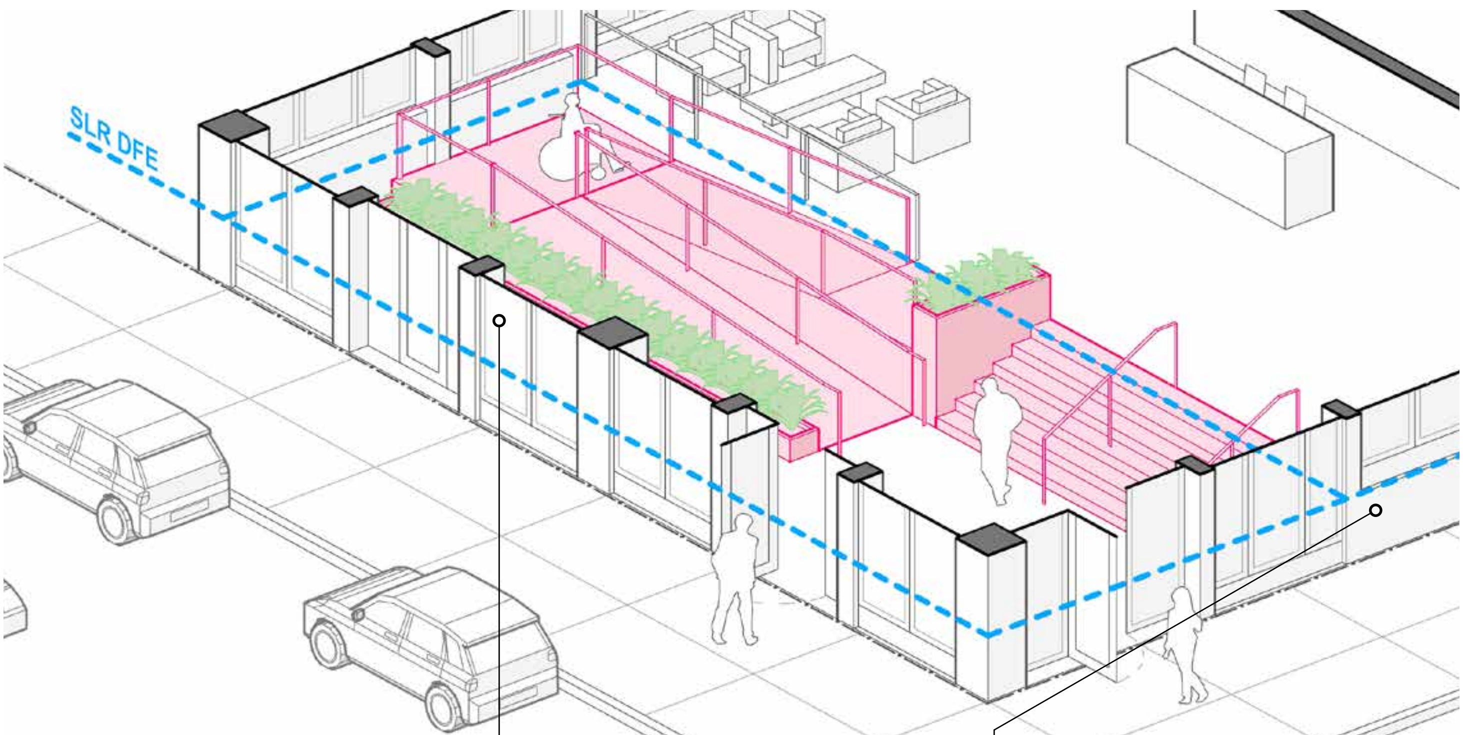
All penetrations, such as openings for HVAC, electrical, and plumbing systems, should be removed and relocated above the design flood elevation.

Floodproofing below the DFE

The resulting space below the elevated interior floor should be filled to create a stem wall or retrofitted with flood openings (see Wet Floodproofing, p44 for details.) Below-grade spaces for storage or parking may be maintained only if dry floodproofed in coordination with review and approval by an engineer for resistance to flood-related loads on the structure (see Dry Floodproofing, p46 for details.) Spaces below the SLR-DFE are non-habitable.

Wet floodproofing of the entry area allows water to enter and exit through vents in the storefront wall or entry door, equalizing hydrostatic pressure. The wet floodproofed vestibule uses flood damage resistant materials.

Large Building Strategy



Ground Floor Height

The floor-to-ceiling height of the ground floor must be high enough to accommodate a reduced ceiling height. While many existing buildings may have this height capacity, an elevated floor may disrupt the way windows and doors relate to the first floor, so this strategy must be coordinated with the character of the existing facades and remain integrated with the public realm.

Dry Floodproofing

Dry floodproofing may be utilized in a limited way to seal and reinforce the interior surfaces of the entry area and/or providing internal flood shields to prevent the seepage of water further into the building. Spaces below the SLR-DFE are non-habitable. This strategy allows for an at-grade connection between the sidewalk and the building to preserve the character of the building's exterior (see Dry Floodproofing, p46, for details).

Elevate Lowest Interior Floor with Exterior Circulation to DFE

Circulation to reach the elevated first floor level is provided outside the building through exterior walkways, ramps, or stairs. Design measures like planted areas, seating, lighting, and contextually appropriate materials are used to contribute to visual interest, break up the scale of larger surfaces, and add to neighborhood character.

To avoid disrupting visual connectivity and interest along the streetscape, designers should carefully consider the public realm when elevating a building's first floor above the SLR-DFE for flood protection.

Applicability

Project Scale	Non-Art. 80 renovations, Art. 80 renovations and new construction
Building Type	Triple decker, Townhouse, pre-war mixed use, contemporary mixed use
Location	Buildings outside of FEMA AE zones

Cost and Insurance Considerations

$ | $$ | **$$$** | **$$$$**

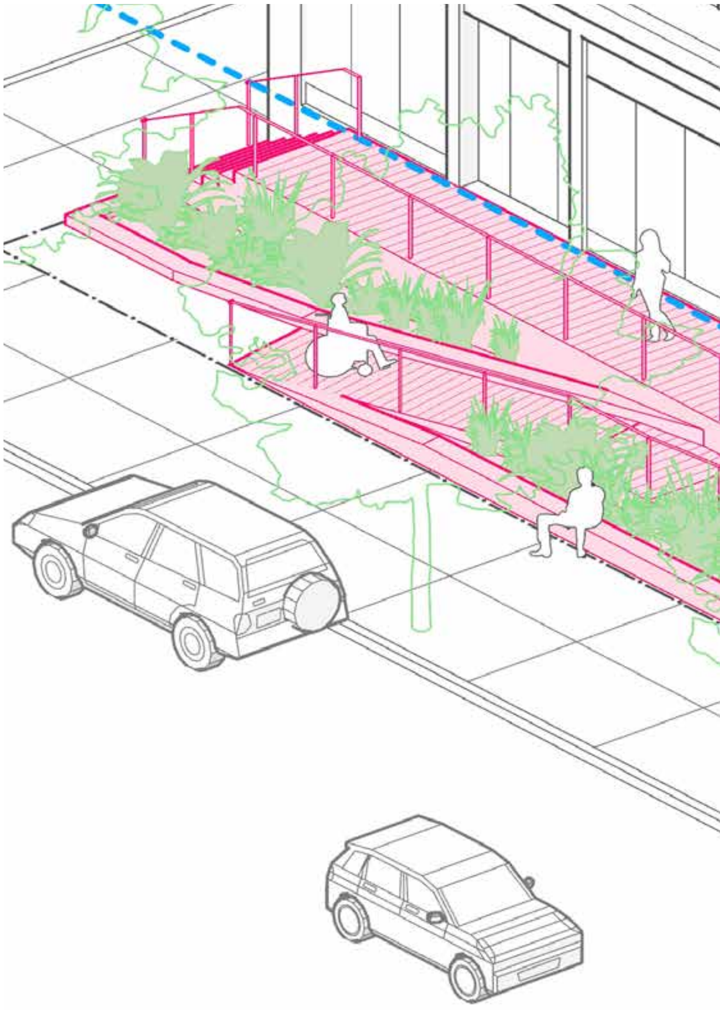
- For projects within Article 25 (FEMA zone), the elevation of structures insured under the NFIP may be eligible for FEMA Hazard Mitigation Assistance grants and flood insurance premium reductions.

Public Realm Considerations

- This strategy can enhance the public realm if designed to add visual interest and to incorporate additional amenities such as landscape and seating.
- The design of exterior circulation elements should pay careful attention to universal design and accessibility. For example, ramps should be designed to be appealing to all users.

Additional Resources

- FEMA P-1037, Reducing Flood Risk to Residential Buildings That Cannot Be Elevated



Exterior Circulation and Vegetation

Saltwater tolerant planting is woven into the edges and railings that flank stairs and ramps, adding to visual interest along the sidewalk and softening the presence of paved areas. The use of vegetated areas also provides additional opportunities for stormwater and temperature mitigation.

Technical Considerations

Alternatives for Access

If a front yard ramp is not possible, an accessible exterior ramp may be provided within the side yard or rear yard.

Resisting Flood Loads

Stairs, ramps, and walkways must be designed to structurally resist design flood loads.

Floodproofing below the DFE

This strategy should be combined with floodproofing measures below the DFE to protect against flood damage. This would include either wet floodproofing to allow automatic entry and/or exit of floodwaters or dry floodproofing.

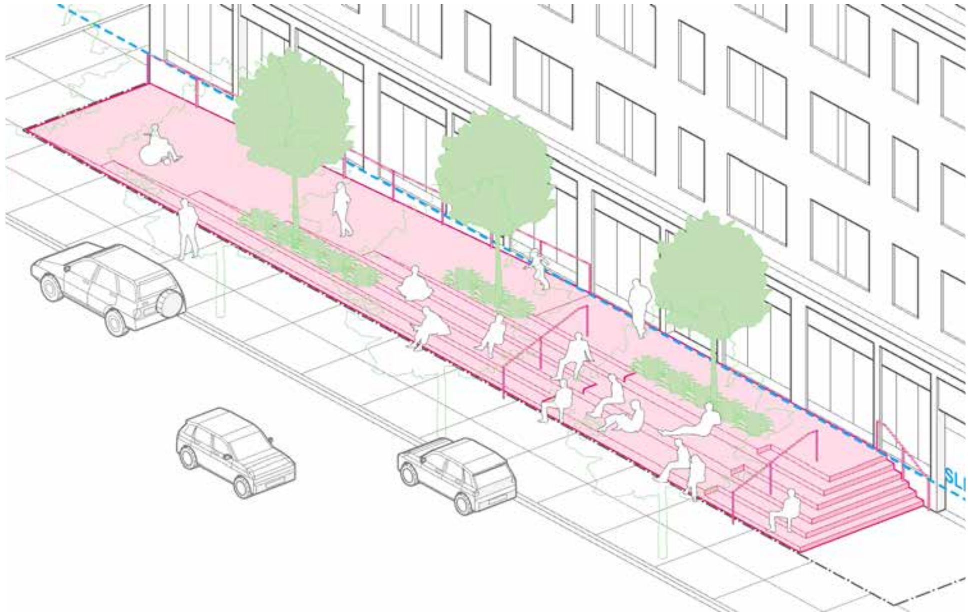
Consider the Public Right-of-way

Exterior ramps and stairs may not encroach into the public right-of-way. If a building has intentional setbacks that provided publicly accessible private space, that space may be used for accessible external ramps.

Furthermore, such additions added onto existing historic buildings will need to observe design guidelines within landmark districts.

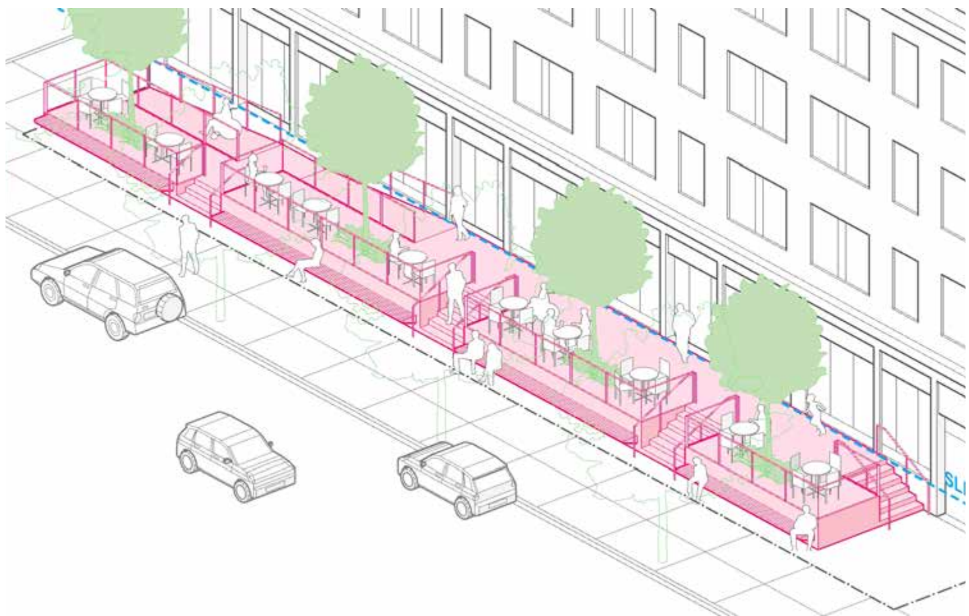
Exterior Circulation and Public Seating

Informal gathering areas can blend seamlessly into stairways and ramps.



Exterior Circulation and Activated Deck

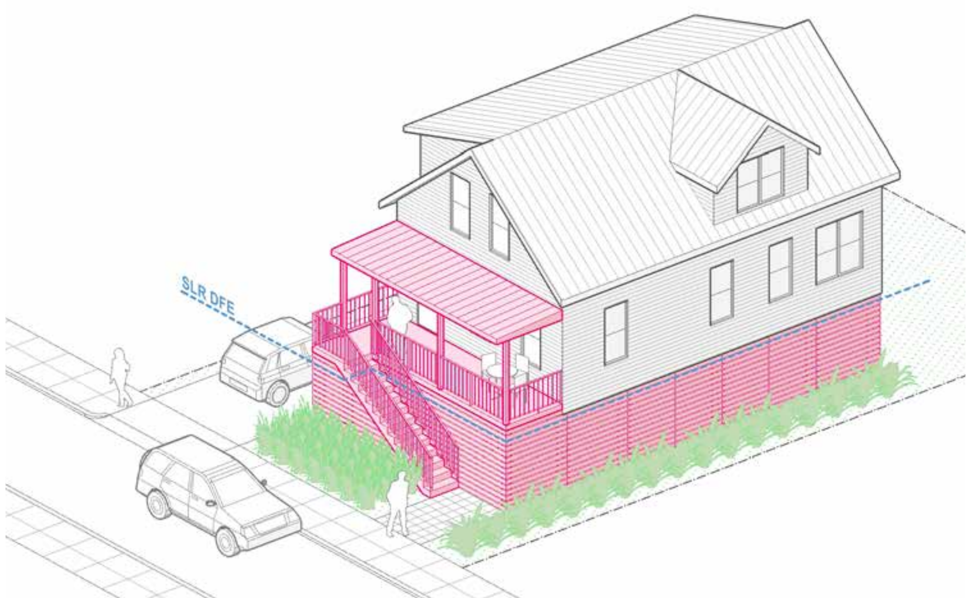
For walkways fronting restaurant or retail spaces, seating areas can activate the elevated areas, contributing to a lively streetscape.



Exterior Circulation for Small-scale Residential Structures

When carefully designed to integrate with context, porches, stair railings, and screens can contribute to the human scale for sidewalk-facing areas.

Note that spaces below the SLR-DFE are nonhabitable and uses are limited to parking, access, and storage. Residential structures cannot use dry floodproofing.



Pier 17, Brooklyn. *Photo: https://www.shoparc.com/projects/pier-17/*

Proposal for General Electric buildings, Fort Point. *Photo: https://www.ge.com/reports/boston/*

Bow Market, Somerville. *Photo: https://www.bow-marketsomerville.com/*

Ink Block, South End. *Photo: https://undergroundinkblock.com/neighborhood*

Elevated building in South Boston Waterfront. *Photo: Google Maps*

Elevated houses in Queens, New York Photo: NYC Housing Recovery Operations

Wet Floodproofing

Wet floodproofing is an adaptation measure that allows flood waters to enter and exit portions of a building not used as living space such as crawl spaces, walk-out basements, or floodable ground floors.

Flood openings are important to allow water to enter and exit the structure and rise and fall at the same rate inside and outside of the building. Therefore, wet floodproofing requires proper planning for the quantity, type, and location of flood openings.

This strategy avoids structural damage by equalizing hydrostatic pressure on walls, as well as damage from buoyancy or uplift forces. In addition to providing openings that allow the entry of flood waters, wet floodproofing requires the use of flood-resistant materials below the flood elevation, the protection of service equipment from flood damage, and the relocation of high value contents. Examples of engineered flood openings include grilles, vents, and hinged panels that automatically open in both directions to allow water to pass.

Top photo: Continuing Education Center / Photo by Smart Vent Products, Inc.

Bottom photo: FEMA. 2013. Floodproofing Non-Residential Buildings.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction
Building Type	Non-residential spaces within typologies such as the triple decker, townhouse, new mixed use, and general industrial

Cost and Insurance Considerations

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- Wet floodproofing is generally less expensive than dry floodproofing. Additional cost considerations should also include expenses for related measures such as building elevation, providing access to elevated areas, installation of flood-resistant materials, rearrangement of utility systems, and post-flood cleaning to control exposure to pollutants and prevent mold growth.
- Wet floodproofing of structures insured under the NFIP in A Zones may be eligible for flood insurance premium reductions.

Public Realm Considerations

- If combined with providing interior circulation to a raised interior floor, a wet floodproofed lobby or access area can maintain an at-grade connection between sidewalk and building entry.
- Alterations on the facades of buildings in historic districts will need to be reviewed by Landmarks Commission.

Additional Resources

- FEMA P-312, Homeowner's Guide to Retrofitting
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience
- FEMA Technical Bulletin 1, Openings in Foundation Walls and Walls of Enclosures
- FEMA Hurricane Sandy Fact Sheet 1, Cleaning Flooded Buildings

Technical Considerations

Materials

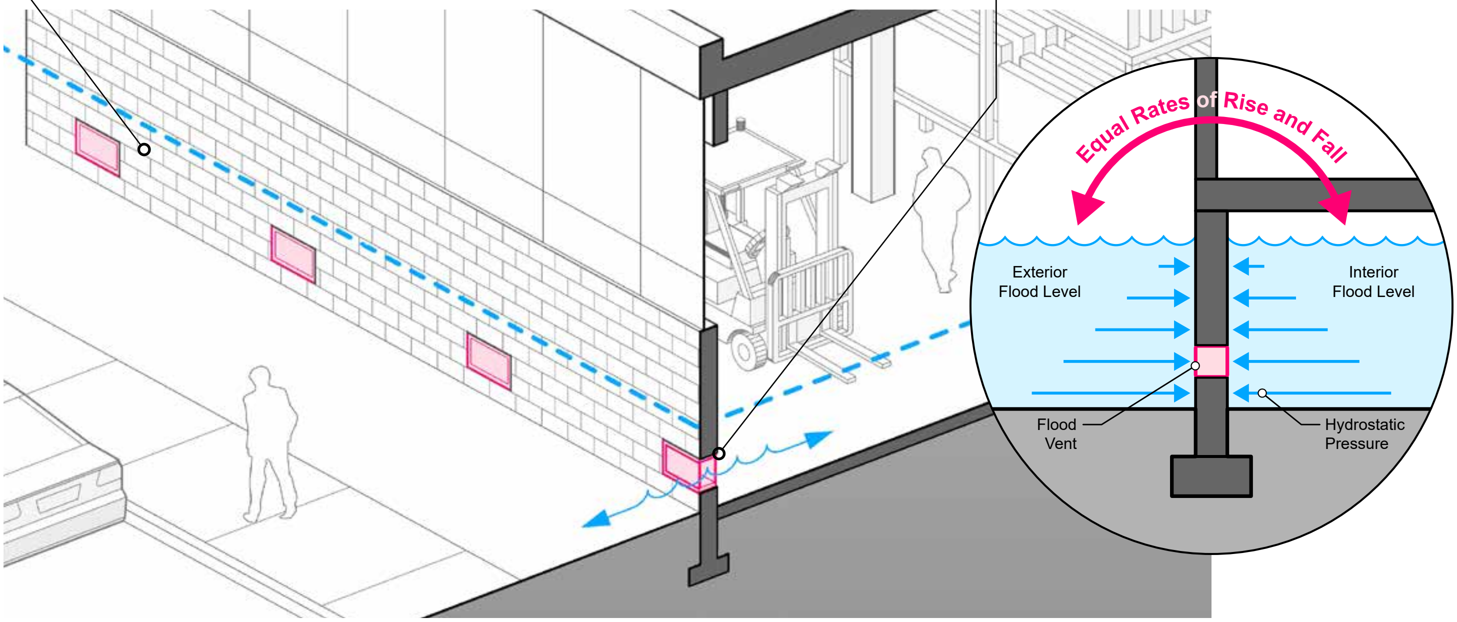
Use flood-damage-resistant materials in wet floodproofed enclosures, such as concrete, stone, masonry block, ceramic and clay tile, pressure-treated lumber, epoxy-based paints, and metal. These materials may require additional treatment to protect against damage from repeated saltwater inundation. Avoid paper-faced gypsum wall board and non-treated wood. (See "Flood-damage Resistant Materials" on p48 for details.)

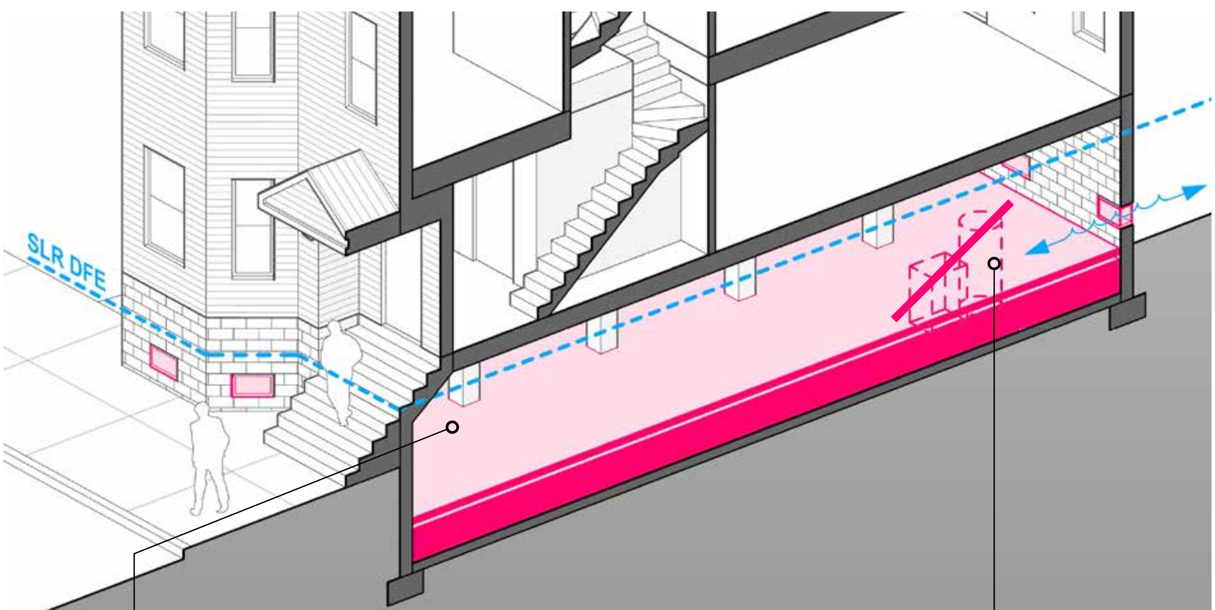
Water from flooding may carry contaminants so post-flooding health risks should be mitigated by contracting certified clean-up professionals. Hazardous household materials should not be stored in wet floodproofed spaces. After flooding, objects and materials that have been exposed to water should be cleaned and dried or disposed of following guidelines from local officials. Affected areas should be allowed to adequately dry with 24 hours to prevent mold growth.

Openings

Per FEMA standards for non-engineered openings, at least two wall openings (one in two different walls) below the base flood elevation in each enclosed area should be provided, at a location of no more than 1' above grade. One square inch of opening for every square foot of enclosed floor area should be provided.

Openings should be carefully maintained to ensure they are not clogged with debris and can be opened if movable parts are part of the system.





Spaces below the DFE

When wet floodproofing a retrofitted building, sub-grade spaces should be filled to the nearest adjacent grade to allow water to drain out of the structure slowly by gravity. Pumping can cause serious structural damage if surrounding soils are still saturated and is not recommended. Spaces below the SLR-DFE are non-habitable and use is limited to storage, parking, and access.

Utilities

Any utility or service equipment such as ductwork, heaters, and electrical lines should be removed from a wet floodproofed space and relocated above the design flood elevation.

Dry Floodproofing

Dry floodproofing is a category of treatments aimed at inhibiting water from entering a structure. This technique is appropriate for low flood elevations and structures that can withstand hydrostatic and hydrodynamic loads imposed by flooding.

Dry floodproofing should be thought of as a system of multiple components working together, including:

- Watertight enclosures for openings, doors, windows, and floors, including shields and barriers, often requiring human intervention prior to a storm event; types of flood shields include sliding, lift-out, modular panel, bolt-on, hinged, and automatic
- Membranes and sealants to reduce seepage of floodwater through walls and utility conduits
- Structural reinforcement to wall assemblies so that they can resist hydrostatic pressure, flotation, or collapse
- Pumping and drainage systems with backup power to control water intrusion
- Backflow or check valves to prevent the entrance of water or waste through plumbing systems
- Flood doors and egress requirements

Cost and Insurance Considerations

$ | $$ | **$$$** | **$$$$**

- Dry floodproofing is generally more expensive than wet floodproofing for new construction. Cost increases for larger structures and for higher design flood elevations. Consider storage requirements and operational elements (time and cost) required to assemble any deployable features.
- For residential buildings, dry floodproofing does not result in NFIP premium rate reductions and is not allowed by the State Building Code for residential spaces below the FEMA BFE plus two feet of freeboard.

Flood panels connected to removable posts.
Photo: Flood Panels LLC

Applicability

Project Scale	Non-Art. 80 renovations, Art. 80 renovations and new construction
Building Type	Non-residential spaces within pre-war mixed use, new mixed use, contemporary commercial

Public Realm Considerations

- Dry floodproofing can allow for active uses such as retail to remain on the ground floor of a building.
- Proponents using dry floodproofing should carefully study how to best integrate any permanent elements such as the mounting and brackets for shields and barriers.
- Buildings in historic and landmarks districts must have hardware reviewed by Landmarks Commission.

Additional Resources

- FEMA P-936, Floodproofing Non-Residential Buildings
- FEMA P-1037, Reducing Flood Risk to Residential Buildings That Cannot Be Elevated
- Boston Public Works Department, Climate Resilient Design Standards & Guidelines For Protection Of Public Rights-Of-Way
- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions

Temporary, portable, and deployable flood barriers
Photo: Aquafence

Technical Considerations

Suitability

Dry floodproofing is not allowed to protect residential buildings, except for parts of a building that are used for access, parking, or storage. For all other uses, if utilizing a temporary flood barrier system, consider setting the barriers back to allow for an area of assisted rescue per state building code requirements, as well as a movable code-compliant stair, handrails, and landing. Any temporary barrier or means of egress should not encroach into the public right of way without coordination with the City of Boston (see BPWD, Section 7 page 72.)

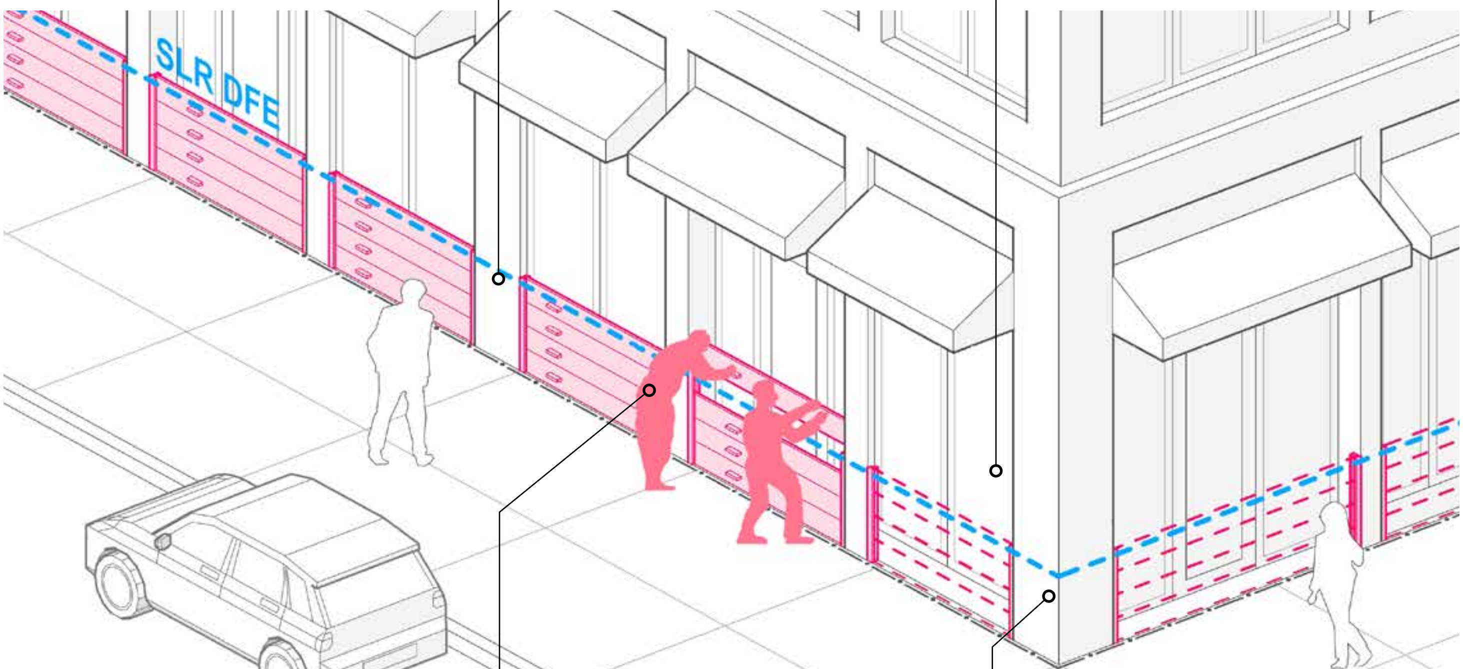
Flooding Depth

Dry floodproofing is most practical where flood depths do not exceed 3' and when flood velocities and durations are low.

Per FEMA standards, dry floodproofing is not allowed in special flood hazard areas with high velocity wave-action (V-zones, Coastal A-Zones) because it does not protect against wave action, erosion, scour, and may make the building subject to greater risk of structural failure.

Means of Egress

Flood barriers cannot block an accessible means of egress. Per ASCE 24-14, a dry floodproofed building must have at least one door satisfying building code egress requirements for an emergency escape above the applicable flood elevation.



Sealants and Interior Drainage

Waterproofing and sealants can be applied either to the exterior or interior side of walls and floors (as shown below) to make them impermeable.

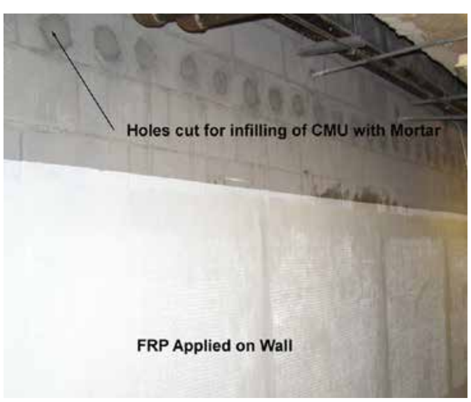
Water may still seep through small openings in a dry floodproofed building. Therefore, a dry floodproofed building requires a drainage system utilizing sump pumps with backup power to remove any leaked water.

Human Intervention

Dry floodproofing often requires human intervention for storage, maintenance, and implementation of shields and barriers, along with training of building owners or facilities personnel to properly deploy and maintain these systems. These dry floodproofing systems should be incorporated into a building's emergency operations plan.

Structural Integrity

Engineering must be performed to ensure the structure can withstand hydrostatic pressure by flood waters and saturated soils. This includes reinforcing above-grade walls and foundations to withstand these flood pressures. Because of the flood pressures imposed by water and saturated soils, dry floodproofing is most appropriate for concrete and load-bearing masonry structures without basements.



Interior waterproofing and structural reinforcing
Source: FEMA. 2013. Floodproofing Non-Residential Buildings.

Drop-in flood shields inserted into brackets
Photo: Flood Panels LLC

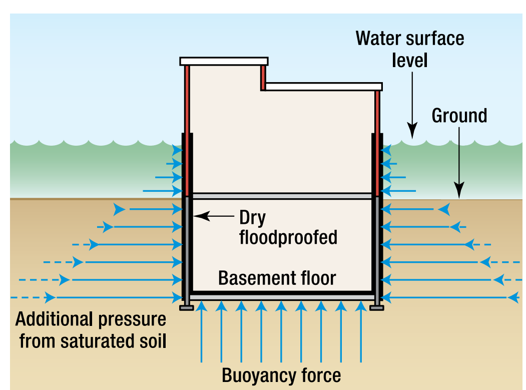


Diagram showing various hydrostatic forces on building
Source: FEMA. 2013. Floodproofing Non-Residential Buildings.

Flood Damage-Resistant Materials

Flood damage-resistant materials are any building material, component or system capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage.

These materials are used in conjunction with other strategies in this guide, such as wet and dry floodproofing, to prevent damage where contact with floodwaters may occur. Flood damage-resistant materials remain intact during wetting and drying and do not deteriorate when cleaned for pollutant removal after a flood event, facilitating faster, safer, and less expensive post-storm recovery.

The NFIP classifies material types according to their ability to withstand flood damage. Highly resistant materials include concrete, stone, masonry block, ceramic and clay tile, pressure-treated and naturally decay-resistant lumber, epoxy-based paints, and metal. Vulnerable materials include gypsum wall board, blown-in and fiberglass batt insulation, carpeting, and oriented strand board.

- Consider the combination of materials when evaluating flood damage resistance. For example, plastic sheet or tile flooring adhered to a concrete slab (both damage-resistant materials) would together qualify as a flood damage-resistant assembly. If the same plastic flooring were placed on an untreated plywood subfloor, the assembly would not qualify as flood damage-resistant, because the floor finish restricts drying of the more vulnerable plywood subfloor.
- Adhesives between materials, as well as fasteners and connectors that hold assemblies together, should be considered when evaluating the resistance of surfaces below the flood elevation.

Applicability

Project Scale	Non-Art. 80 renovations, Art. 80 renovations and new construction
Building Type	Non-residential spaces within all typologies

- As an incremental solution for buildings outside of the FEMA floodplain, partial retrofitting of ground floor spaces with flood damage resistant materials can make cleaning and repair easier in the event of flooding. Lower portions of a wall under the flood elevation can be fitted or retrofitted with flood tolerant materials or with materials that can be easily removed and replaced.

Cost and Insurance Considerations

- The use of flood damage resistant materials can contribute to eligibility for insurance premium reductions for projects insured under the NFIP.
- Dry floodproofing methods should not be used in FEMA V zone for spaces below the lowest floor.

Additional Resources

- FEMA Technical Bulletin 2: Flood Damage-Resistant Materials Requirements
- Building Science Corporation, BSD-111: Flood and Hurricane Resistant Buildings

Class descriptions of flood damage-resistant materials

The NFIP classifies material types according to their ability to withstand flood damage.

NFIP Class	Class Description	Example Materials
Acceptable		
Class 5	Highly resistant to floodwater[a] damage, including damage caused by moving water.[b] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[c] Materials in this class are permitted for partially enclosed or outside uses with essentially unmitigated flood exposure.	• Concrete • Stone • Masonry block • Ceramic and clay tile • Pressure-treated lumber
Class 4	Resistant to floodwater[a] damage from wetting and drying but less durable when exposed to moving water.[b] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[c] Materials in this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection.	
Unacceptable		
Class 3	Resistant to floodwater[a] damage from wetting and drying but less durable when exposed to moving water.[b] These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants.[c] Materials in this class may be exposed to and/or submerged in floodwaters in interior spaces and do not require special waterproofing protection.	• Gypsum wall board • Blown-in and fiberglass batt insulation • Carpeting • Oriented strand board
Class 2	Not resistant to clean water[d] damage. Materials in this class are used in predominantly dry spaces that may be subject to occasional water vapor and/or slight seepage. These materials cannot survive the wetting and drying associated with floods.	
Class 1	Not resistant to clean water[d] damage or moisture damage. Materials in this class are used in spaces with conditions of complete dryness. These materials cannot survive the wetting and drying associated with floods.	

Source: NFIP Technical Bulletin 2 (FEMA 2008a).

[a] Floodwater is assumed to be considered “black” water; black water contains pollutants such as sewage, chemicals, heavy metals, or other toxic substances that are potentially hazardous to humans.

[b] Moving water is defined as water moving at low velocities of 5’ per second or less. Water moving at velocities greater than 5’ per second may cause structural damage to building materials.

[c] Some materials can be successfully cleaned of most of the pollutants typically found in floodwater. However, some individual pollutants such as heating oil can be extremely difficult to remove from uncoated concrete. These materials are flood damage-resistant except when exposed to individual pollutants that cannot be successfully cleaned.

[d] Clean water includes potable water as well as “gray” water; gray water is wastewater collected from normal uses (e.g., laundry, bathing, food preparation).

Protect Critical Systems

Building utility systems, including electrical and mechanical equipment, should be protected from flood risk to avoid costly damage, safety risks, and loss of habitability and other critical building functions during a flood event. This should be among the highest priority resilience actions for property owners.

For all new construction and substantial improvements, electrical, heating, ventilation, plumbing and air-conditioning equipment and other service facilities shall be designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding. These systems and equipment include:

Mechanical

- Boilers and furnaces
- Air-handlers, condenser units, and heat pumps
- Ductwork and piping
- Fuel storage tanks
- Water heaters
- Fire-suppression sprinkler controls
- Elevator machine rooms

Electrical

- Electrical panels and switchgear
- Backup generators
- Alarm controls and components
- Service wiring and receptacles
- Building management systems
- Telecommunications equipment
- Electric and gas meters
- Utility shut-off switches

With proper planning, new buildings can easily accommodate the protection of critical systems by locating equipment in upper floors or in a mechanical penthouse. For renovation projects, the three main types of protection are elevation, relocation, and protection in place.

- **Elevate:** Outdoor equipment or ground floor equipment located in spaces with high ceilings can usually be elevated on pedestals or platforms to bring the systems above the flood elevation.
- **Relocate:** Depending on the available space within an existing building, service equipment from a basement or other area below the flood level can be relocated to an upper floor to bring the equipment and distribution systems above the flood elevation.
- **Protect in place:** When elevating and relocating are not practical or feasible, the last option to increase the resilience of critical systems is to protect them in place.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction

This includes elevating to the greatest extent possible and dry floodproofing with low floodwalls and shields and with anchors and tie downs to prevent flotation.

Sustainability Co-benefits Considerations

- When replacing equipment, choosing high-efficiency models can reduce energy use, utility bills, and emissions of greenhouse gases and other pollution. It also reduces strain on the energy grid, making the whole system more resilient. This is exemplified in the case of replacing an old sub-grade furnace with a more fuel-efficient electric heat-pump system, located above the SLR-DFE.
- Electrification of heating systems, in combination with choosing clean sources of electricity and implementing energy efficiency improvements, will support Boston's efforts to achieve carbon neutrality.

Cost and Insurance Considerations:

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- In FEMA V zones, elevating mechanical equipment is required for NFIP premium reduction.
- Relocating/Replacing critical utilities is also an opportunity to upgrade and increase the energy efficiency of a building's systems, which may lead to a reduction in annual utility costs.

Additional Resources

- FEMA 348: Protecting Building Utilities From Flood Damage
- FEMA P-312, Homeowner's Guide to Retrofitting
- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions
- FEMA Recovery Advisory 2: Reducing Flood Effects in Critical Facilities

Technical Considerations

Repair and Replacement

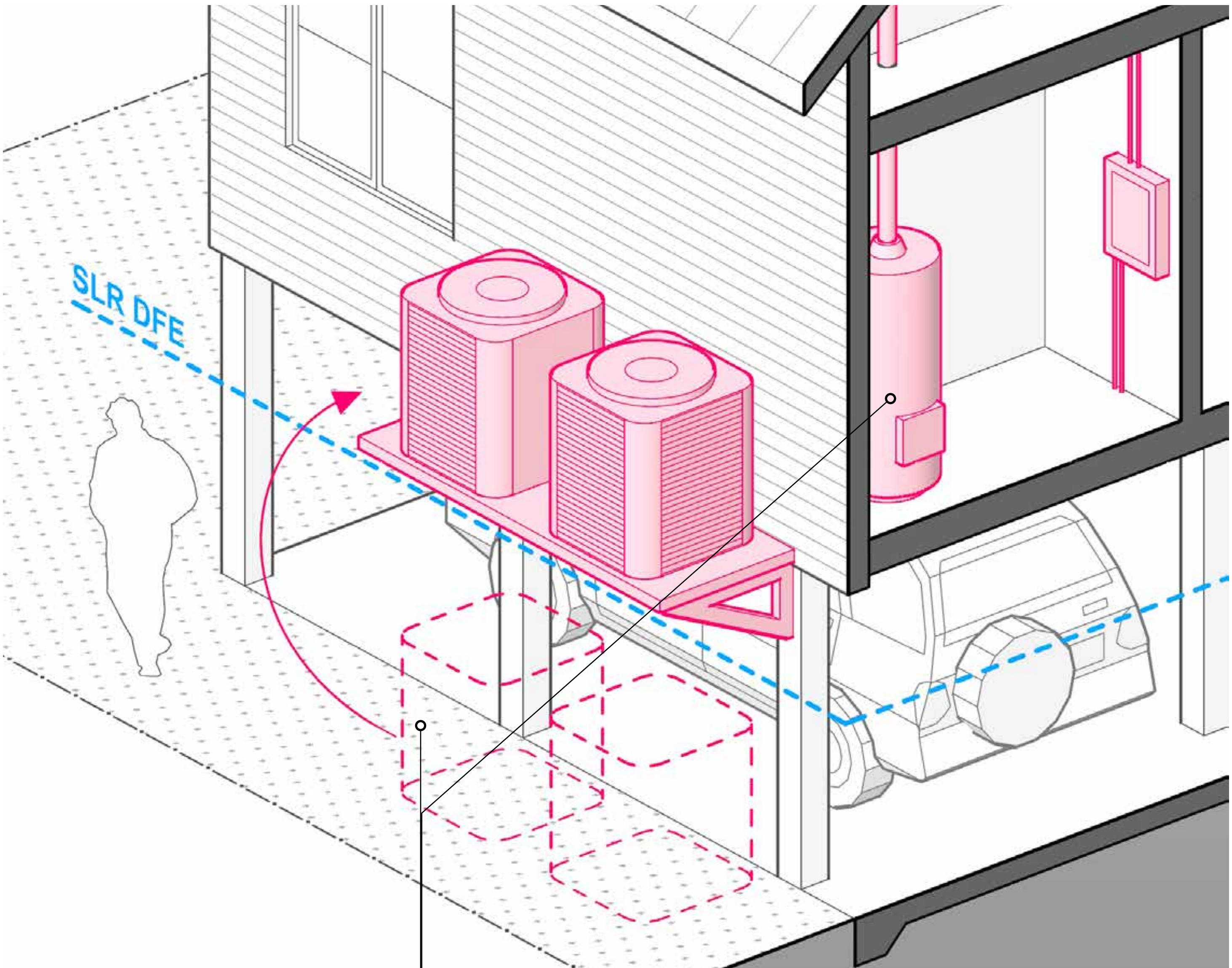
Use natural cycles of repair and replacement as opportunities to improve the flood resilience of building utility systems and equipment. For example, replacing an old furnace in the basement with a more compact mini-split heat pump can improve efficiency, reduce fossil fuel use, and make relocating or elevating heating and cooling systems more feasible in space-constrained buildings.

Energy Audits

Building owners should conduct an energy audit to identify opportunities for improvements in energy efficiency to coincide with resilience upgrades. This is not only limited to replacing old equipment with higher-efficiency models. An energy audit can reveal how upgrades to the building envelope can reduce heating and cooling loads, which can result in equipment down-sizing in addition to added efficiency.

Utility Coordination

Coordinate with the local utility company when planning modifications to the placement of electric and/or gas meters.



Protecting in Place

If protecting in place is the most feasible option, watertight walls and shields are most practical when flood depths are less than 3'. Utilize a watertight closure panel if a floodwall is too high to step over. Utilize anchors and tie-downs to hold equipment in place.

Elevating Equipment

When relocating or elevating MEP systems, consider horizontal and vertical clearances for routine maintenance; venting requirements for combustion equipment; drain pans for equipment containing water storage to prevent leakage; and provisions to prevent equipment from freezing.

Resilient Elevators

Resilient elevators include strategies to protect or relocate vulnerable motors and controls, protecting the elevator cab, and providing backup power solutions.

Elevator systems are vulnerable to flood damage because elevator pits and control components typically extend below the lowest floor. Hydraulic elevators may face damage to the hydraulic cylinder and piping, whereas traction elevators may be exposed to damage to hoist ropes and wiring. By raising or making watertight components that are sensitive to water exposure and establishing flood-protected backup power, flood damage to elevators can be avoided and post-flood accessibility maintained.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction

Cost and Insurance Considerations

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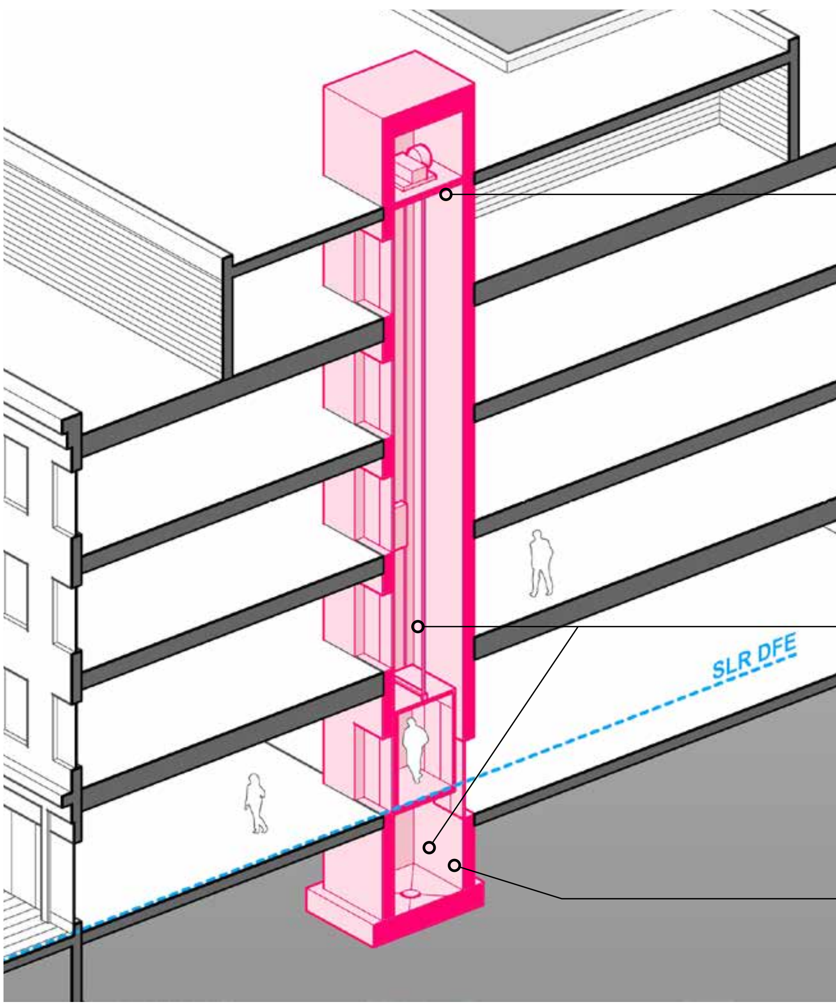
Additional Resources

- FEMA 348: Protecting Building Utilities From Flood Damage
- FEMA Technical Bulletin 4: Elevator Installation for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program

Technical Considerations



Elevator Penthouse

Consider wind and water resistance of elevator overrun or penthouse walls to protect the elevator shaft, controls, and motors.

Controls

Locate controls above the SLR-DFE.

Backup Power System

For buildings four stories or greater, provide a standby power system to keep one elevator operational while parking the other elevator cars out-of-service at a flood-safe floor. Provide visual indication for out-of-service cars at the control panel.

Elevator Cab

To protect the elevator cab, consider installing a detection system with one or more water detection switches in the elevator shaft. This prevents the cab from descending into a flooded pit.

Emergency Protocol

Establish emergency protocol in the event of water infiltration.

Protection below DFE

Electrical switches and wiring installed in the hoistway below the design flood elevation should be waterproofed to NEMA 6 where available or NEMA 4 standards.

Backup Systems

Backup water management systems, including sump pumps and backflow preventers, protect buildings from unintended flood water entry in conjunction with floodproofing strategies.

Sump pumps: Sump pumps remove water from below-grade spaces that may have made its way through gaps in sealed openings or walls. They also remove water from an underdrain system at the perimeter of below-grade walls or under a slab on grade. These devices collect seeped water into a sump pit, and then discharge this water out of the building. The Boston Water and Sewer Commission regulate the installation of sump pumps, and require that these devices drain water to a lawn or other yard area to avoid overburdening the sanitary sewer system.

Backflow prevention: Sewage backflow can happen for a variety of reasons, although the risk is largest during flood and extreme storm events. Options for backflow prevention include check, gate, and dual backflow valves. Backflow preventers are already required by the Uniform State Plumbing Code of Massachusetts for all buildings containing plumbing fixtures below the top of the sewer manhole cover serving the building.

Cost and Insurance Considerations

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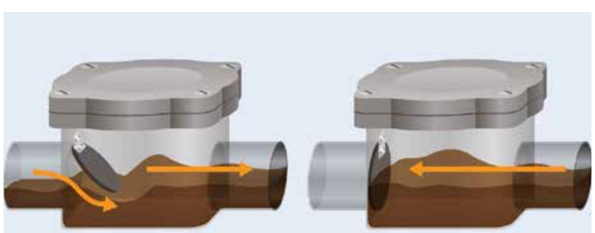
- Property owners are responsible for installing and maintaining backflow prevention devices.
- A backflow preventer is a relatively inexpensive device to retrofit in smaller buildings, although cost increases with larger commercial buildings.



Backflow Prevention

Consider installing a sewer backup alarm to warn the building occupants when a backwater valve is activated and to curtail plumbing fixture use.

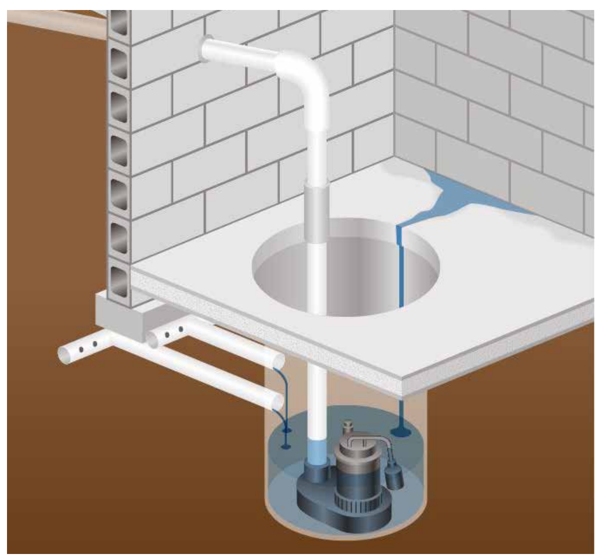
Backflow prevention devices require regular inspection and maintenance to ensure functionality and to check that debris is not caught in the valve or cleanout.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction

Additional Resources

- FEMA P-936, Floodproofing Non-Residential Buildings
- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience
- FEMA 348: Protecting Building Utilities From Flood Damage
- FEMA Technical Bulletin 4: Elevator Installation for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program
- Uniform State Plumbing Code of Massachusetts



Photos: Enterprise Green Communities / Strategies for Multifamily Building Resilience

Sump Pump

Sump pumps and internal drainage systems should be properly maintained to remove sediment or debris that has settled in the sump. Refer to requirements by the MA Uniform State Plumbing Code and BWSC before installation.

Ensure that a heavy-duty, properly sealed lid is placed on the sump pump. Some soils below buildings contain radon or other pollutants that can be released into an enclosed space through a sump that is not adequately covered.

Sump pumps run on electricity, and therefore backup power should be considered to maintain functionality during a power outage.

District-scale Strategies

This is an overview of strategies that are being developed through the Climate Ready Boston Coastal Resilience Solutions neighborhood plans. Strategies for the public right-of-way are outlined in Climate Resilient Design Standards & Guidelines for Protection of Public Rights-of-Way, a comprehensive document by the City's Public Works Department that provides additional details for flood barriers shown here.

Image: Coastal Resilience Solutions for East Boston and Charlestown

Waterfront Parks

- New and existing open spaces can be designed to function as elevated structural barriers to flooding. Sites can be raised using compacted fill or incorporate other district and site scale flood protection design strategies such as berms, Harborwalk barriers, and flood walls.
- An important advantage of preserving open space along the waterfront, as compared with adapting developed sites, is that space provides flexibility to further adapt and elevate waterfront areas should climate projections worsen in the future.
- Floodable areas, expected to be exposed to flooding, should utilize flood damage resistant materials including vegetation.
- Waterfront parks can be designed to enhance neighborhoods and the waterfront by providing open space for passive and active recreation, enhance access and connections throughout, natural landscapes, carbon mitigation, heat island reduction, and stormwater flood mitigation.
- Waterfront open spaces should be designed with community participation. Because waterfront parks have the space available to set the design flood elevation further back from the shoreline, this strategy can minimize impacts on waterfront views.

Vegetated Berm

- A vegetated berm is a compacted earthen levee, constructed parallel to the shoreline, that acts as a barrier to flooding. A berm will have at least one access path along its crest, grass-type plantings, water-side erosion protection, and land-side drainage.
- In order for a levee system, and the area protected by it, to be recognized for National Flood Insurance Program purposes, it must meet specific design, inspection, and maintenance requirements set by the US Army Corps of Engineers.
- Modifying a FEMA Flood Insurance Map to recognize the protection provided by a levee also requires completing a Letter of Map Revision process, administered by FEMA. Levees may not be used to bring a substantially damaged or substantially improved structure into compliance with Article 25 of the Boston Zoning Code.
- Berms can be designed to enhance neighborhoods and the waterfront by providing open space for passive recreation, enhance access and connections throughout, and natural landscapes. They can also have negative impacts, if not mitigated through design, including reduced view corridors, the creation of a sense of separation from the water, and reduced accessibility.

Photo: Aquafence

Photos (top and bottom): Climate Resilient Design Standards and Guidelines for Protection of Public Right-of-Way

Temporary Flood Barriers

- Temporary flood barriers are vertical flood protection structures used as more robust, efficient, and effective alternatives to sandbags. Various products exist, ranging from systems made up of modular structural components that must be brought on-site from storage and assembled by a team of workers, to systems that are permanently installed on-site in ground or wall recesses and automatically deployed using the buoyancy forces of rising flood water.
- In the context of district and site scale strategies, temporary flood barriers are most applicable for blocking narrow flood pathways between permanent elevated structural barriers, and where more permanent solutions are constrained by cost, limited available space, existing development and infrastructure, or the need to maintain access at existing grade under all but storm conditions.
- Temporary flood barriers may be considered flood walls or components thereof for purposes of flood insurance. For a flood wall system, and the area protected by it, to be recognized for National Flood Insurance Program purposes, it must meet specific design, inspection, and maintenance requirements set by the US Army Corps of Engineers. Modifying a FEMA Flood Insurance Map to recognize the protection provided by a flood wall also requires completing a Letter of Map Revision process, administered by FEMA. Flood walls may not be used to bring a substantially damaged or substantially improved structure into compliance with Article 25 of the Boston Zoning Code.
- See BPWD guidelines for technical considerations.

Harborwalk Barrier / Seawall

- The Harborwalk, which provides connectivity and waterfront access along much of the City's shoreline, can be adapted to also serve as a barrier to flooding by raising the top of the walking path on compacted fill and/or adding additional height to associated shoreline protection structures (seawalls, bulkheads, revetments, etc.).

Raised Roadway

- Raising roadways can be an effective strategy to control flooding and maximize the usability of roads for evacuation, emergency response, and general mobility during flooding events. However, it is generally only feasible in corridors along which there is no or limited development, such as parkways or large areas undergoing redevelopment.
- Raising roadways before the adjacent land is developed will minimize design challenges of creating accessible transitions from grade to the elevated ground floors of new buildings and other negative externalities of elevated buildings on urban streetscape quality.

Enhanced Building Envelope

A better performing exterior envelope can improve the way existing and new construction maintain comfortable indoor conditions during outages.

Envelope upgrades that have the greatest impact on indoor temperatures include increased wall, roof, and floor insulation; operable, energy-efficient, well-sealing windows; sealing of cracks and leaks in a building's air barrier; exterior shading devices; and cool roof surfaces. While each upgrade can improve a building's resilience, addressing measures can together achieve multiple benefits, such as savings on both energy and equipment costs.

Assessment

- Conduct an energy audit to identify problem areas and prioritize efficiency measures. An energy audit should consider mechanical systems as well as envelope upgrades, because enhancing the envelope can often reduce the energy demand on heating and cooling equipment, which can result in the down-sizing of systems. Consider future repairs and the lifecycle of the building's components to coincide energy efficiency investments with the natural cycle of repair and replacement.

Walls and roof

- Adding wall and roof insulation slows the rate of heat and cool loss from interior to exterior. Insulation can be retrofitted to older buildings by adding a layer of insulation on either the interior or exterior side of a wall or roof. The R-value of the insulation should be calculated and upgraded to appropriate targets meeting, at a minimum, energy code insulation levels (the higher the R-value the better).

Windows

- For windows, a lower U-value for both the glazing and frame will mean more heat is retained in the winter. Triple glazed windows are the best performing but typically cost more than double-glazing. In the summer, a window's solar heat gain coefficient (SHGC) will influence how well the glazing can reflect the sun's heat to keep an indoor space cool; this is most often accomplished with low-emissivity (low-e) coatings. Consider well-sealing operable windows to allow for passive ventilation.
- Window treatments like overhangs, awnings, screens, and curtains on south, east, and west facing windows can control overheating by blocking the sun in the summer. Shading elements are the most effective when installed on the exterior side of the window. South-facing windows are the easiest to protect using simple overhangs designed to block higher-angle summer sun while letting in the lower-angle winter sun.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction

Air Leakage

- Air leakage can be evaluated using a blower door test, which can also help to target areas of the building to seal and weatherstrip. When improving a building's air tightness, ensure a proper ventilation system is in place, such as balanced whole-building energy recovery ventilation, to control indoor moisture levels.

Cost and Insurance Considerations

- These resilience measures significantly save energy. While first costs may be significant, long-term operational savings can be captured in the form of reduced heating/cooling bills.

Sustainability Co-benefits

- Enhanced envelope measures combine resilience benefits with the reduction of building heating and cooling loads, resulting in reduced greenhouse gas emissions in alignment with the goals of Carbon Free Boston. Envelope upgrades also make interiors more comfortable in general by minimizing drafts and cold spots in the winter, and by mitigating excess solar heat in the summer.

Additional Resources

- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions
- Building Green, Passive Survivability: A New Design Criterion for Buildings
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience

On-Site Energy Generation

In the event of a blackout, providing reliable on-site backup power for continued operation of critical services can greatly increase a building's resilience. A backup power system includes generation equipment, dedicated circuitry, and associated components.

Examples of power generation include:

- Fuel-fired generator, with stored fuel supply;
- Piped natural gas generator;
- Bi-modal solar-electric system with battery storage
- Combined Heat and Power, sometimes referred to as cogeneration, or "cogen," which generates on-site electricity and utilizes waste thermal energy for heating end-uses.

Each of the above systems vary in terms of energy or fuel storage, quantity of emissions, fuel cost, and safety and maintenance. Because emergency generators sit idle 99% of the time, they may not be as reliable in the event of interrupted power as systems that are designed for continued use, such as solar-electric with storage and cogen.

Technical Considerations

- Depending on building use and size, electrical loads essential for life safety are required by state building code to be powered by emergency systems, such as emergency voice/alarm communication systems, means of egress lighting, fire suppression systems, and elevators, as well as standby systems for other safety measures.
- In addition to required loads, identify and prioritize which electrical loads and equipment are most important to run on the backup power supply. For example, consider providing back-up power to sump pumps if the building is also employing dry floodproofing techniques, or domestic water pumps if they are part of a building's access to potable water.

Generators

- For rooftop mounting, consider building an enclosure to provide protection from air-borne debris during a storm.
- Because of the weight of large equipment, ensure that the structure can carry the added live load of the generator.
- Develop an emergency equipment operations and maintenance plan. Building codes typically require regular inspections and testing.
- Generators often create high levels of noise and vibration, so mounting and location should be coordinated to avoid disturbing occupants.

Applicability

Project Scale	Non-Art. 80 renovations and new construction, Art. 80 renovations and new construction

Additionally, ensure adequate ventilation for any indoor equipment.

Solar Electric Systems

- Most grid-connected solar electric systems have inverters that are designed to automatically cease power production as a safety precaution if the electrical grid goes down.
- Any design for a system that switches to battery backup during an outage, such as an AC coupled system, needs to be coordinated with local authorities for full system compliance.

Cost and Insurance Considerations

- The cost of emergency generators is tied to the type and capacity of the system.
- For solar electric systems, upfront costs for panels and battery storage systems can be high. First costs can be offset by federal, state, and local tax credits as well as utility incentive programs. Long term savings can be captured through avoided electricity costs and building value appreciation.

Sustainability Co-benefits

- Depending on the size and coverage of the system, backup power generation has the potential to reduce business interruption costs.
- On-site solar electric systems reduce peak demand on the electric grid, improving resilience and reducing greenhouse gas emissions.

Additional Resources

- A Better City Report, Enhancing Resilience in Boston: A Guide for Large Buildings and Institutions
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience
- LEED Resilient Design Pilot Credit: Passive Survivability and Back-up Power During Disruptions
- FEMA Recovery Advisory 2: Reducing Flood Effects in Critical Facilities

Landscape Strategies

Saltwater Tolerant Planting

Design areas of vegetation with plant species that can withstand flood events, including salt-water inundation. This is especially important in the selection of street tree species. When flooding does occur, a landscape maintenance program should be in place to immediately flush plant-toxic salt out of soils with water and amendments that bind or help drain salts such as humic acids with compost tea, gypsum with watering trucks on an irrigation system. Elevated salt levels can kill plants through reverse osmosis and make soils uninhabitable for plants in the future.

Photo: Perkins&Will, Spaulding Rehabilitation Hospital

Flood Damage-Resistant Landscape Materials

Choose landscape materials that will not corrode with salt-water inundation. Installation details shall consider the forces of flood water and structural requirements to prevent water damage.

City of Key West, Florida / "Propane Tank Flood Hazards" Photo: Erica Miller

Securing Large Objects and Minimizing Debris

Large site objects such as fuel tanks, rainwater harvesting systems and other site objects shall be structurally secured to prevent mobilization of debris and release of hazardous materials in flood events.

Photo: Flickr / Flickr User Kirt Edblom

Blue Belt

(block or neighborhood scale)

Diverts stormwater away from buildings and important facilities in a large precipitation event to low-lying areas by gravity. Blue belts can be comprised of water squares, detention basins, non-critical roadways designed to accept water, channels, natural waterways etc.

Green Roofs, Blue and Brown Roofs

Green, blue and brown roofs retain stormwater on the top of buildings to mitigate precipitation events and help lower temperatures. Green roofs feature soils and planting that evapotranspiration water. Brown roof provide a ballast where spontaneous vegetation can grow and water can evaporate. Blue roofs detain and slowly release water or mitigate stormwater and heat through evaporation of the water surface. Challenges to roof retrofit in New England is the structural integrity for roof enhancements on aging building stock.

Photo: Flickr User Chesapeake Bay Program

Cool Pavements and High-Albedo Landscape Materials

Cool pavements and other high albedo materials reflect sunlight, staying cooler and helping to reduce urban heat islands.

Photo: Flickr User NACTO

Shade Trees (south and west sides of building and paved areas)

Trees help lower temperature by providing shade and mitigate stormwater through evapotranspiration. Preserve large existing trees wherever possible since they have higher evapotranspiration rates and increased shading capabilities.

Maximize Vegetated Areas and Plantings

Plantings mitigate heat and stormwater events through evapotranspiration. Include high evapotranspiration-rate tree species (only where trees can tap groundwater during dry weather) to maximize volatilization of stormwater after large precipitation events.

Photo: Flickr User Annette Dubois

Photo: 2030 Palette

Cool Roofs

Roofing system that reflects light and therefor has low thermal capture and emittance.

Source: Massachusetts Real Estate Law Blog Photo: www.heritagelawncare.ca

Ongoing Tree Pruning

Prune vegetation to remove limbs in decline and provide clearance from other structures.

Photo: http://www.buildncook.com/made-in-the-shade/

Shade Mechanical Equipment

AC equipment that is shaded in the summer utilizes less energy and therefore is less carbon-intensive.

Photo: Wikimedia Commons User Manuguf

Green Walls

Vegetated exterior wall surfaces provide an additional layer of building insulation. Green walls that have an active air filtering system also can mitigate air pollutants and, in some cases, be designed to manage rooftop stormwater runoff.

Photo: Hive Miner / by Aaron Volkening

Landscape Retention/ Detention Features

Areas of a site designed to accept stormwater during large scale precipitation events, such as water squares or other open spaces areas designed to flood and hold water.

Permeable Pavements

Pavement areas that infiltrate stormwater, reducing runoff and potential flooding in storm events.

Photo: Flickr User Chesapeake Bay Program

Stormwater Infiltration or Extended Detention Practices

Below-ground stormwater infrastructure designed to infiltrate (where feasible) or detain stormwater runoff to attenuate and/or mitigate peak flows, reducing potential flooding.

Photo: Wikimedia Commons User Arbitrarily0

Rainwater Harvesting

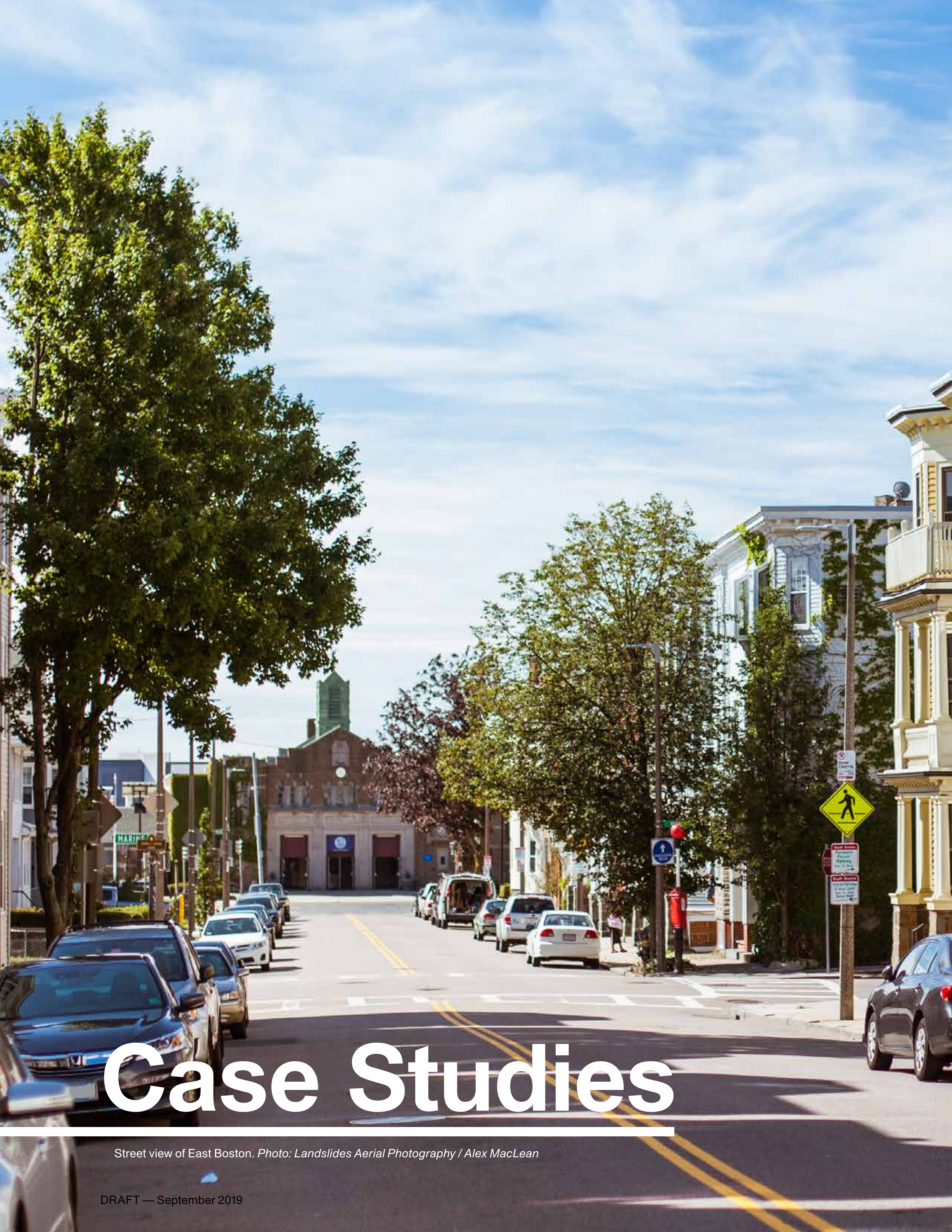
Rainwater harvesting and reuse, including rain barrels, cisterns, and detention ponds with real-time controls.

Photo: Innovative Water Solutions LLC / "Galvanized Metal Cisterns"

Green Stormwater Infrastructure

Vegetated features including rain gardens, bioswales, stormwater tree pits, infiltration planters, constructed wetlands and other green stormwater practices designed to infiltrate, evapotranspire, or temporarily store stormwater runoff during and after rain events. These stormwater management practices provide other landscape co-benefits, including mitigation of urban heat island effect, habitat creation, water and air quality benefits.

Photo: Flickr User Eric Fischer



Case Studies

Street view of East Boston. *Photo: Landslides Aerial Photography / Alex MacLean*


South Boston
Resident Permit Parking
TOW ZONE
SNOW
Street Cleaning

Case Studies Overview

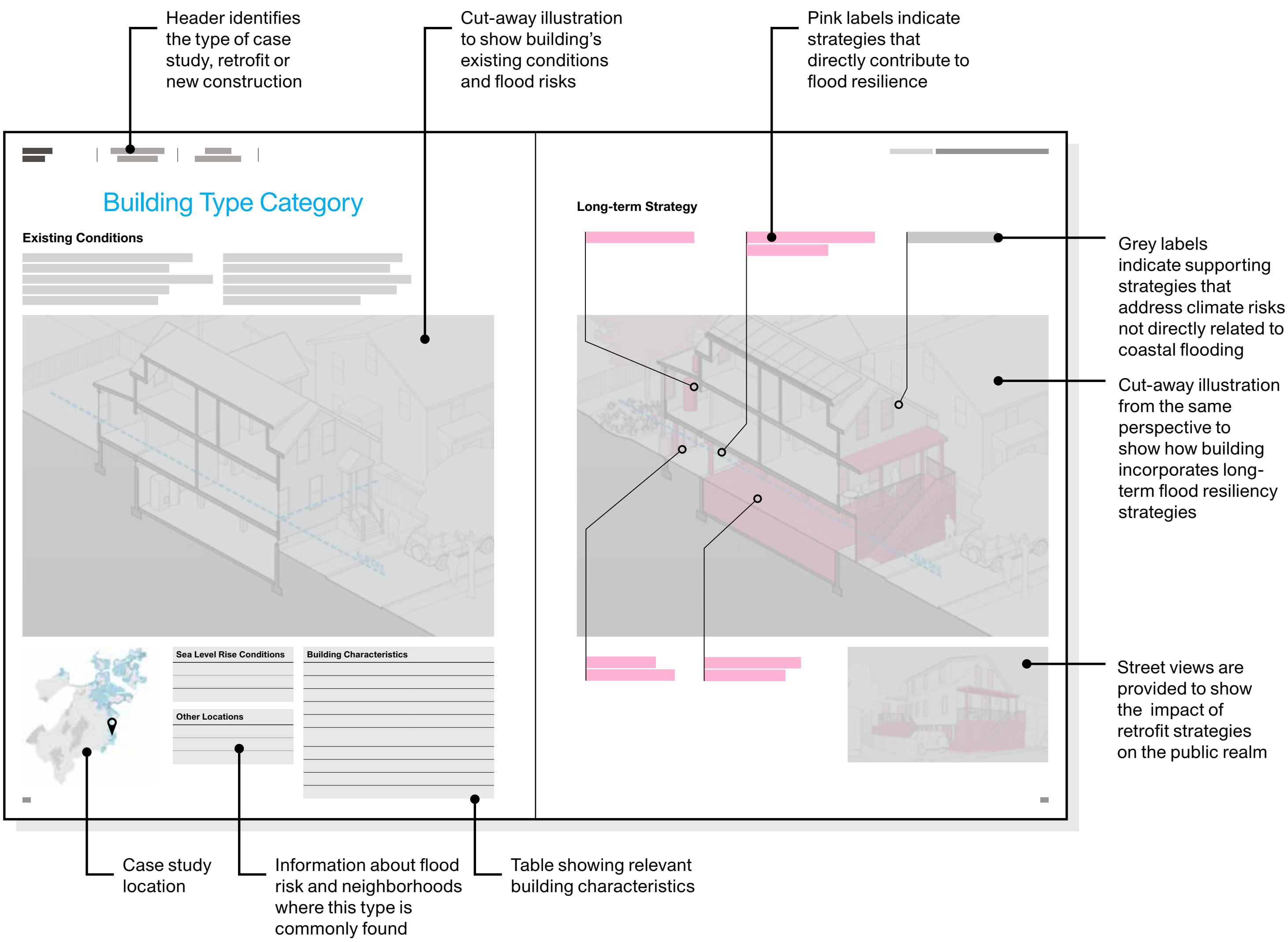
Understanding the Case Studies Spreads

The following case study spreads illustrate how individual design guidelines presented in the previous section are applied to various building types to increase their resilience to coastal flooding.

On the first spread, the illustration on the left page shows a cut-away view of the existing condition highlighting vulnerabilities to future flooding, such as the location of critical systems (e.g., boilers, electrical panels) in the basement.

The right page shows the same view with a long-term strategy for flood resilience highlighted in pink. Text boxes provide more information about these strategies. Strategies that directly contribute to coastal flood resilience are tagged with a pink label. Strategies that address climate risks not directly related to coastal flooding but nevertheless improve a building's sustainability (e.g., back-up generators, planting strategies) are tagged with a gray label.

Case Study Spread 1

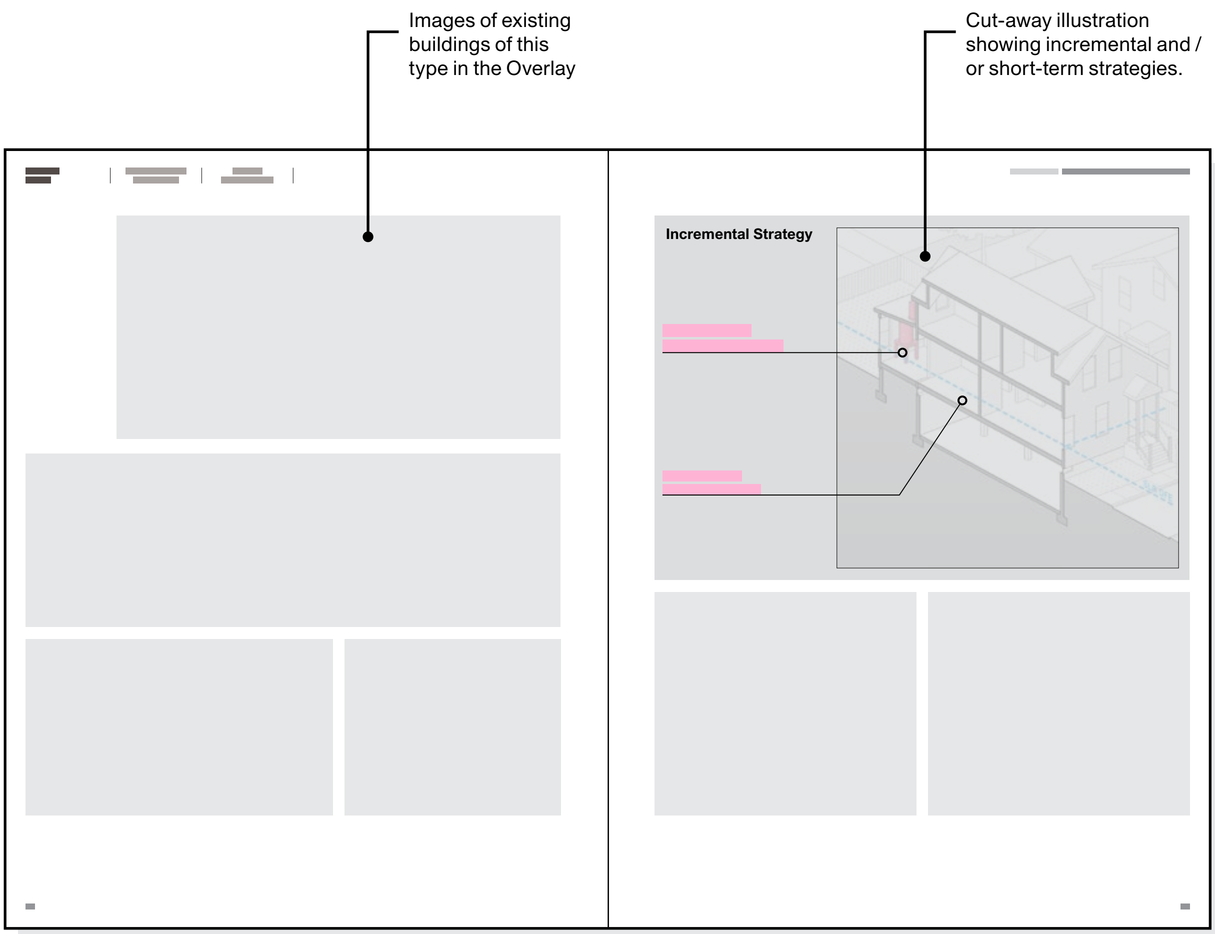


64

The second spread shows photographs of existing buildings of this type along with incremental or short-term flood resilience strategies. Where long-term strategies are not feasible due to cost, building code, or other constraints, owners should consider short-term or incremental strategies. Incremental strategies are those that can be integrated into long-term strategy over time, such as elevating critical systems above the SLR-DFE. In contrast, short-term strategies are those that are temporary measures which can be implemented as a "stop-gap" until a long-term strategy becomes feasible. Where possible, incremental strategies should be prioritized over short-term strategies.

The last two case studies in this section illustrate how flood resilience strategies can be incorporated into new construction. This is illustrated through two examples, a small-scale three-family residential building, and a large-scale residential mixed-use building with retail and commercial space on an elevated ground floor level.

Case Study Spread 2

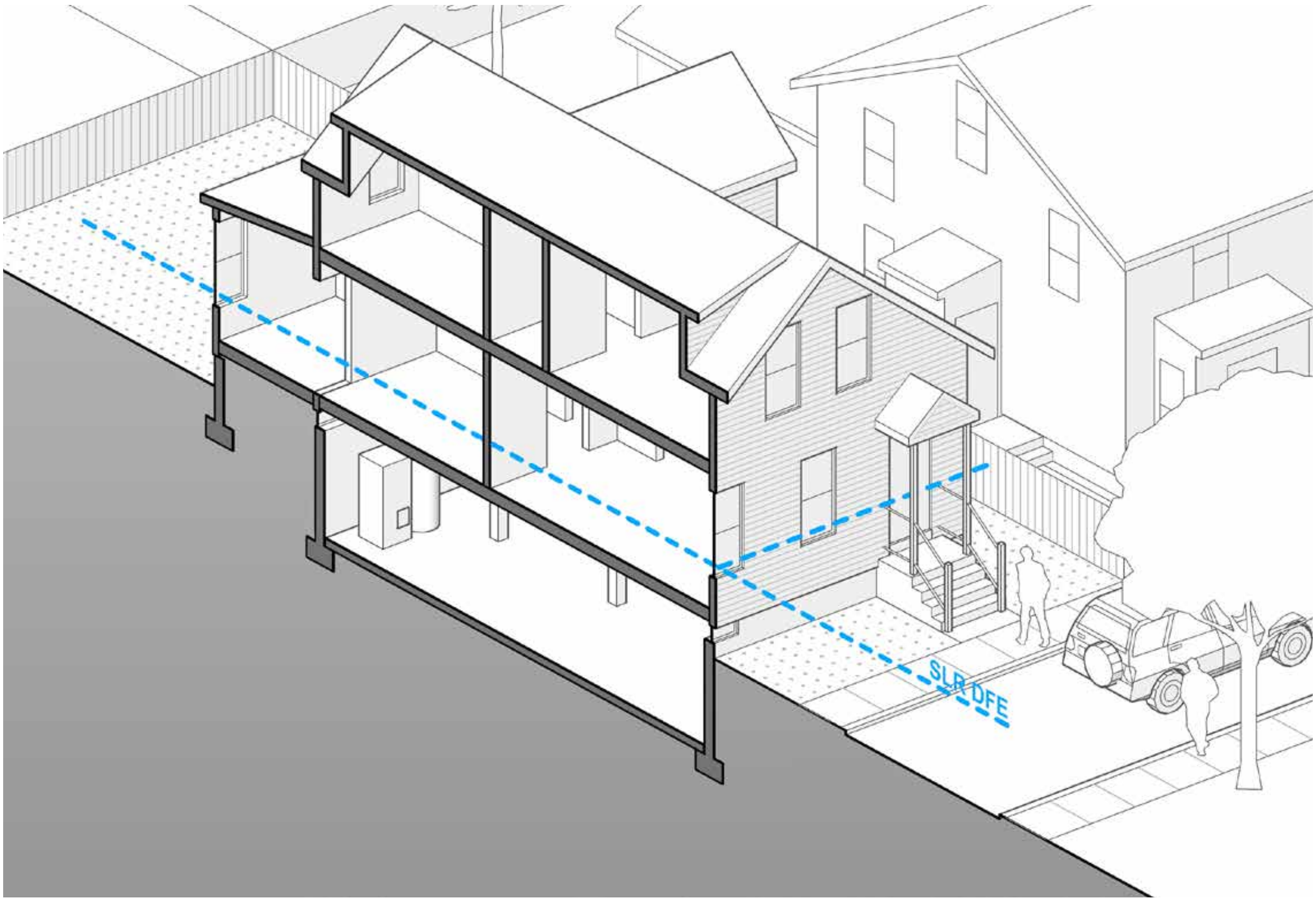


65

One- and Two-Family Residential

Existing Conditions

This type is commonly found in Dorchester within the Overlay neighborhoods. Structures are typically one or two-story wood-framed structures with pitched roofs and fieldstone foundations. They are commonly free-standing and often set back a few feet from the sidewalk, with porches covering raised stoops. Because of the scale of these buildings and their separation from adjacent structures, elevating the building is a viable adaptation measure.



Case Study Location

Sea Level Rise Conditions

SLR-BFE	19.50' BCB
SLR-DFE	20.50' BCB
FEMA BFE	16.46' BCB

Other Neighborhoods

Dorchester, East Boston

Building Characteristics

Grade elevation	approx. 14.57' BCB
Lowest occupiable floor	approx. 17.57' BCB
Cellar elevation	Unknown
Critical systems location	Basement
Construction type	Wood frame
Year built	Late 19th–early 20th century
Stories	2
Units	1
Sidewalk width	4'
Zoning district	Two-family Residential

Long-term Strategy

Building Systems

Protect Critical Systems

Locate water heater and critical systems above the SLR-DFE.

Evaluate life of systems and upgrade where possible. Consider upgrading heating to high-efficiency mini-split heat pump system with equipment mounted outside and above the SLR-DFE.

Building Form

Elevate on Open Foundation

Elevate house on posts above SLR-DFE on new foundation system. Consider elevating higher to accommodate storage and/or parking. Abandon basement and fill it to the lowest adjacent grade.

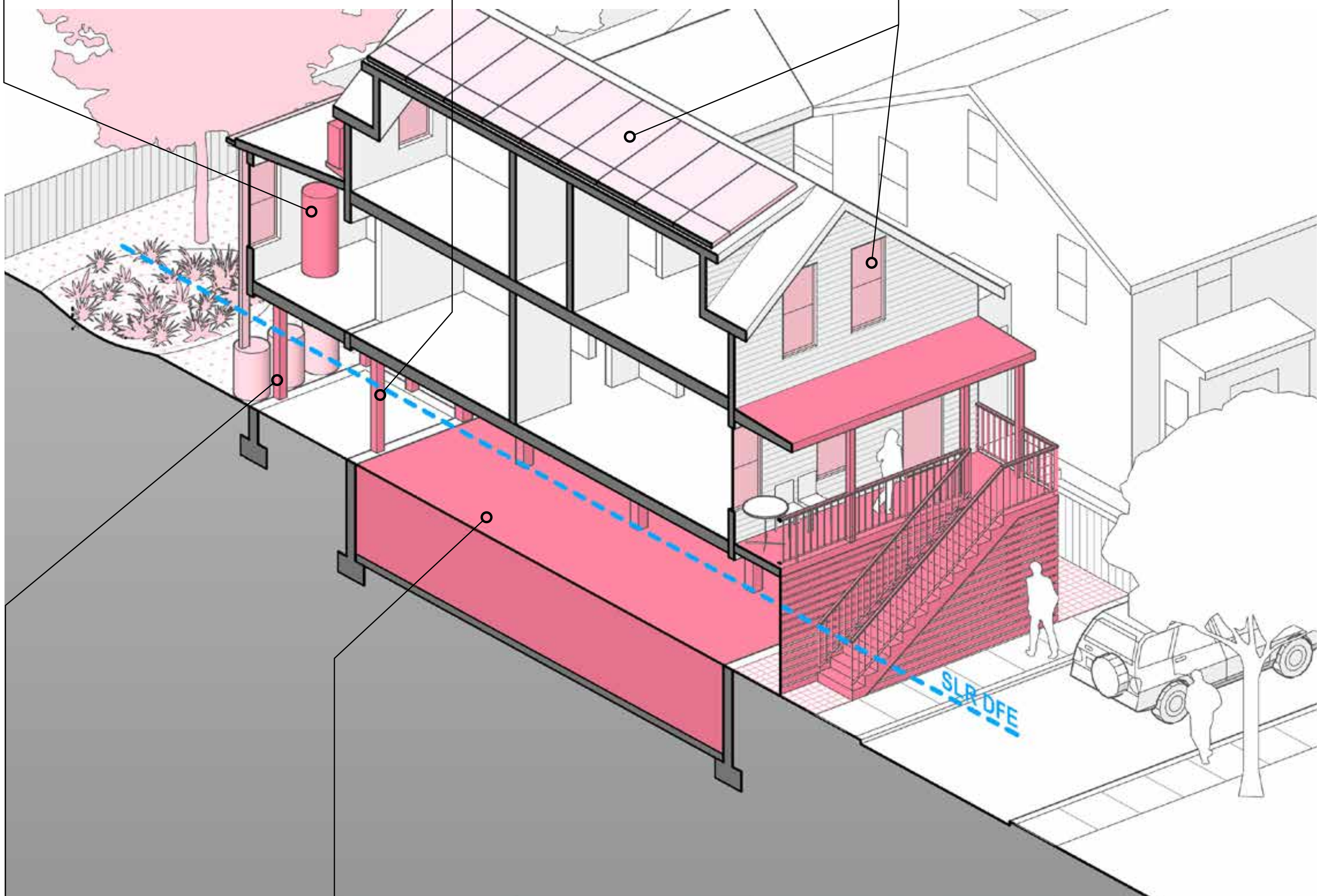
When elevating, incorporate screens, porches, and stairs to integrate with the public sidewalk.

Supporting Strategy

Enhanced Envelope

Conduct energy audit and blower door test. Air-seal at windows, doors, and penetrations. Upgrade windows to low-e, low-U-factor units.

Install blown-in cellulose insulation to wall cavities; add roof insulation outboard of deck. Install islandable, grid-connected solar PV system on the roof for on-site energy generation.



Building Envelope and Access

Flood-Damage-Resistant Materials

Use saltwater-damage-resistant materials below SLR-DFE.

Building Form

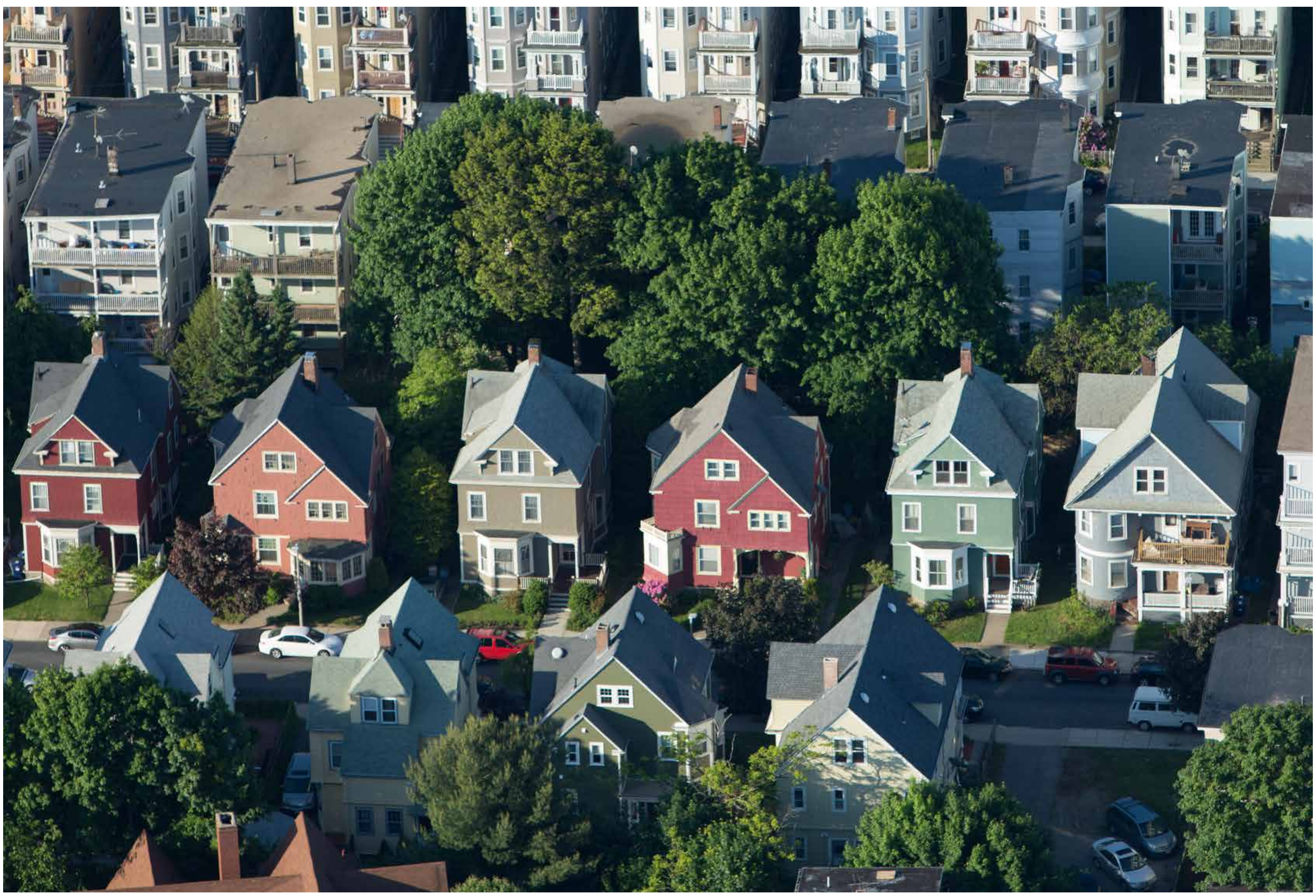
Repurpose / Relocate Ground Floor Use

Abandon basement and ground floor. Fill basement to the lowest adjacent grade.

Convert ground floor use to storage, parking, or access. Eliminate any habitable spaces below SLR-DFE. Recuperate lost FAR at roof addition.

When filling basement, consider structure and envelope to prevent wicking of moisture up into building after flooding.

View from the street



Above photo: Landslides Aerial Photography / Alex MacLean

Incremental Strategy

Floodproofing the basement and protecting the components of critical systems are priority short-term measures.

Building Systems

Protect Critical Systems

Locate systems above SLR-DFE. Consider mini-split system with condenser mounted to the side of house above SLR-DFE.

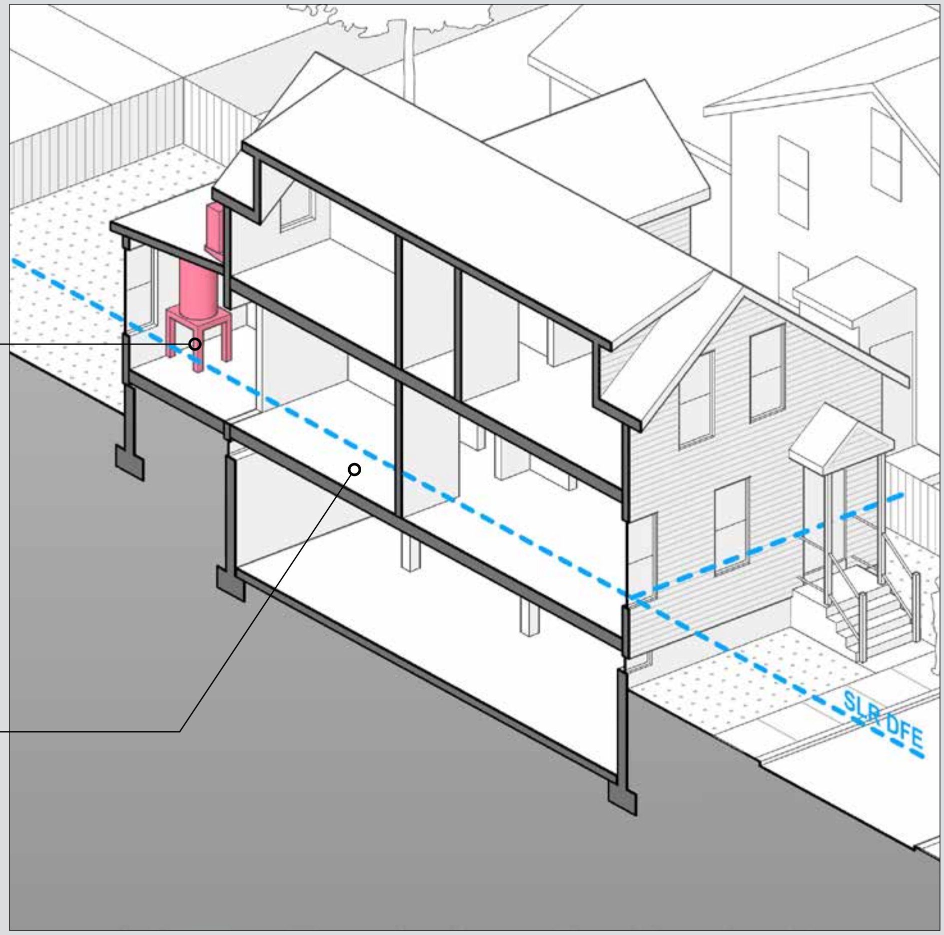
Backup Systems

Install backflow preventers to limit wastewater backup and sump pumps to provide internal drainage.

Building Envelope and Access

Flood-Damage-Resistant Materials

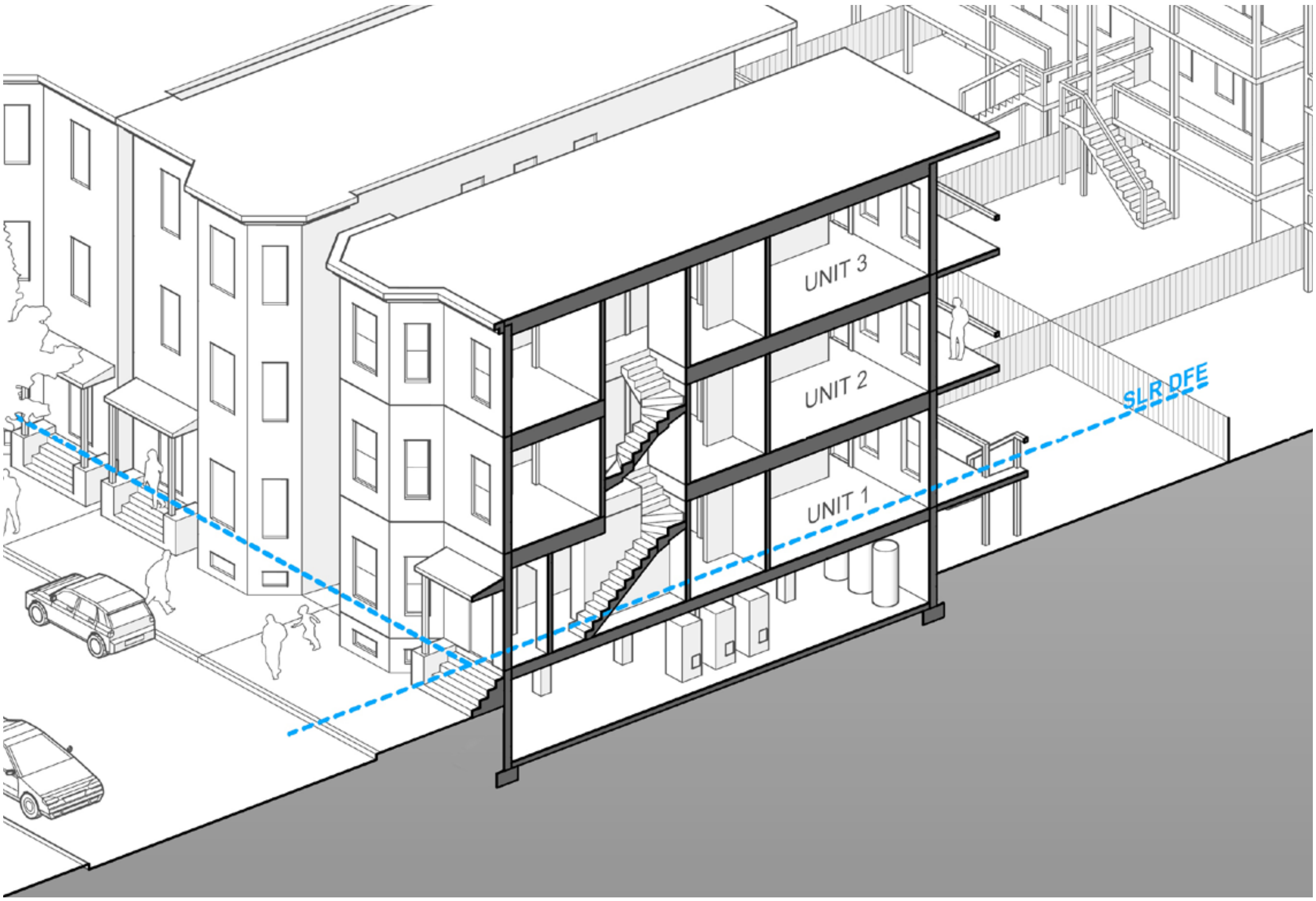
Use flood-damage-resistant materials below SLR-DFE.



Triple-decker

Existing Conditions

One of the most prevalent building types in Boston, triple-deckers are commonly found in the Overlay neighborhoods of East Boston, South Boston, Dorchester, and Charlestown. They are typically free-standing, three-story wood structures commonly supported on fieldstone and brick foundations, with bay windows and covered stoops facing the sidewalk and tiered decks facing the rear yard.



Case Study Location

Sea Level Rise Conditions

SLR-BFE	19.50’ BCB
SLR-DFE	20.50’ BCB
FEMA BFE	17.46’ BCB

Other Neighborhoods

Dorchester, Charlestown

Building Characteristics

Grade elevation	approx. 15.56’ BCB
Lowest occupiable floor	approx. 18.75’ BCB
Cellar elevation	10.10’ BCB
Critical systems location	Basement
Construction type	Wood frame
Year built	Late 19th–early 20th century
Stories	3
Units	3
Sidewalk width	10’
Zoning district	Three-family Residential

Long-term Strategy

Supporting Strategies

Enhanced Envelope

Conduct energy audit and blower door test to identify air leaks.

Install blown-in cellulose insulation to wall cavities; add roof insulation outboard of deck.

Upgrade windows to low-e, low-U-factor casement windows.

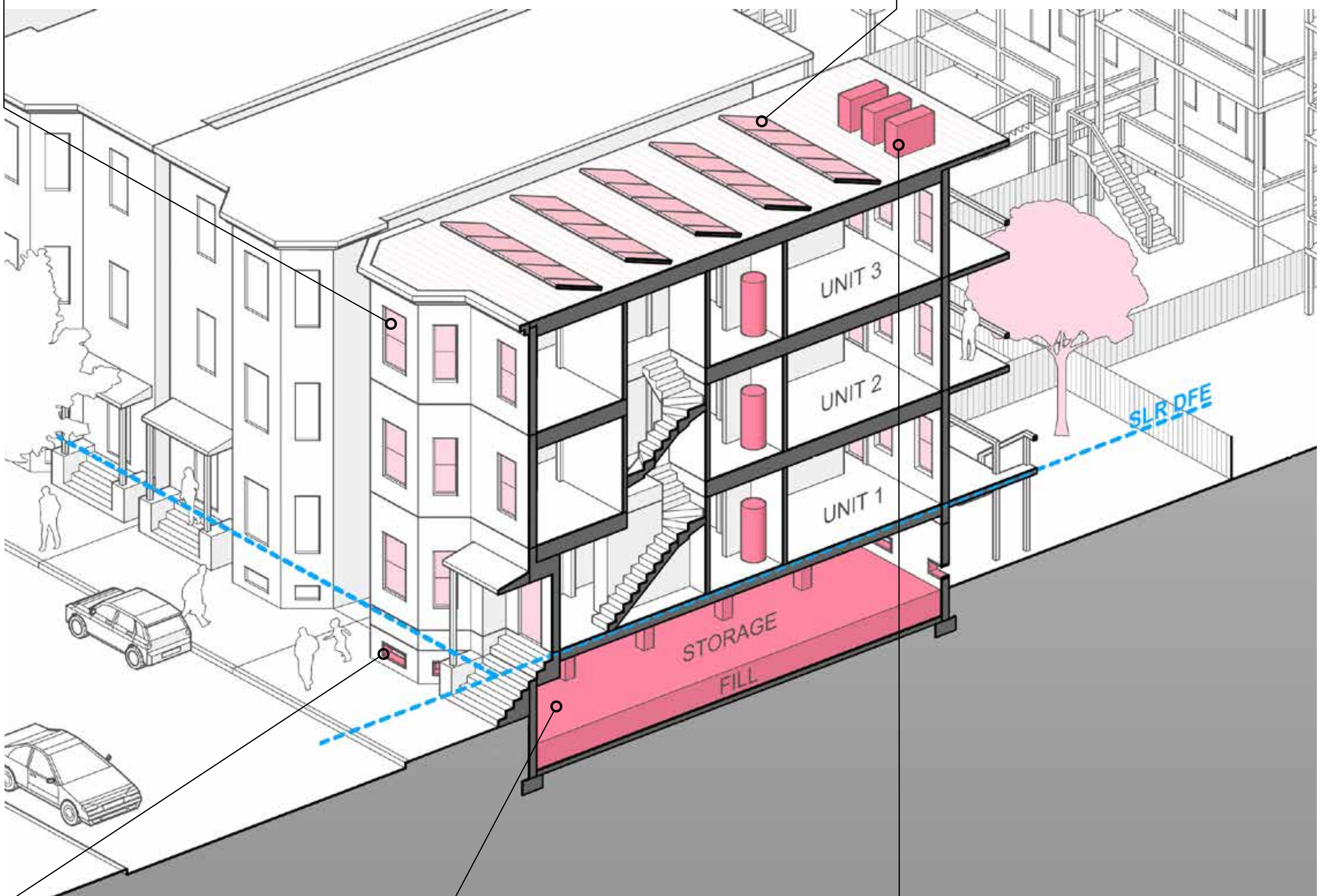
Cool roofing mitigates overheating by reducing roof temperatures

Consider envelope upgrades in conjunction with replacing critical systems for resilience. A better envelope can result in down-sized HVAC systems that are less expensive to operate.

Supporting Strategies

On-Site Energy Generation

Install islandable, grid-connected solar PV system on the roof.



Building Envelope and Access

Wet Floodproof

Install flood vents at foundation walls in order for water to enter and balance hydrostatic forces.

Use saltwater-damage-resistant materials below SLR-DFE.

Eliminate any habitable spaces below SLR-DFE. Limit uses below SLR-DFE to parking, access, and storage.

Building Form

Elevate Building on Extended Foundation Walls

Abandon basement and fill it to the lowest adjacent grade.

Elevate building such that first occupiable floor is above SLR-DFE. Extend foundation walls.

When filling basement, consider structure and envelope to prevent wicking of moisture up into building after flooding.

Building Systems

Protect Critical Systems

Locate water heater and critical systems above the SLR-DFE.

Upgrade heating to high-efficiency mini-split heat pump system with equipment located outside and above the SLR-DFE.

Incremental Strategy

Floodproofing the basement and moving critical systems out of sub-grade space are priority short- and medium- term measures.

Building Systems

Protect Critical Systems

Relocate equipment from sub-grade space.

Backup Systems

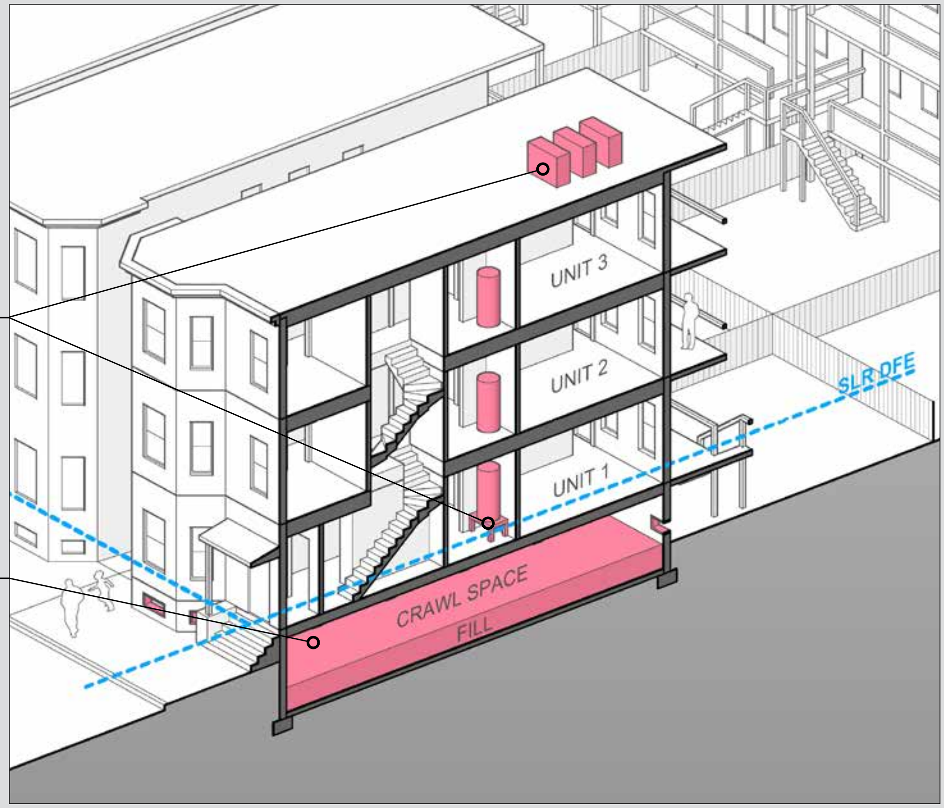
Provide interior drainage system (sump pump and emergency power source). Install backwater preventers.

Wet Floodproofing

Fill the basement slab to the rear yard grade, and provide flood vents at basement windows.

Use flood-damage-resistant materials below SLR-DFE.

When filling basement, consider structure and envelope to prevent wicking of moisture up into building after flooding.



Short-term Strategy

In the interim, it is important to provide component protection and back-up drainage if equipment cannot be moved out of the basement in the short-term.

Building Systems

Protect Critical Systems

Elevate water heaters and heating equipment as high as possible, and create dry floodproofed component protection around the equipment.

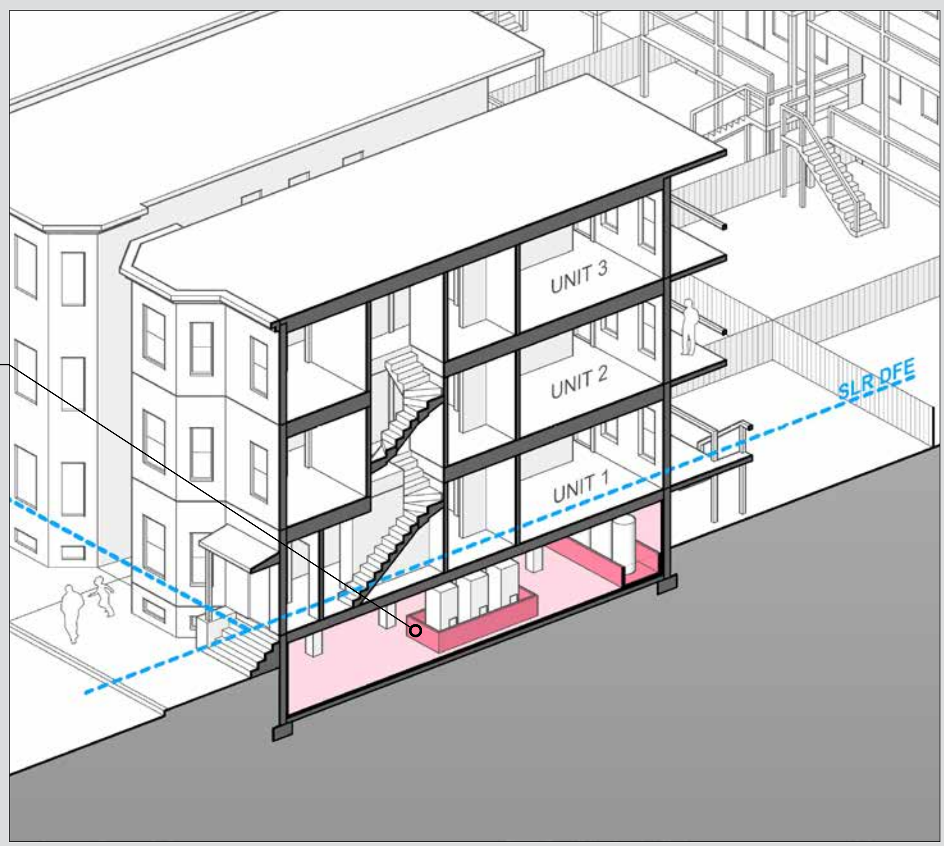
Backup Systems

Provide interior drainage system (sump pump and emergency power source) and install backflow preventers.

Building Envelope and Access

Flood-Damage-Resistant Materials

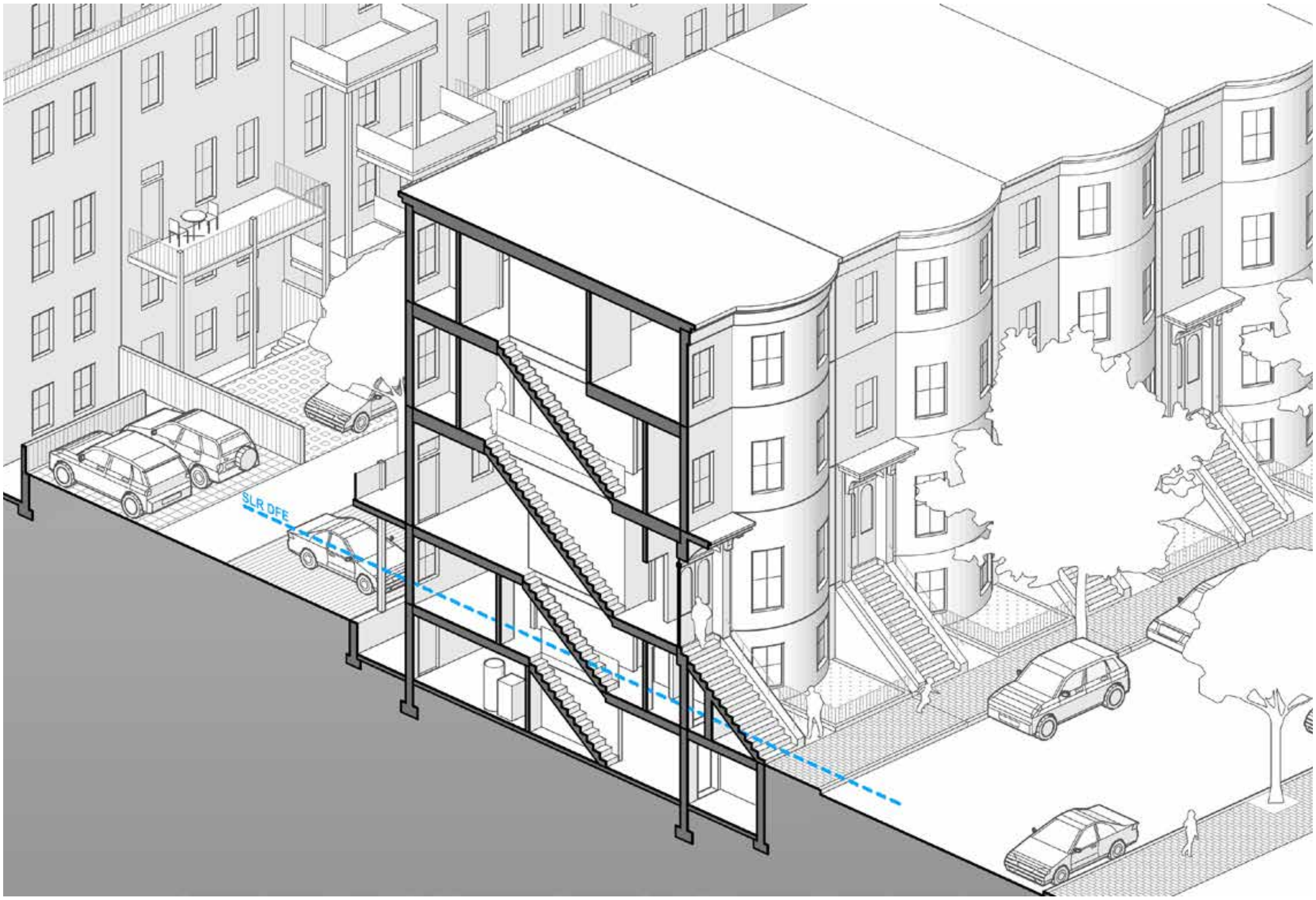
Use flood-damage-resistant materials below SLR-DFE.



Attached Townhouse

Existing Conditions

Commonly found in the South End, attached townhouses typically have solid masonry exterior and demising walls supporting wood framed floors and roofs. Bay windows and raised stoops commonly face the sidewalk, and the rear yard is often at a significantly lower elevation than the front.



Case Study Location

Sea Level Rise Conditions

SLR-BFE	17.90' BCB
SLR-DFE	18.90' BCB
FEMA BFE	N/A

Other Neighborhoods

East Boston, Charlestown

Building Characteristics

Grade elevation	approx. 16.5' BCB
Lowest occupiable floor	approx. 16.5' BCB
Cellar elevation	approx. 8.0' BCB
Critical systems location	Basement
Construction type	Brick masonry
Year built	Mid-1800s
Stories	4 stories with basement
Units	1
Sidewalk width	8'–10'
Zoning district	MFR

Long-term Strategy

Building Envelope and Access

Relocate Ground Floor Use

Abandon basement and ground floor. Fill basement to the lowest adjacent grade. Eliminate any habitable spaces below SLR-DFE and convert ground floor use to storage and access.

Recuperate lost FAR at roof addition. Addition designs should be contextually sensitive per landmark district design standards and criteria.

Building Systems

Protect Critical Systems

Locate water heater and critical systems above the SLR-DFE.

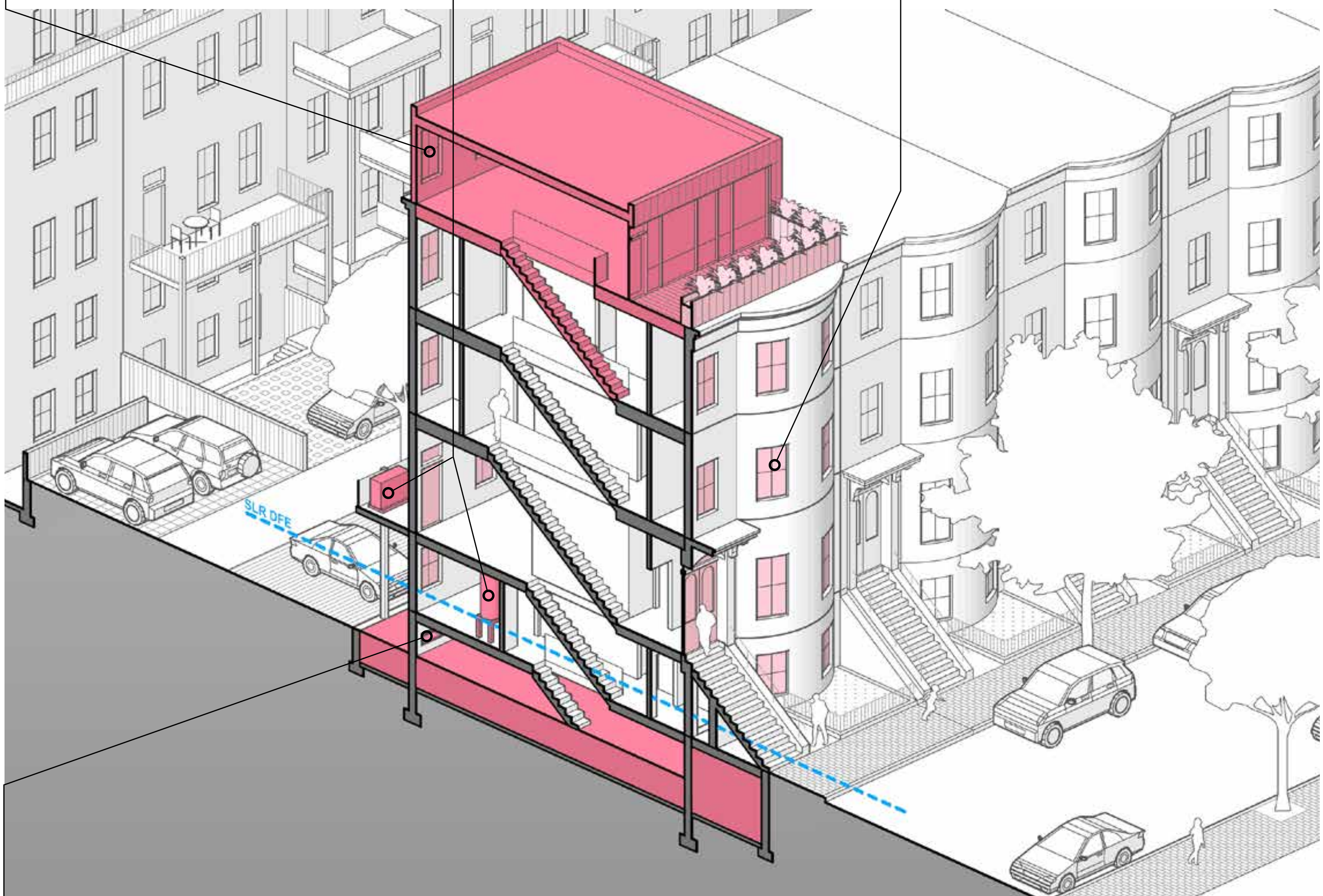
Evaluate life of systems and upgrade where possible. Consider upgrading heating to high-efficiency mini-split heat pump system with equipment mounted outside and above the SLR-DFE.

Supporting Strategy

Enhanced Envelope

Conduct energy audit and blower door test. Air-seal at windows, doors, and penetrations.

Upgrade windows to historically sensitive low-e, low-U-factor units.



Building Adaptation

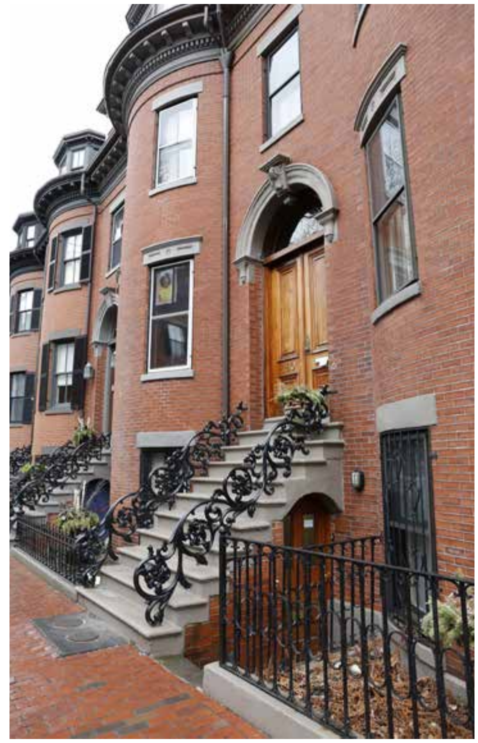
Wet Floodproofing

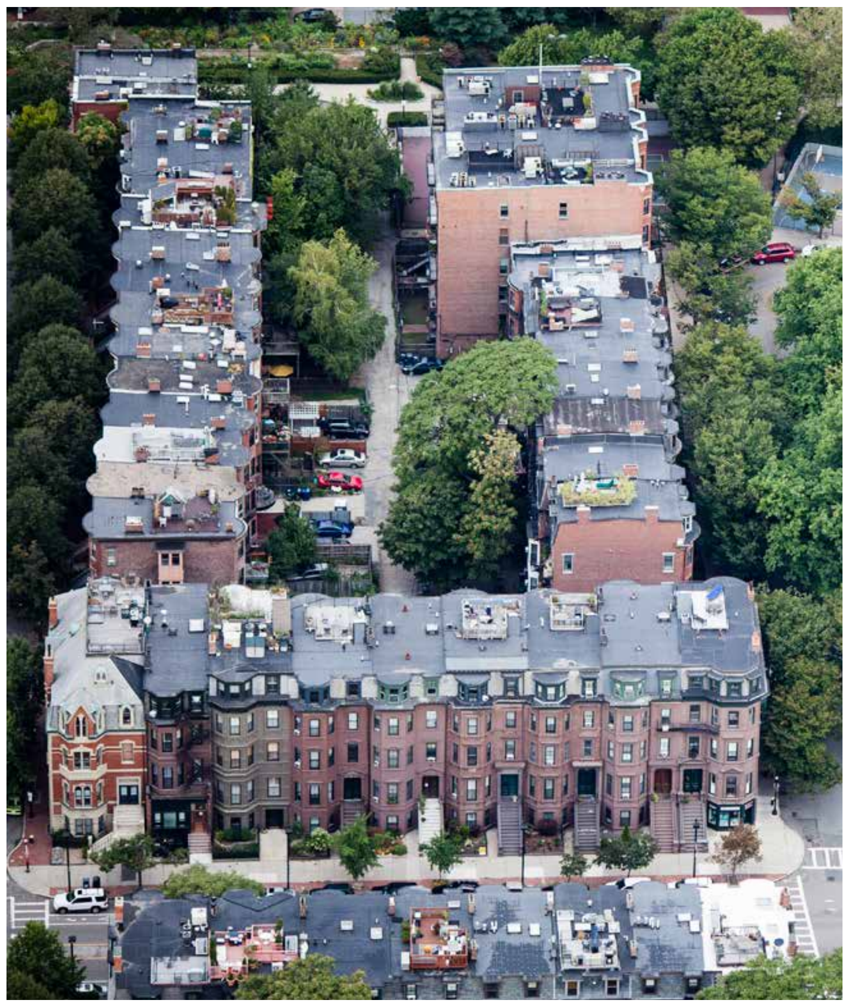
After filling basement to the lowest adjacent grade, install flood vents at basement walls in order for water to enter and balance hydrostatic forces. Vents should be installed on at least 2 different walls.

Use saltwater-damage-resistant materials below SLR-DFE.

When filling basement, consider structure and envelope to prevent wicking of moisture up into building.

View from the street





Above photo: Landslides Aerial Photography / Alex MacLean

Incremental Strategy

Elevating critical systems out of the basement is a **priority** short-term measure to prevent damage, before larger and more expensive retrofits are undertaken.

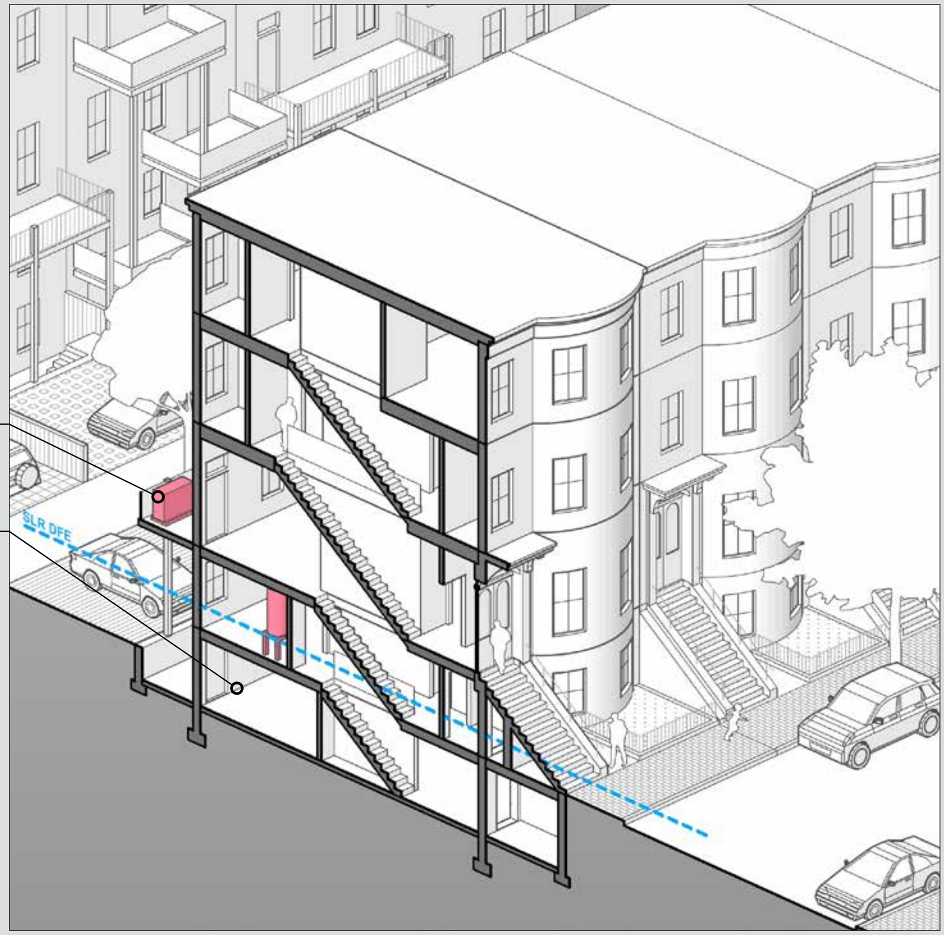
Building Systems

Protect Critical Systems

Relocate equipment from sub-grade space.

Backup Systems

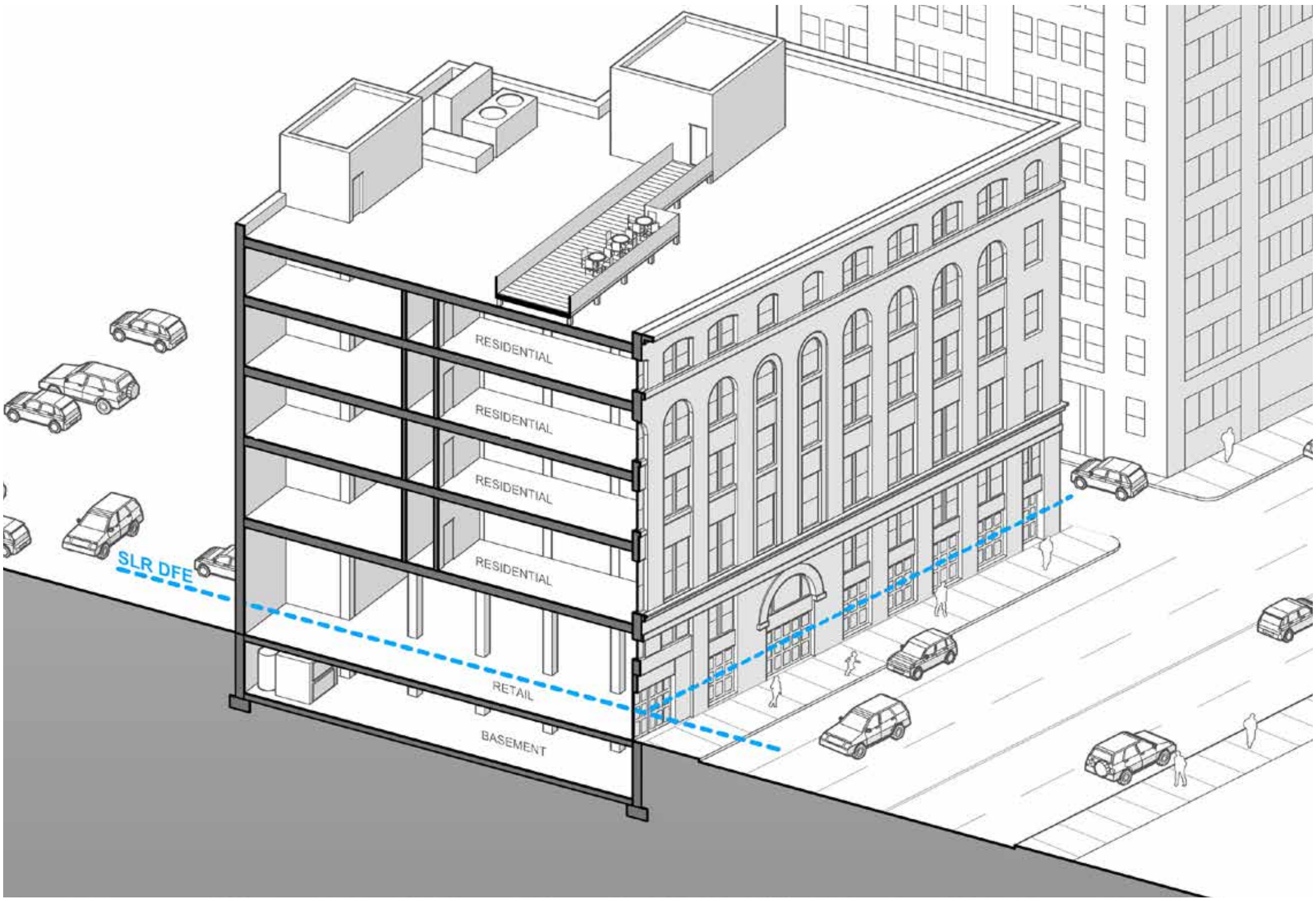
Provide interior drainage system (sump pump and emergency power source). Install backwater valve(s) or flow preventer(s).



Pre-war Mixed-use

Existing Conditions

Pre-war mixed use buildings are historic multi-story structures commonly found in Downtown, Fort Point, North End and the South End. While structural systems vary, they typically include solid masonry walls with heavy timber post and beam framing or concrete slab and post construction. Ground floor levels often have high ceilings, making it feasible to accommodate resilience adaptations require greater floor-to-floor height on the first floor.



Case Study Location

Sea Level Rise Conditions

SLR-BFE	19.50' BCB
SLR-DFE	20.50' BCB
FEMA BFE	16.46' BCB

Other Neighborhoods

South Boston, Downtown, Charlestown

Building Characteristics

Grade elevation	approx. 15.00' BCB
Lowest occupiable floor	approx. 15.00' BCB
Cellar elevation	Unknown
Critical systems location	Basement / Roof
Construction type	Brick masonry, timber
Year built	Late 19th–early 20th century
Stories	5
Units	45
Sidewalk width	10'
Zoning district	South Boston M-4

Long-term Strategy

Strategies not pictured:
Emergency power
Renewable energy systems
Resilient elevators

Building Systems

Protect Critical Systems

Locate systems for ground floor retail above SLR-DFE.

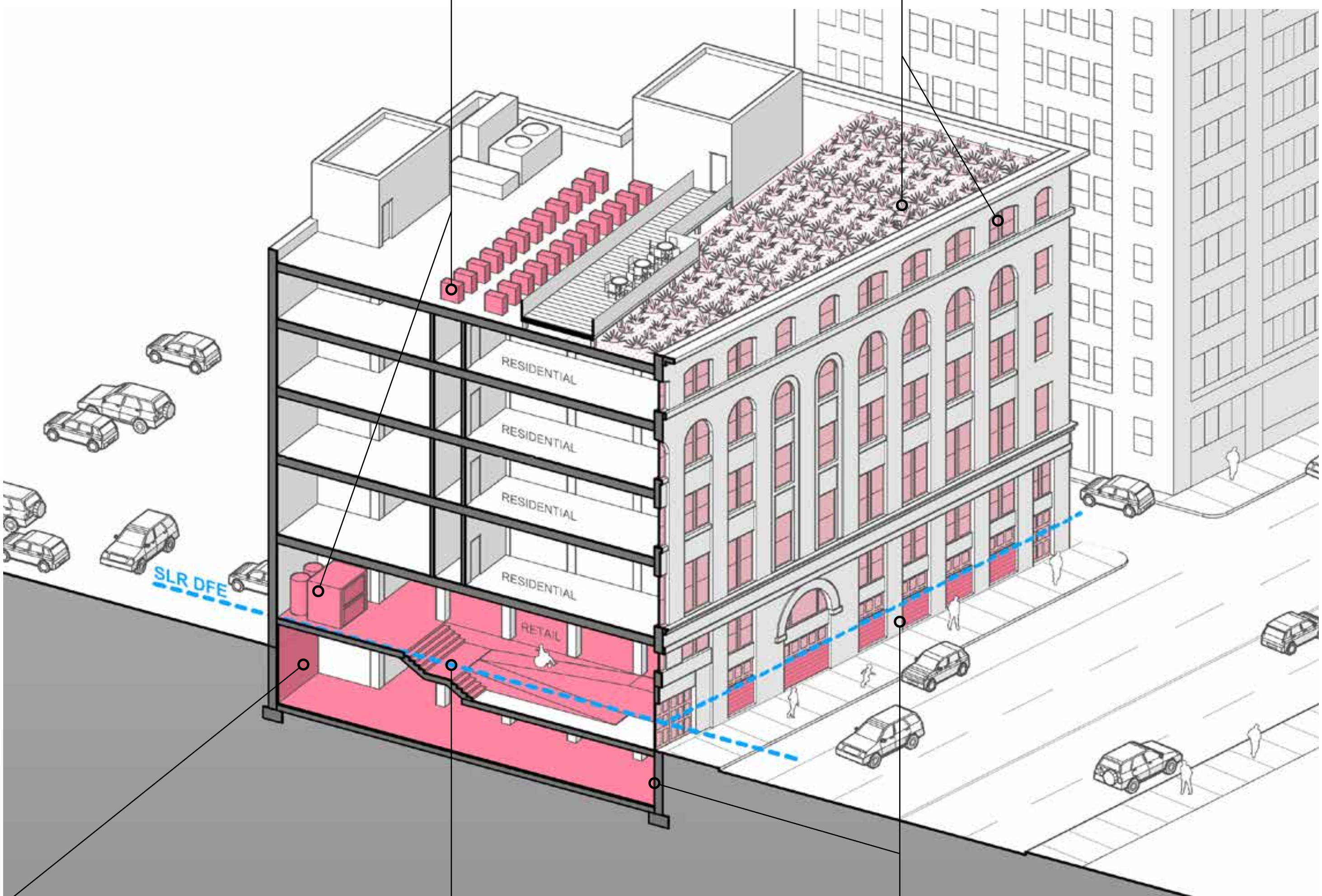
Upgrade residential space conditioning to systems that can be elevated out of basement, such as unitized variable refrigerant flow (VRF) system with energy-recovery ventilation.

Supporting Strategy

Enhanced Envelope

Conduct energy audit and blower door test. Air-seal at windows, doors, and penetrations.

Add roof insulation outboard of deck and use high-albedo or green roofing (shown) to mitigate urban heat islands. Upgrade windows to historically sensitive low-e, low-U-factor units.



Building Systems

Backup Systems

Protect sub-grade areas from the backflow of municipal wastewater by installing backwater valve(s) or flow preventer(s).

Building Envelope and Access

Elevate Lowest Interior Floor + Provide Interior Circulation to DFE

Ramps and stairs mediate an at-grade entry area with an elevated main floor. High ceilings in the existing ground floor can accommodate this adaptation.

Building Envelope and Access

Dry floodproofing

Install historically sensitive brackets for temporary shields at windows and doors below the SLR-DFE.

Parge and structurally reinforce stone foundation to resist hydrostatic forces. Historic and older buildings may require fortifying or replacing materials designed to breath and flex.

Install sump pumps for backup drainage.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Short-term Strategy

Floodproofing the basement and protecting the components of critical systems are priority short-term measures.

Building Envelope and Access

Dry Floodproofing

Protect openings before a storm with portable deployable shields or fencing. Maintain egress at doors.

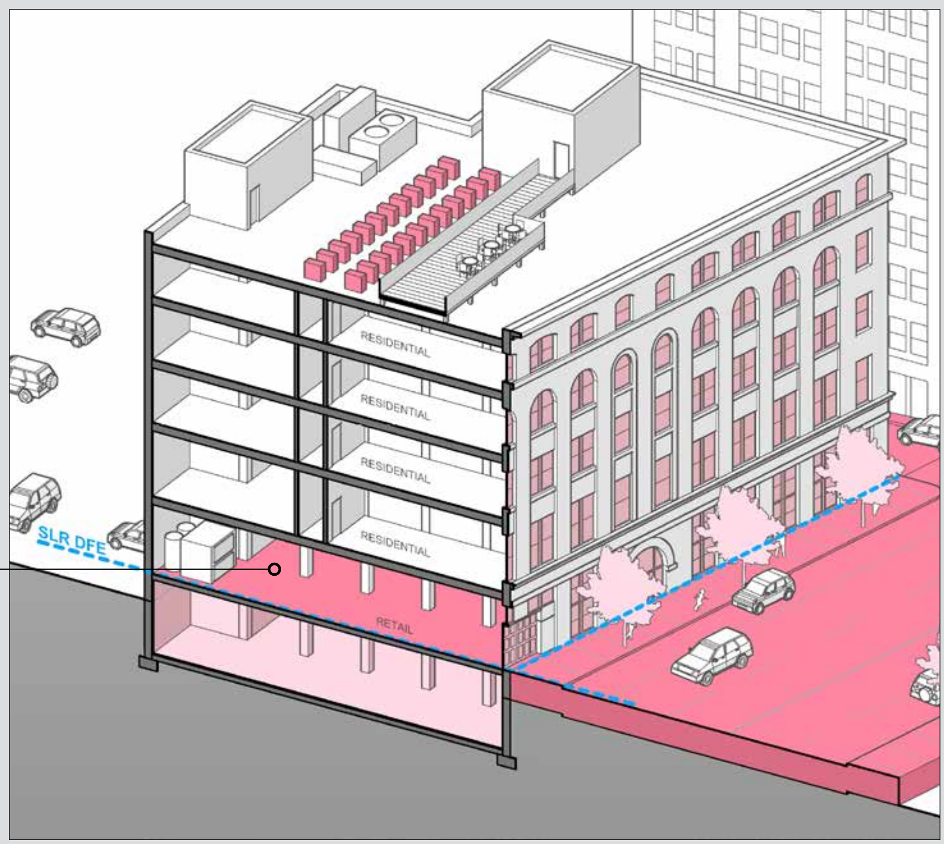
Building Systems

Protect Critical Systems

Encase the base of critical systems to protect from minor floods.

Relationship to Future District-scale Adaption

Should the public realm be elevated as part of a future district-scale adaptation, the ground floor of the existing structure can be elevated to meet a higher future grade.



Building Envelope and Access

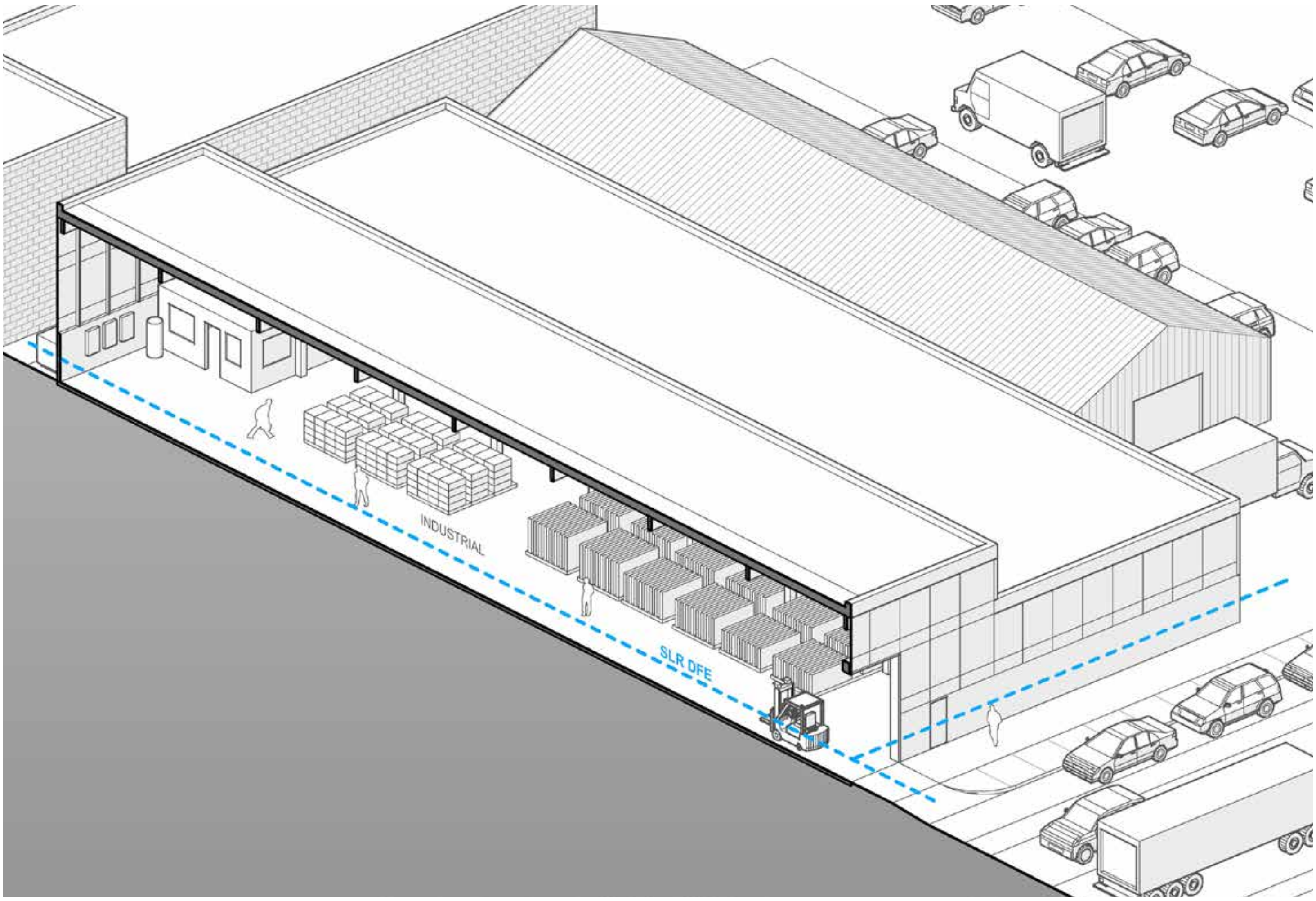
Elevate Lowest Interior Floor

Prepare for future district-scale adaptations by elevating ground floor slab to meet raised sidewalks and roads.

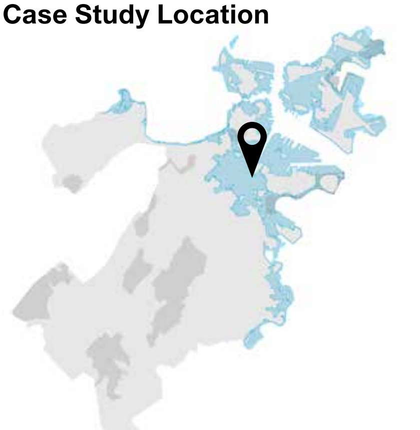
General Industrial

Existing Conditions

This type is prevalent in parts of South Boston and Dorchester, as well as some waterfront areas of Charlestown and East Boston. They are one to two stories in height. Some examples may have elevated loading docks and ground floors, which make them easier to adapt to the SLR-DFE.



Case Study Location



Sea Level Rise Conditions

SLR-BFE	18.00' BCB
SLR-DFE	19.00' BCB
FEMA BFE	N/A

Other Neighborhoods

Dorchester, South Boston

Building Characteristics

Grade elevation	approx. 15.58' BCB
Lowest occupiable floor	approx. 15.58' BCB
Cellar elevation	N/A
Critical systems location	Ground floor
Construction type	Steel
Year built	Unknown
Stories	1 + Mezzanine
Units	N/A
Sidewalk width	8'
Zoning district	General Industrial

Long-term Strategy

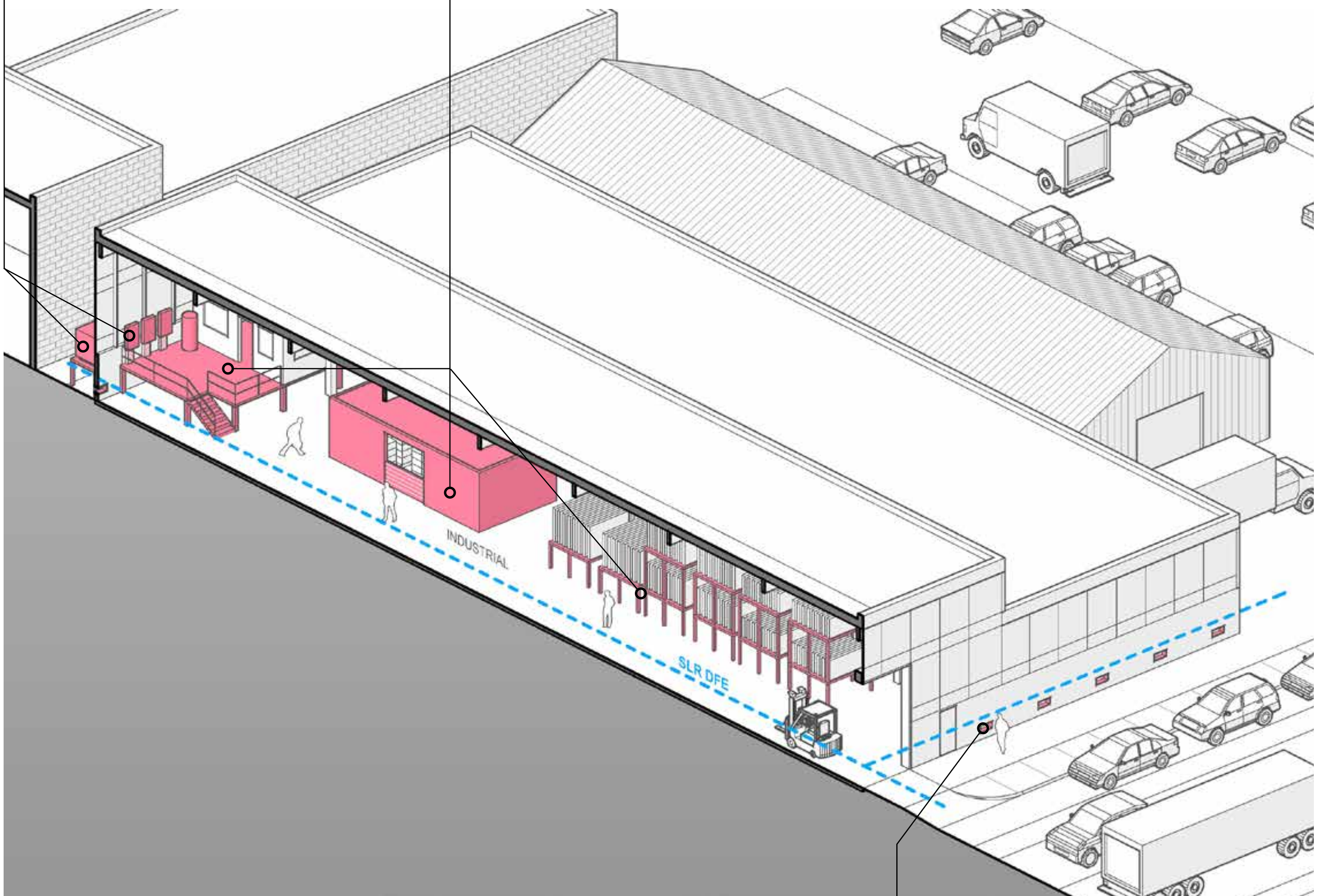
Building Systems

Protect Critical Systems

Locate critical systems above the SLR-DFE. This includes elevating exterior generators or sub-stations onto concrete pads or platforms, elevating electrical panels, and raising mechanical systems. Where space is limited, considering elevating systems onto roofs.

Protect sensitive content inside potentially environment-controlled dry floodproof room with floodgates. Protect general content with elevated storage racks and shelving.

Elevate work stations onto raised platforms or mezzanines to reduce flood damage and help restore operations more quickly.



Building Envelope and Access

Wet Floodproofing

Install flood vents at basement walls in order for water to enter and balance hydrostatic forces.

Use water-damage-resistant materials below the SLR-DFE.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Incremental Strategy

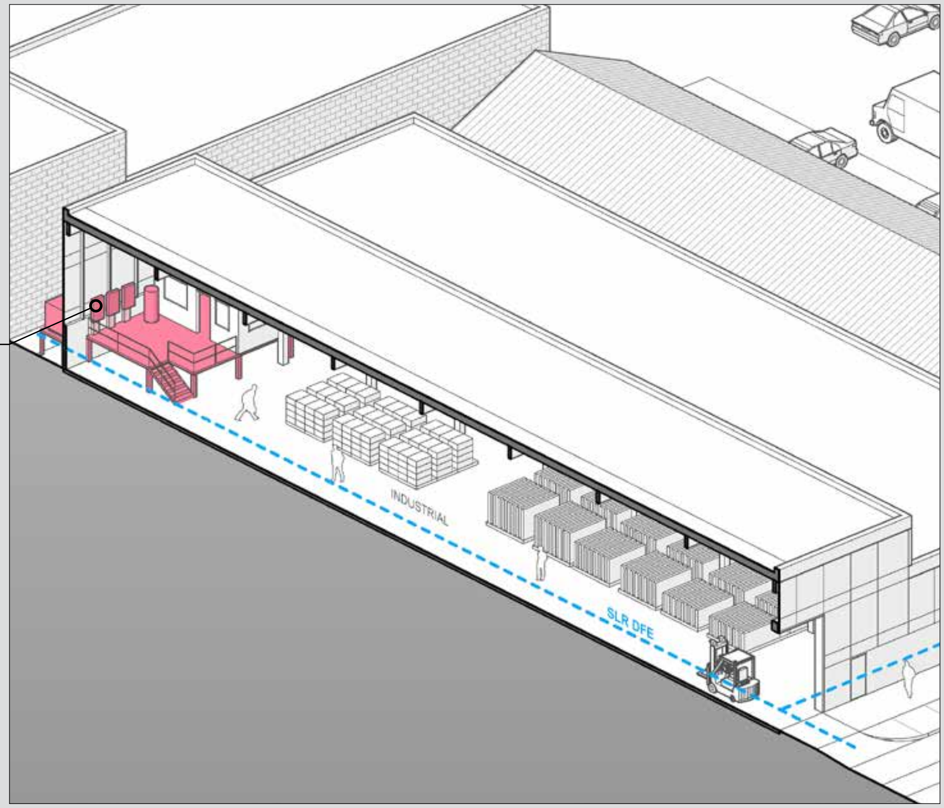
Protecting the critical systems and work stations are priority short-term flood resilience measures.

Building Systems

Protect Critical Systems

Locate critical systems above SLR-DFE including generators, electric panels, boilers, and other mechanical systems.

Elevate work stations onto raised platforms or mezzanines to reduce flood damage and help businesses restore operations quickly.



Alternate Long-term Strategy

While typically more expensive than wet floodproofing, dry floodproofing is an alternative strategy that can protect the building and its contents.

Building Systems

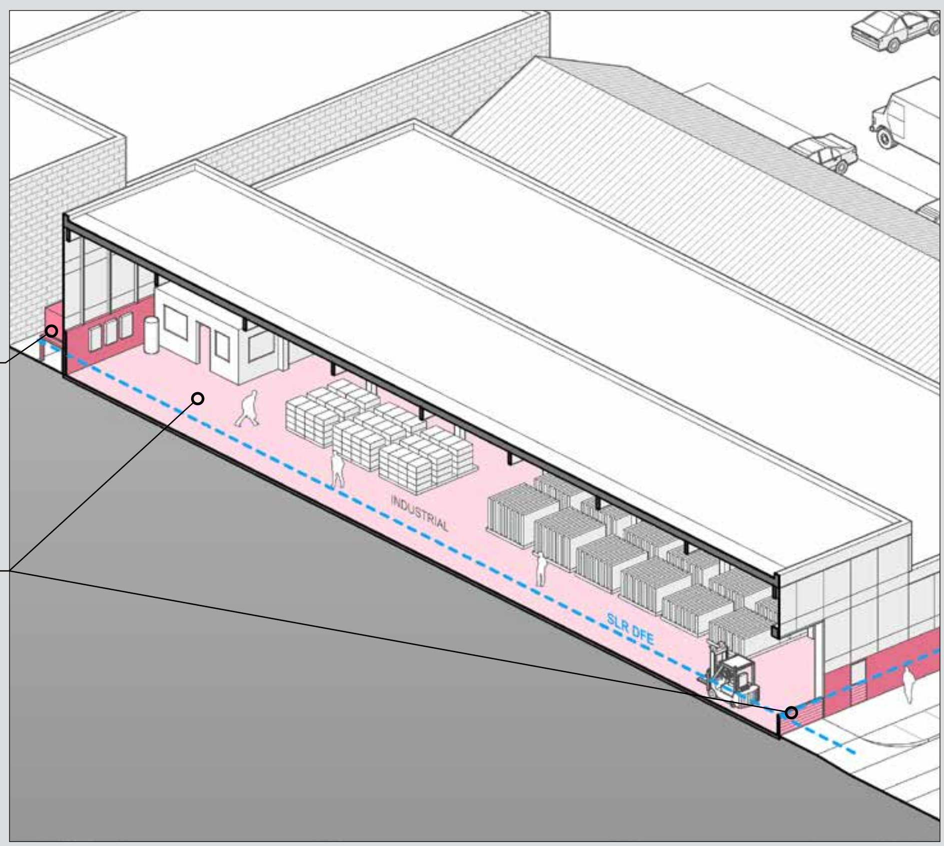
Protect Critical Systems

Place exterior mechanical systems (generator, sub-stations) on concrete pads or platforms.

Building Envelope and Access

Dry Floodproofing

Install floodshields and barriers at exterior walls and openings, reinforce wall structures to withstand hydrostatic pressure, seal all cracks in walls and flooring, and provide sump pumps to drain any incidental flood leaks.



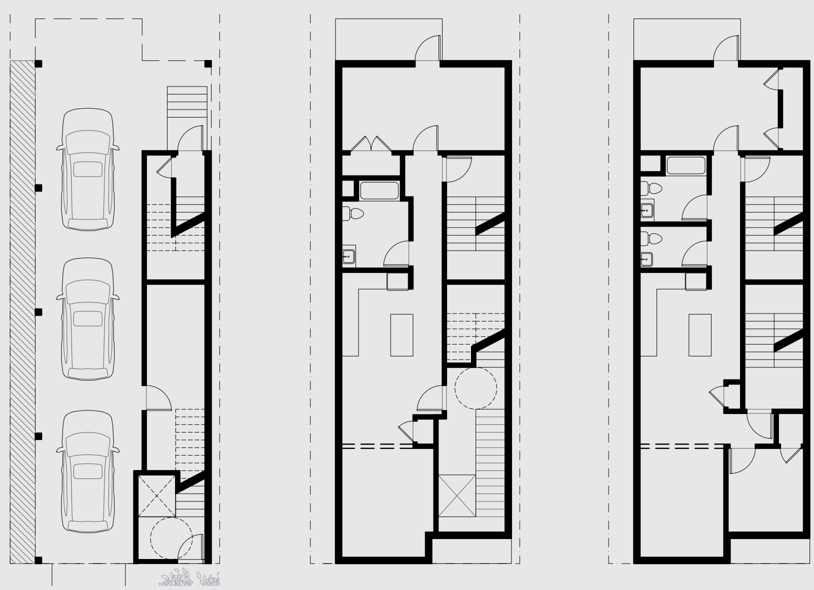
Three-family Residential

New Construction

Sea Level Rise Conditions

SLR-BFE	18.00’ BCB
SLR-DFE	19.00’ BCB
FEMA BFE	N/A

Conceptual Floor Plans



Ground floor
(below SLR-DFE)

First residential floor
(above SLR-DFE)

Second and third residential floors

Resilient Design Strategy

Supporting Strategy

Enhanced Envelope

Provide sun shading on southerly facing windows to reduce heat gains. Provide continuous exterior insulation and high-performance windows.

Supporting Strategy

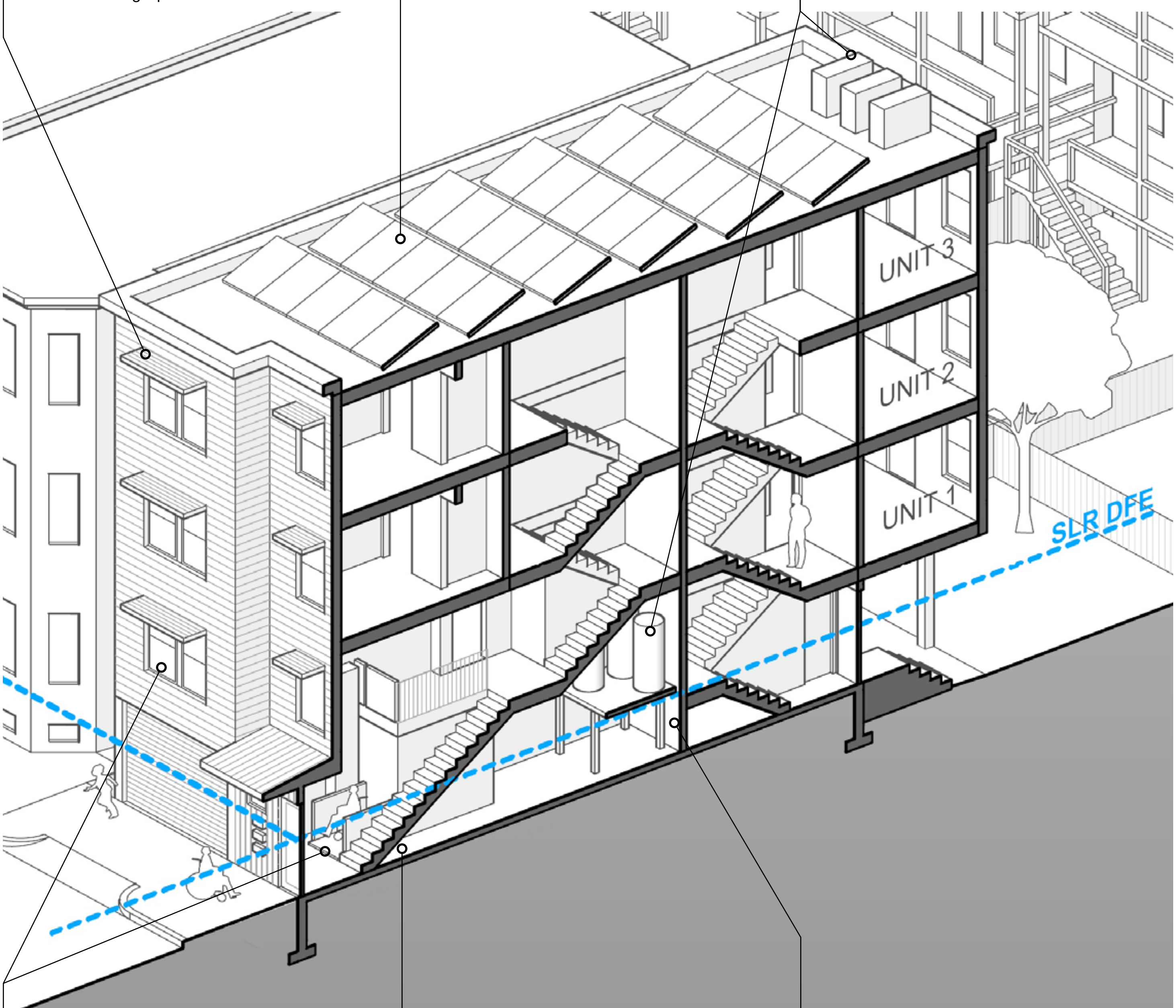
On-Site Energy Generation

Install islandable, grid-connected solar PV system on the roof.

Building Systems

Protect Critical Systems

Heating, cooling, water heating, and electrical systems are elevated above the SLR-DFE.



Building Adaptation and Access

Elevate Lowest Interior Floor + Provide Interior Circulation to DFE

The lowest residential floor is elevated above the SLR-DFE.

Access is provided by an internal stair and wheelchair lift.

Building Form

Elevate Building on Fill

The ground floor is designed as a slab on grade, with the excavated area filled in to structurally resist site-specific design flood loads and protected from scour and erosion.

The at-grade lower floor is used only for access, parking, and storage.

Building Envelope and Access

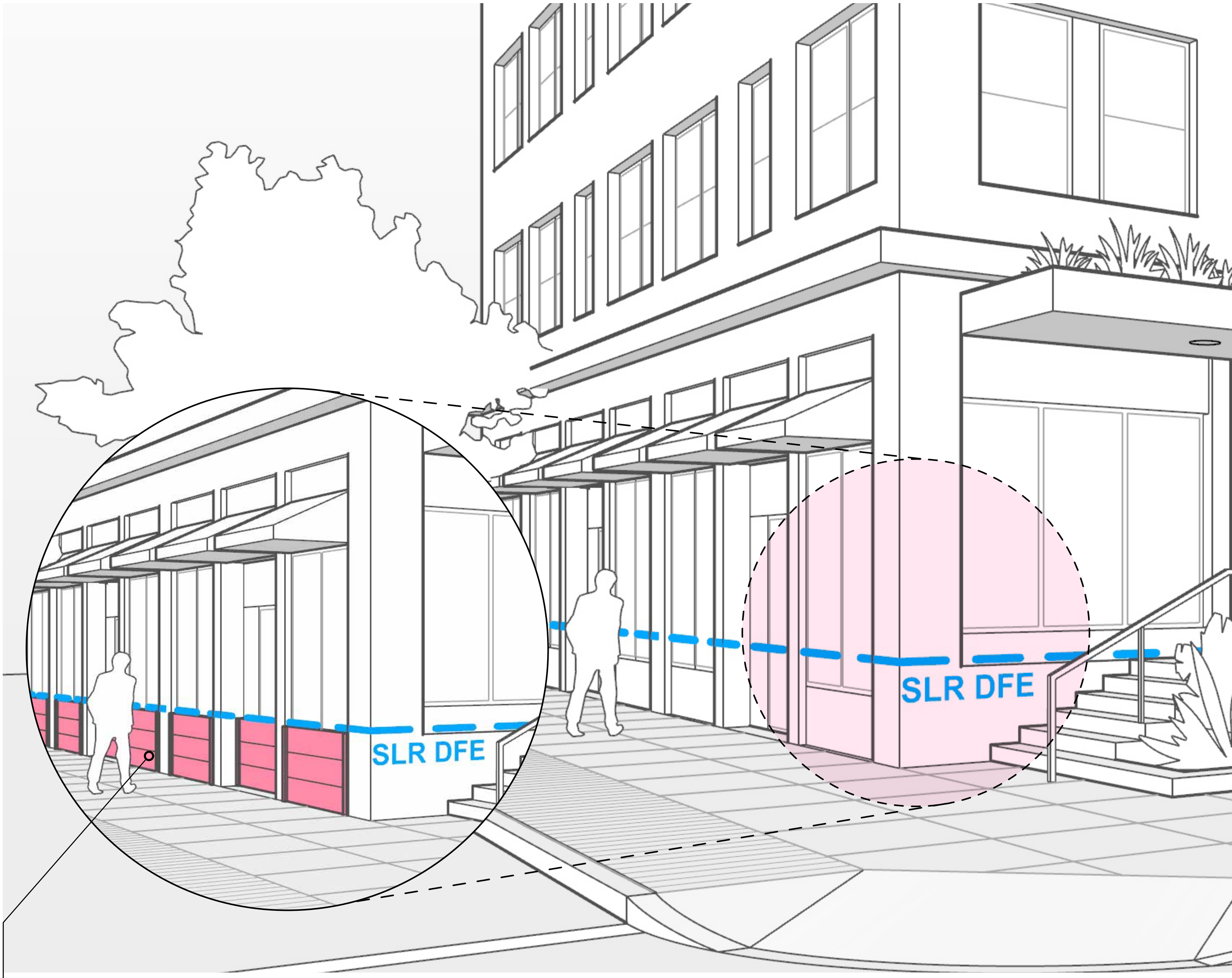
Wet Floodproofing

Ground level parking, storage, and access area is wet floodproofed to allow flood waters to enter and exit, equalizing hydrostatic pressure on either side of the structure. Flood vents are not shown.

Saltwater-damage-resistant materials are used below SLR-DFE.

Multi-family Mixed-use

New Construction



Resilient Design Strategy

Building Envelope and Access

Dry Floodproofing

Retail is kept at grade for sidewalk activation. During storm events, storefront doors are fitted with flood shields into built-in brackets. Retail space must be vacated prior to storm event. Walls, glazing supports, and building structure must be engineered to withstand hydrostatic pressure from floodwaters.

Building Envelope and Access

Wet Floodproofing

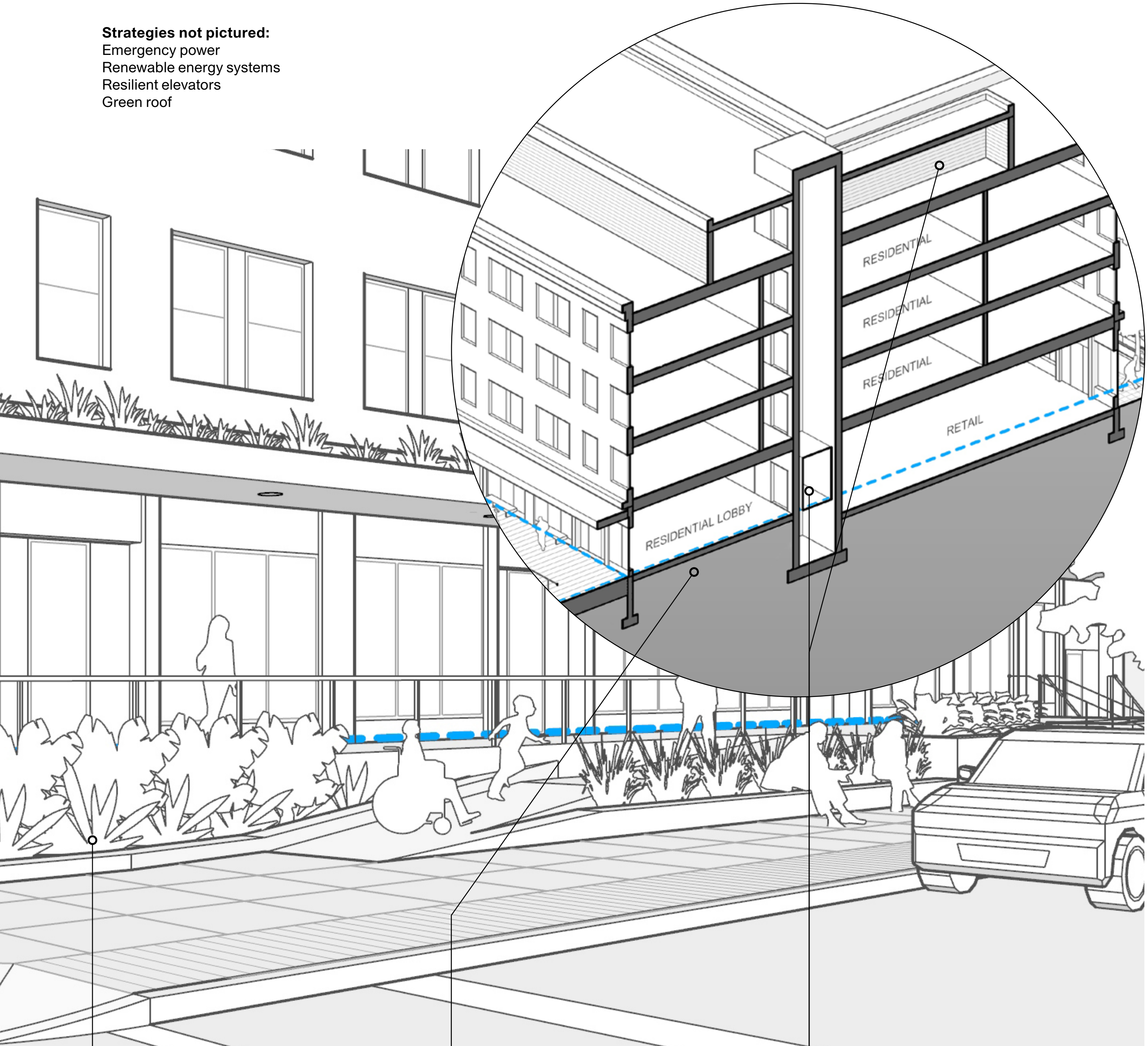
Residential access doors have flood vents and wet floodproofed lobby has saltwater-resistant materials. Access door and flood vents not shown.

Supporting Strategy

Enhanced Envelope

Exterior insulation and high performance windows allow interior spaces to maintain interior temperatures despite loss of heating during a power outage.

Strategies not pictured:
Emergency power
Renewable energy systems
Resilient elevators
Green roof



Building Adaptation and Access

Elevate Lowest Interior Floor + Provide Exterior Circulation to DFE

Front facade is set back to allow for elevated walkways, accessible ramps, and stairs. Planters soften the transition between elevated hardscape and sidewalk, contributing to an improved public realm experience.

Building Form

Elevate Building on Fill

Elevate residential lobby on structural fill above SLR-DFE. The fill must be compacted and designed to resist scour and erosion.

Podium construction of first floor is separate from upper levels.

Building Systems

Protect Critical Systems

Locate critical systems and backup power generator in mechanical penthouse.

Resilient Elevators

Locate electrical controls and hydraulic pumps above the SLR-DFE. Use NEMA Type 4-rated enclosure for any electrical equipment that must be installed below the SLR-DFE.

Appendix

Pleasure Bay. *Photo: Landslides Aerial Photography / Alex MacLean*

Resilience Resources

To find your property relative to the 1 percent annual chance of flooding in 2070 floodplain:

Turn on the "SLR-BFE" layer from the layer panel on the Boston Zoning Viewer
http://maps.bostonredevelopmentauthority.org/zoningviewer/

To learn more about the City's on-going efforts to make Boston more resilient please see these documents:

Climate Ready Boston
https://www.boston.gov/departments/environment/climate-ready-boston

Resilient Boston Harbor
https://www.boston.gov/departments/environment/resilient-boston-harbor

Climate Ready Boston Map Explorer
https://www.boston.gov/departments/environment/climate-ready-boston-map-explorer

Other reports and resources mentioned in this document:

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NYC Mayor's Office of Recovery and Resiliency. 2019. "Climate Resiliency Design Guidelines". https://www1.nyc.gov/assets/orr/pdf/NYC_Climate_Resiliency_Design_Guidelines_v3-0.pdf.

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