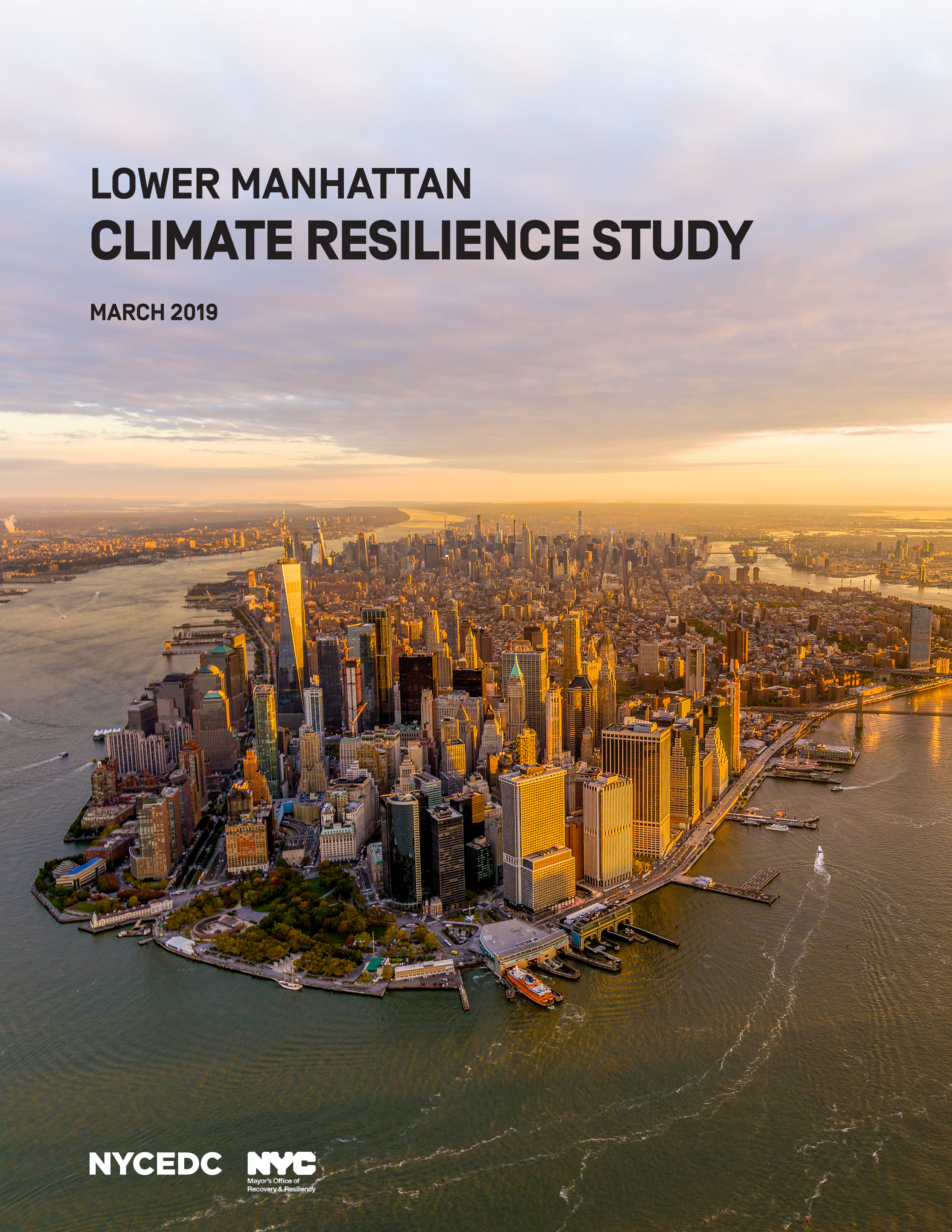
LOWER MANHATTAN
CLIMATE RESILIENCE STUDY

MARCH 2019



NYCEDC
NYC Mayor's Office of Recovery & Resiliency

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PUBLIC OFFICES AND AGENCIES
Mayor's Office of Recovery and Resiliency (ORR)
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COMMUNITY STAKEHOLDERS
Community Board 1
Community Board 3

PRIMARY PROJECT CONSULTANTS
AECOM
HR&A Advisors
Bjarke Ingels Group
One Architecture
James Lima Planning + Development

PHOTOGRAPHY
Zoran Photography (Front Cover)
Julienne Schaer (Page 53)

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CHAPTER 1

INTRODUCTION

STUDY BACKGROUND AND PURPOSE

New York City, like many other cities around the world, is facing the complex reality of climate change and its severe impacts on the urban environment.

In October 2012, Hurricane Sandy hit New York City, flooding 17% of the city's land, claiming 44 lives, and causing $19 billion in damages and lost economic activity. Storm surge reached a record 14 feet high in New York Harbor, and the hurricane caused power outages across the city that impacted over 2 million New Yorkers, some lasting for weeks or longer. In Lower Manhattan (the "District"), the impact of Hurricane Sandy was extreme, causing two deaths and affecting thousands of homes.

For over 400 years, the historic identity of New York City has been rooted in Lower Manhattan. Serving for generations as a doorstep for immigrants through Ellis Island and Castle Clinton, in more recent decades the District has also transformed into a global economic and financial capital. Representing over 10% of all New York City jobs, this District holds immense importance to the city and regional economies. Wall Street was closed for two days after Hurricane Sandy, completely suspending trading at the two largest stock exchanges in the world by market capitalization, the New York Stock Exchange and NASDAQ. The impacts of Hurricane Sandy underscored not only Lower Manhattan's value as an economic, civic, and cultural heart of New York City, but also its particular vulnerability and exposure to climate change. Any impacts of climate change to Lower Manhattan will likely be felt across the city and beyond.

Hurricane Sandy is the most significant experience of a climate change-related disaster in New Yorkers' collective memory. Out of the catastrophe came a citywide energy and focus on climate change, with collaborative efforts across communities, boroughs, and levels of government to envision and plan for New York City's future. This renewed focus after Sandy produced several studies and initiatives that were foundational to the Lower Manhattan Climate Resilience Study, including the New York City Special Initiative for Rebuilding and Resiliency (SIRR), NY Rising Community Reconstruction Program through the Governor's Office of Storm Recovery, the federal Rebuild by Design competition, Mayor Bill de Blasio's OneNYC Plan, and the Southern Manhattan Coastal Protection Study.

In the six years since Hurricane Sandy, the District has continued to show its ability to not only recover from disaster, but also learn from it and thrive thereafter. Billions of dollars in investments across the city from public agencies and regulated utilities have contributed significantly to the climate resilience of the District. ConEd's Storm Hardening Plan, the MTA's Fix and Fortify Program, and Verizon's efforts to replace copper cables with fiber-optic cables that are fully water-resistant, are all underway to protect the functioning of the power grid, subway system, and telecommunications in the event of future storms. The Governor's Office of Storm Recovery has administered hundreds of millions of dollars in federal funding to assist the recovery of communities across the state, including this one, through its NY Rising program. Private actors, including many building owners in the Financial District, have also implemented protective measures in individual buildings. The Lower Manhattan communities have been engaged in thoughtful climate planning for several years. Community Boards 1 and 3 have been deeply involved and invested in the development of near-term resilience measures, and the Battery Park City Authority are planning and designing several resilience projects.

As part of the Lower Manhattan Coastal Resiliency project, an integrated coastal protection initiative, this study was funded by both the City and the State through federal post-Sandy disaster appropriations. After Sandy, climate resilience initiatives and the investment of community stakeholders led New York City to successfully receive funds to mitigate coastal storm surge flood risks in Two Bridges through the federal National Disaster Resilience Competition. Although the rest of Lower Manhattan was not prioritized for funding from the federal government based on their criteria for post-Sandy recovery – targeting residential populations and low- and moderate income households – the City allocated $100 million of City capital to projects south of the Brooklyn Bridge (in the Community Board 1 district), as well as $8 million specifically to a project in the Battery.

In producing recommendations and guiding investments, the Lower Manhattan Climate Resilience Study followed these guiding objectives:

- **Identify the extent of climate hazards and exposure in Lower Manhattan in the 2050s and 2100;**
- **Assess options for adapting to climate threats over the long-term and maximize climate adaptation wherever possible to address a comprehensive set of climate hazard impacts;**
- **Support the creation and integration of urban co-benefits for Lower Manhattan, where possible, to serve the Lower Manhattan community;**
- **Establish a phased series of recommendations to maximize near- and long-term solutions and develop a long-term climate resilience strategy, informed by existing planning efforts and projects that are already underway.**

Major reports in 2018 have solidified the scientific consensus that, absent significant action, climate change will produce devastating global consequences at a faster rate than previously thought. In November 2018, thirteen federal agencies released a report projecting that climate change could reduce the United States' gross domestic product by up to 10% by 2100. The report asserts that the impacts of climate change – including extreme events like hurricanes and wildfires, heat waves, and droughts – are likely to impact economies and communities all across the country. Sea level rise is already accelerating the occurrence of daily tidal flooding in Atlantic and Gulf Coast cities. New York City is particularly vulnerable to sea level rise, with projections exceeding the global average.

One month prior to the US National Climate Assessment, the Intergovernmental Panel on Climate Change, a group of scientists convened by the United Nations, released a report finding that climate change would produce severe economic and humanitarian catastrophes at a lower threshold of global warming than previously predicted. If greenhouse gas emissions continue at the current rate, the atmosphere may reach 1.5°C of warming from preindustrial levels as early as 2040, triggering severe climate change impacts on a global scale. Limiting global warming to 1.5°C would require changes to the world's societal and economic systems at an unprecedented and transformational scale. These most recent findings have only reinforced the urgency of this study's objectives and underscored the need to take action for the climate resilience of Lower Manhattan.

This Lower Manhattan Climate Resilience Study builds on past efforts and leadership by the Lower Manhattan communities and the City after Hurricane Sandy, and lays the path forward for the next phase of climate resilience planning for Lower Manhattan's future.

STUDY PROCESS AND STRUCTURE

Our study was conducted in three phases: first, collecting information on present day Lower Manhattan; second, identifying the threat that climate change poses to Lower Manhattan in the future; and third, identifying and evaluating solutions for the climate hazards to which Lower Manhattan is exposed. Our findings are organized accordingly in the three following chapters. A glossary defining key terms is also included on pages 54-55.

CHAPTER 2: OVERVIEW OF LOWER MANHATTAN

- Studied existing conditions in the District as a whole and in the neighborhoods along the coastal edge of the study area, including market and land use trends, built environment, existing investments in resilience and infrastructure, social and demographic characteristics

CHAPTER 3: CLIMATE RISK ASSESSMENT

- Used latest climate science available from the New York City Panel on Climate Change (NPCC), with the most conservative projections, and conducted additional modeling of climate impacts to develop a comprehensive climate risk analysis of Lower Manhattan in the 2050s and 2100

CHAPTER 4: CLIMATE ADAPTATION TOOLKIT AND APPROACHES

- Assessed global precedents and best practices to assemble a set of adaptation tools that tackle different climate hazards, at different scales of implementation, with varying levels of risk reduction
- Grouped tools from the toolkit into approaches that achieve climate adaptation at different scales of implementation, from the individual building-level to the Districtwide-level
- Analyzed and evaluated approaches based on a set of criteria: technical difficulty, neighborhood considerations, sectoral responsibility, and potential co-benefits

KEY IMPACTS BY THE 2050S, OR WITHIN THE LIFETIME OF THE AVERAGE ADULT NEW YORKER:

- 100-year storm surge projected to put 37% of properties in the District with a combined assessed value of $13 billion (2018 dollars) at risk of damage
- Combined sewer system may be at high risk of overflowing and causing street flooding and backups into building basements in a 10-year rain event
- Heat waves projected to be 250% more frequent and 50% longer

KEY IMPACTS BY 2100, OR WITHIN THE LIFETIME OF A YOUNG NEW YORKER:

- 100-year storm surge projected to put almost 50% of the District's properties with a combined assessed value of nearly $14 billion (2018 dollars) at risk, including over two thirds of buildings that are landmarked or located in a historic district
- Over 10% of properties with a combined assessed value of $4 billion (2018 dollars) projected to be exposed to tidal inundation on a daily basis
- Over 150 of the District's older buildings projected to be at risk of destabilization due to groundwater table rise
- Nearly 40% of streets may have below-ground utilities exposed to groundwater table rise and its effects of corrosion, water infiltration, and other damage

STRATEGY FOR THE CLIMATE RESILIENCE OF LOWER MANHATTAN

With the findings of the study, the City has identified approximately $500 million worth of investments and developed an overall strategy for the climate resilience of Lower Manhattan. This strategy is discussed in full detail in Chapter 5. As part of this strategy, the City is making targeted, ambitious investments that will deliver significant climate adaptation for key neighborhoods of Lower Manhattan in the near future, while continuing to plan with innovation and flexibility for the threat of climate change to New York City's long-term future.

These investments include permanent infrastructure projects that the City is advancing in Two Bridges, the Battery, and Battery Park City. These interventions are critically important to the future of Lower Manhattan and represent strong climate protection and integration of public benefits for the District's residents and workers.

RESILIENCE STRATEGY PROJECTS

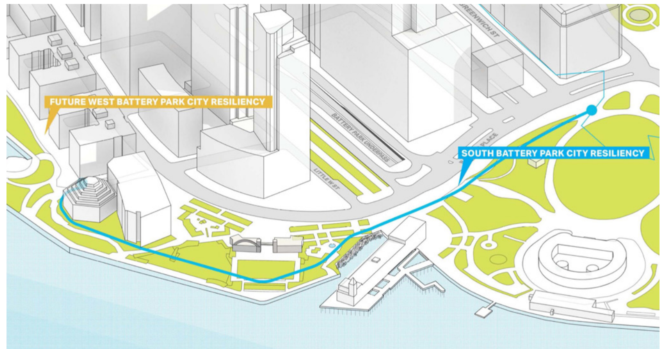
TWO BRIDGES COASTAL RESILIENCE

Climate Hazards: 100-year storm surge in the 2050s; extreme precipitation
Tools: Deployable Protection (Flip-up Barriers); Parallel Stormwater System
Status: EDC does final design, Department of Design and Construction (DDC) does construction

THE BATTERY COASTAL RESILIENCE

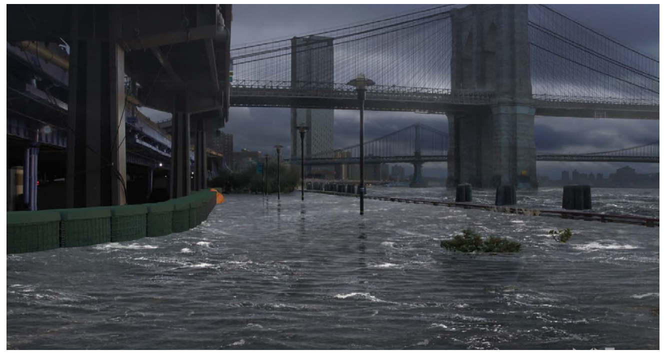
Climate Hazards: 100-year storm surge in the 2050s; tidal inundation; groundwater table rise
Tools: Raised Edge – Sea Level Rise (Elevated Esplanade); Raised Edge – Surge (Flood Wall or other intervention, subject to further design); Seepage Barrier
Status: EDC does design and construction of esplanade in coordination with Department of Parks and Recreation (DPR)

BATTERY PARK CITY RESILIENCE PROJECTS



Climate Hazards: 100-year storm surge in the 2050s
Tools: Deployable Protection; Raised Edge; Structure Hardening
Status: City approves bond financing for project, Battery Park City Authority (BPCA) does design and construction

INTERIM FLOOD PROTECTION MEASURES (IFPM)



Climate Hazards: Current 10-year storm surge
Tools: Deployable Protection (HESCO Barriers, Tiger Dams, other "just in time" deployables)
Status: NYC Emergency Management (EM) does design and implementation

THE FINANCIAL DISTRICT AND SEAPORT CLIMATE RESILIENCE MASTER PLAN

More intensive planning is needed to adapt the Financial District and South Street Seaport (the "Seaport"), which represent a unique convergence of high climate risk and few adaptation options. In these two neighborhoods with low-lying topography which requires higher interventions, the waterfront is highly constrained by existing infrastructure and buildings and therefore lacks the physical space needed to implement most large-scale adaptation projects. Complex circulation needs, transportation, active waterfront uses, and a large number of historic buildings all further exacerbate the complexity of planning and implementing solutions in these two neighborhoods. Due to the unique and varying set of physical constraints in this geography and 100-year storm surges of 9 to 16 feet in height projected in 2100, shoreline expansion, or new land creation, needs to be seriously evaluated and considered.

This study has identified a need for the City to initiate the Financial District and Seaport Climate Resilience Master Plan (the "Master Plan") to deeply examine the only option for protecting these two neighborhoods with the expansion of their shoreline. The Master Plan will consider a range of outboard options, varying in width and location. The Master Plan will also identify financing strategies to maximize the integration of public and private resources and identify critical funding sources for implementation, including study of opportunities for development to assist with financing. The City will determine a first phase project and establish a new public-benefit corporation to finance, construct, and manage it. The Financial District and Seaport Climate Resilience Master Plan will bring a targeted focus to closing the gap in climate protection for the District, and open a potential path forward for adaptation projects in other similarly challenging neighborhoods across the city.

With these investments in infrastructure and further planning, Lower Manhattan will be stronger and more resilient to the impacts of climate change for decades to come.

CHAPTER 2

OVERVIEW OF LOWER MANHATTAN

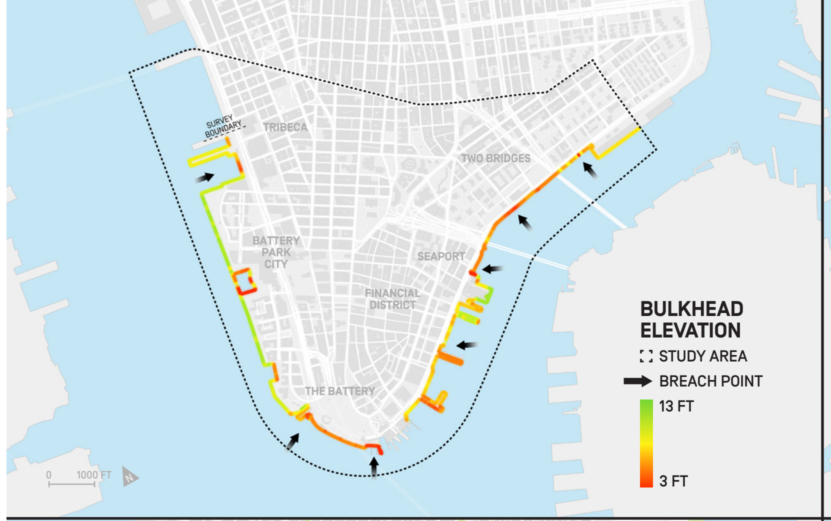
CURRENT CONDITIONS

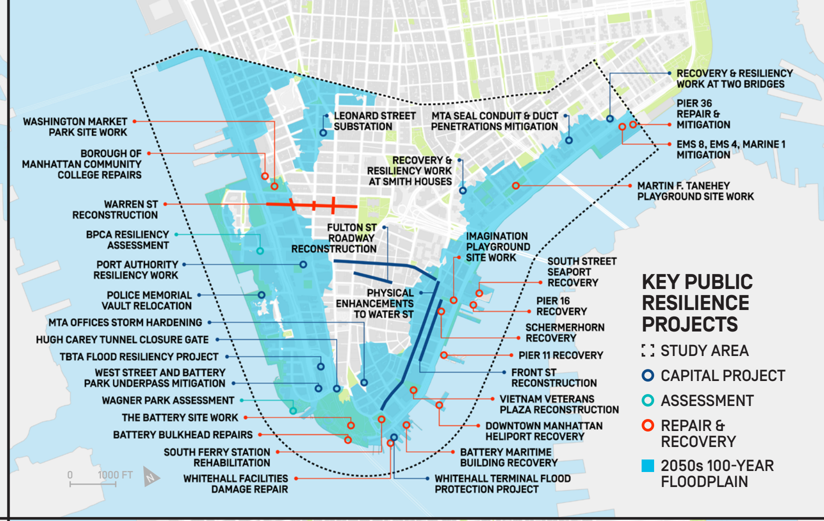
Because Lower Manhattan is a critical economic, cultural, and civic hub for New York City and the region, the impacts of climate change on Lower Manhattan will extend far beyond the District. A plan for action is needed to ensure that Lower Manhattan's vitality and growth continues in this century and into the next.

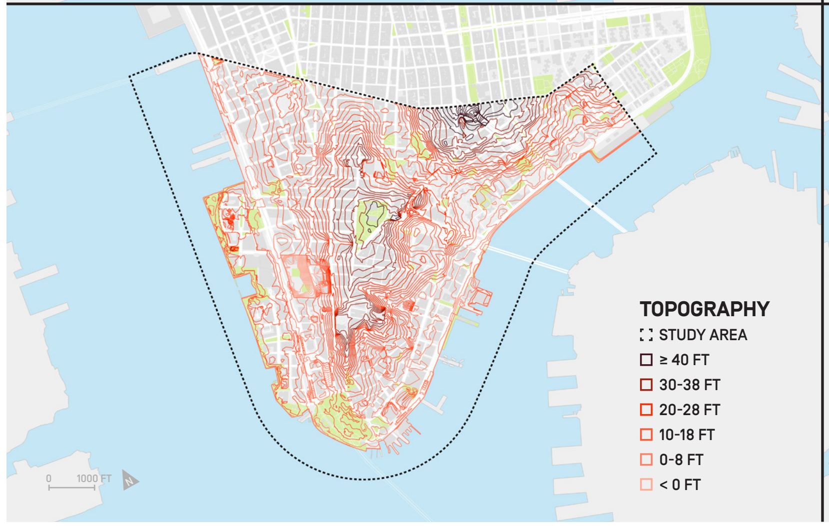
Lower Manhattan comprises less than 1% of the entire city's land area, but generates **almost 10% of the city's total economic output**, as measured by Gross City Product, and is the location of **over 10% of all New York City jobs**. Workers in Lower Manhattan come from all parts of the city. The District's growth is supported by excellent access to transit, with **19 out of 25 subway lines and 26 ferry lines** passing through the District. Any climate impacts in the District will reverberate across the city as a whole and beyond.

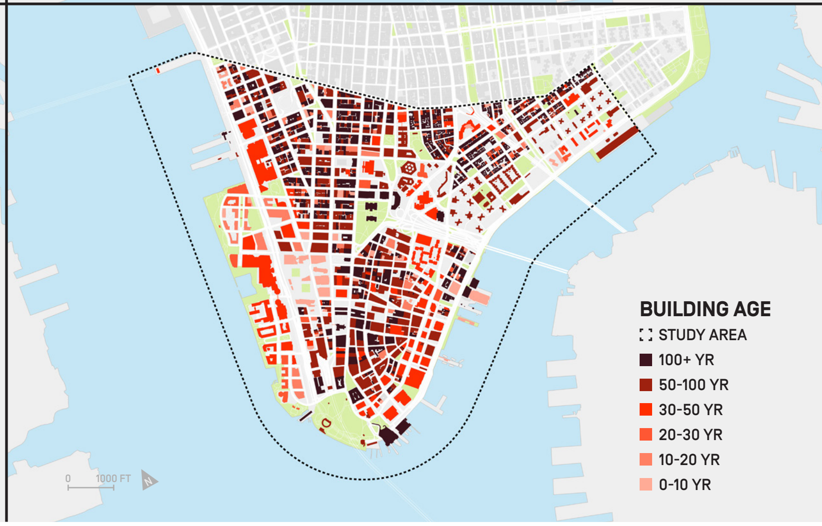
Although Lower Manhattan suffered greatly from the tragedy of 9/11, its recovery proved the District's strength, as it turned disaster into an opportunity to rebuild and prosper. Since 2001, over $20 billion of public and private investment has bolstered Lower Manhattan's transformation into a thriving, 24-hour live-work district. Major investments have been made in the District's transit assets and commercial real estate, including Fulton Center, Brookfield Place, and the World Trade Center. Hotel development has catalyzed tremendous growth in tourism in Lower Manhattan: in 2016, nearly 15 million tourists visited the District, a 19% increase over the previous year. Lower Manhattan is not only a successful central business district, but also a growing residential community, with a 129% increase in residents living below Chambers Street since 2000.

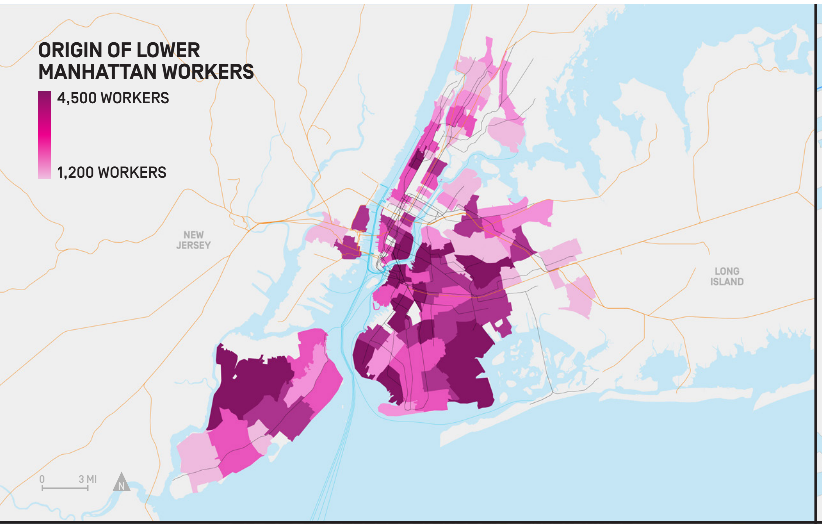
In 2012, Hurricane Sandy revealed just how vulnerable Lower Manhattan is to coastal storm surge events. Extensive coastal flooding affected nearly 400 buildings, including over 21,000 homes, and caused significant damage to transportation assets, power supply, open space, and water and sewer infrastructure in Lower Manhattan. The combined volume of stormwater and sewage during the hurricane overwhelmed the City's wastewater treatment system, causing 5.2 billion gallons of untreated or partially treated sewage to be discharged into the City's waterways. In addition, thousands of jobs in the District were lost due to Hurricane Sandy's direct, indirect, and induced impacts. This job loss disproportionately affected low- to moderate-income households, as many of the jobs lost were in industries like food services and retail with fewer resources to reopen immediately after the disaster.

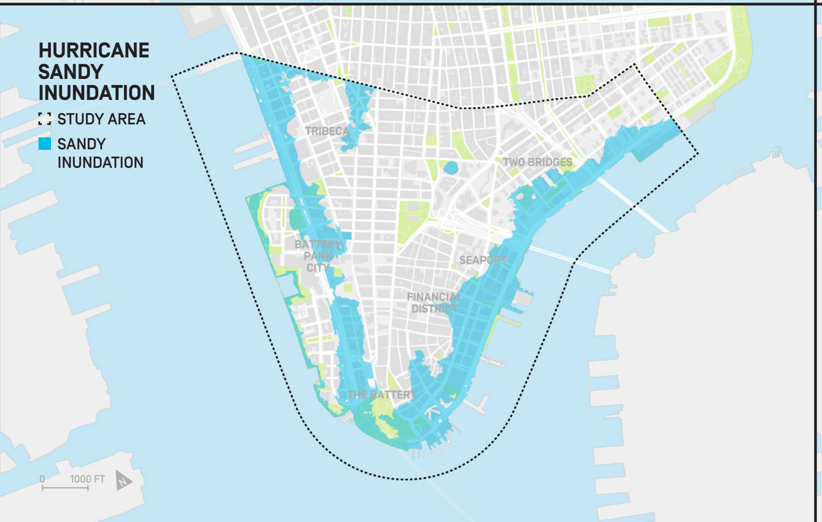


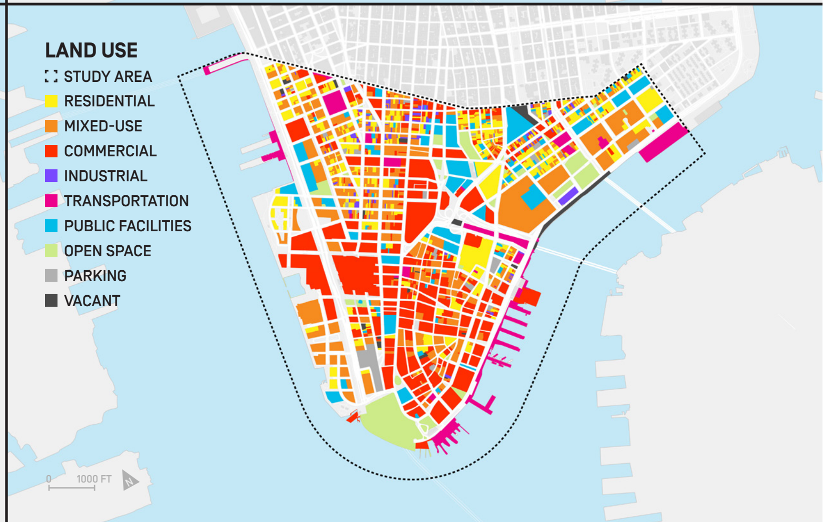












Both Lower Manhattan and New York City as a whole are more resilient than they were when Hurricane Sandy hit, due to significant, multi-layered public and private investments made in the six years since, as well as the tremendous leadership and effort of community stakeholders. The map above, Key Public Resilience Projects, represents hundreds of millions of dollars of public investments that have been made in the resilience of Lower Manhattan since Hurricane Sandy, including $123 million in NYCHA housing. In addition to public resilience investments, private property owners have invested over $100 million in building-level protections and improvements in the Financial District and the Seaport. City-wide, Con Edison has invested $1 billion to harden, protect, and elevate key electric, gas, and steam infrastructure. One year after Hurricane Sandy, a disaster recovery budget of $10.5 billion was approved for the MTA to rebuild and increase the climate resilience of the city's subway system. The City has updated its building codes, zoning rules, and design guidelines to ensure that our built environment and future capital investments are designed to withstand the impacts of a changing climate. The City has also worked extensively on community-based resilience efforts, conducting emergency preparedness trainings for community-based organizations, sending teams of emergency planning experts and providing resilience technologies to small businesses, and conducting outreach campaigns to inform New Yorkers about flood risk and insurance.

Lower Manhattan's physical conditions present both vulnerabilities and opportunities. The District on the whole is characterized by a distinctive, densely developed mix of tall, newer towers and a large proportion of old, historic buildings. These older buildings are particularly vulnerable and challenging to adapt due to their age and structure. The District also has particularly low-lying topography in some areas, dipping below the aging bulkhead at the coastal edge.

This study recognizes the unique mix of challenges and opportunities in Lower Manhattan and builds on existing efforts towards the long-term climate adaptation and resilience of the District.

STUDY AREA

Bounded by the Hudson River to the west, the East River to the east, New York Harbor to the south, and Canal Street and Montgomery Street to the north, this study focuses on six of the neighborhoods that comprise Lower Manhattan: Two Bridges, the Seaport, the Financial District, the Battery, Battery Park City, and Tribeca.

The northern boundaries of this study area were determined based on vulnerability to climate hazards and in coordination with adjacent resilience efforts. Canal Street, on the west side, was revealed to be a significant breach point from which floodwater entered Manhattan's interior during Hurricane Sandy. Montgomery Street, on the east side, picks up where East Side Coastal Resiliency (ESCR), a planned integrated coastal protection project, leaves off at its southern boundary. ESCR stretches from East 25th Street to Montgomery Street, where there exists ample open space and City-owned land to implement the project. The Lower Manhattan study area includes Community Board 1 in its entirety and a portion of Community Board 3.

Each of the six neighborhoods has its own unique set of physical conditions and climate vulnerabilities that need to be weighed when planning climate adaptation strategies. Due to the diversity of building typologies, topographies, infrastructure assets, social and community characteristics, and other factors across the District, there is no single, uniform strategy that can protect all of Lower Manhattan. Rather, tools must be tailored to each unique neighborhood context in order to protect the District as a whole from climate change. Below is a short description of existing conditions in each neighborhood.

TWO BRIDGES

Two Bridges is a primarily residential immigrant neighborhood, comprised predominantly of high- and mid-rise buildings, including mixed-income affordable housing and NYCHA public housing. The neighborhood is so-named for the Brooklyn Bridge and the Manhattan Bridge. Combined with the elevated FDR Drive, these two bridges form a complicated network of vehicular transportation infrastructure. Preserving view corridors, waterfront access, and public open space for residents is a primary design challenge for climate protection in this community.

THE SEAPORT

Part of the Seaport is a designated historic district and one of Manhattan's oldest neighborhoods, with some areas built on landfill in the 19th century. The Seaport serves as a major tourist attraction and is home to a number of businesses. It is also the site of recent commercial redevelopment, and has an increasing residential population. Preserving access to active waterfront uses, view corridors and public open space is key to consider in designing flood protection at the edge. The waterfront contains several structures built on piles, such as some of the piers and parts of the esplanade. Similar to Two Bridges, the elevated FDR Drive and the Brooklyn Bridge present a complex infrastructure network along the waterfront edge. The Seaport also has a concentration of other critical infrastructure, such as the A/C subway tunnel and a Con Edison substation. Overall, the neighborhood's topography is low-lying with an aging bulkhead, with a high edge relative to the upland interior, and is particularly susceptible to flooding.

THE FINANCIAL DISTRICT

The Financial District is an economic engine for the city and region. It is mostly comprised of large, commercial office buildings with some residential uses in an extremely dense network of narrow streets. Open space is limited in this neighborhood. Like other neighborhoods on the east side, the Financial District is constrained by the FDR Drive, but especially so as the elevated freeway slopes down to street level and into the Battery Park Underpass tunnel. The coastal edge is particularly complex where this tunnel intersects with the Battery Maritime Building ferry terminal. The Staten Island Ferry/Whitehall Terminal is also located in this neighborhood.

THE BATTERY

The Battery is a historically significant, signature New York City park, with views of and boat access to the Statue of Liberty and Ellis Island. The park's relatively ample open space offers the opportunity for more flexibility and integration with flood protection measures. Preserving the historic character and waterfront access for tourists and residents are key design considerations in adapting the park.

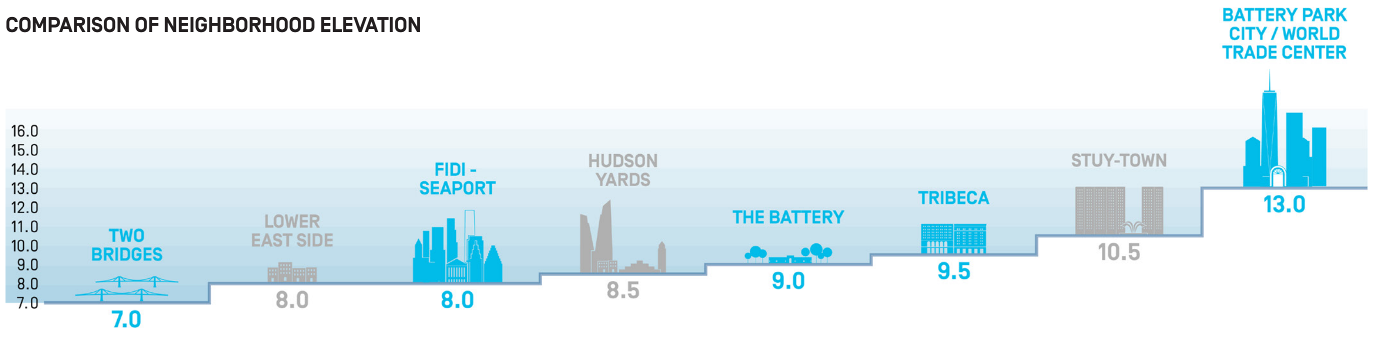
BATTERY PARK CITY

Created in the 1970s by using landfill excavated mostly from the construction of the World Trade Center, Battery Park City is a primarily residential, mixed-use neighborhood with open space along the waterfront. It was built through land reclamation at a relatively high elevation, meaning much of it avoided flooding during Hurricane Sandy. Battery Park City Authority (BPCA) has undertaken several resilience projects since Hurricane Sandy including completing a resilience assessment in 2016. EDC rebuilt Pier A on behalf of BPCA in 2015 after Hurricane Sandy with a climate resilient design.

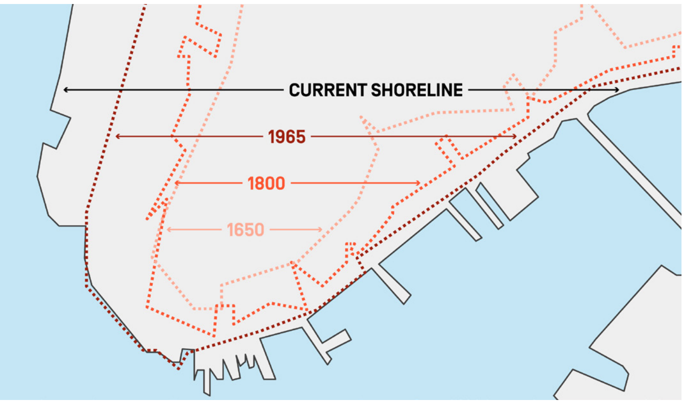
TRIBECA

Tribeca is a mixed-use neighborhood with a large proportion of older buildings. It is relatively low in elevation, particularly around Canal Street. Hudson River Park offers open space at the coastal edge that is also relatively low-lying. Tribeca has a complex jurisdictional landscape, including the City- and State-controlled public benefit corporation, Hudson River Park Trust, and the adjacent State highway, Route 9A.

COMPARISON OF NEIGHBORHOOD ELEVATION



This graphic shows the average grade elevation within the 2050s 100-year storm floodplain for each neighborhood. Floodplain based on FEMA and NPCC.
Source: GIS - US Geological Survey National Elevation Dataset.



Lower Manhattan shoreline over time.

CHAPTER 3

CLIMATE RISK ASSESSMENT

METHODOLOGY

This study used the most conservative projections from the most up-to-date climate science that is specific to New York City to assess Lower Manhattan's vulnerability to a range of climate hazards.

This study used projections and data from the 2015 NPCC report, which are reaffirmed in the 2019 NPCC report update. The NPCC is an independent body of climate experts and leading earth scientists that was convened to provide up-to-date scientific information and advise the City on climate risks and resilience. The NPCC provides flood maps and future projections at different confidence intervals for the timeframes of 2020s, 2050s, 2080s, and 2100. This study used 90th percentile projections, which are the most conservative available in the NPCC report. Analysis focused on the long-term timeframes of the 2050s, or within the average adult New Yorker's lifetime, and 2100, or within a young New Yorker's lifetime.

For this study, additional modeling was done using similar technology to the FEMA models that the NPCC models build on to examine a specific storm scenario that was not studied by the NPCC. Whereas the FEMA models were designed to cover the whole Eastern Seaboard, our modeling was more targeted to the study area of Lower Manhattan and thus had a higher resolution.

These climate projections use the most up-to-date scientific data available at the time of this study. Ongoing research demonstrates that concrete, multifaceted impacts of climate change are likely to happen in New York City's near future if no action is taken towards adaptation and mitigation. The City's strategy for adapting to future climate change risks should continue to evolve as more up-to-date projections become available, and as climate science itself evolves with new technology, data, and political and economic realities.

NEW YORK CITY PANEL ON CLIMATE CHANGE (NPCC)

The report uses work done by the NPCC from 2015 to 2019. NPCC consists of leading climate scientists and climate impact experts across disciplines of earth science, engineering, and social science. Members of NPCC are professors and researchers at Columbia University's Earth Institute, Mailman School of Public Health, and Lamont-Doherty Earth Observatory; NASA Goddard Institute for Space Studies; Hunter College at the City University of New York (CUNY) and the CUNY Institute for Sustainable Cities; New York City College of Technology; Stony Brook University; Rutgers University; University of Pennsylvania; Princeton University; and Wesleyan University.

CLIMATE HAZARD CATEGORY	MODELING	DATA SOURCE
Precipitation	2050s 10-year rainstorm	Additional Modeling
Coastal Storm	2050s 10-, 50-, 100-year coastal storm surge	FEMA; NPCC, 2015*
Coastal Storm	2100 10-, 50-, 100-year coastal storm surge	FEMA; NPCC, 2015*
Sea Level Rise	2100 tidal inundation (Mean Higher High Water)**	NOAA; NPCC, 2015*
Sea Level Rise	2100 groundwater table rise***	Additional Modeling; NYC Open Data

*90th percentile projections, reaffirmed in the 2019 NPCC Report.

**Mean Higher High Water (MHHW) is the average height of the highest tide recorded at a tide measuring station each day over the course of a recording period.

***2100 sea level rise, subtracting 4 ft. This study follows the understood assumption that the groundwater table rises in roughly equal proportion to the mean sea level. Underground infrastructure depths vary widely in Lower Manhattan. For the purposes of measuring the impacts of groundwater table rise on underground infrastructure, this study assumes that potentially impacted utilities are located four feet below street level.

Image of additional modeling done for study.
- ● Manhole
- ▼ Outlet
- — Pipe
- — Interceptor

CLIMATE HAZARD DEFINITIONS

Unlike other studies of Lower Manhattan that have come before it, this study examines a wide range of climate hazards beyond coastal storm surge events. Climate hazards include climate events, which are single and isolated occurrences, and chronic conditions, which happen on a continuing basis.

CHRONIC CONDITIONS

SEA LEVEL RISE

Refers to the increase in sea level caused by a change in the volume of the world's oceans due to temperature increase, deglaciation (uncovering of glaciated land because of melting of the glacier), and ice melt. Sea level rise is usually measured as the distance from a specified baseline. Sea level rise can impede the combined sewer system's ability to discharge in event of extreme precipitation when the system is at capacity, which then leads to flooding in the streets and backups into building basements.

GROUNDWATER TABLE RISE

An impact of sea level rise. Groundwater table rise refers to the increase in the level of groundwater underneath a landmass, such as Lower Manhattan. A rising and constantly shifting groundwater table can cause destabilization of building foundations, increase pressure and potentially infiltrate underground utilities with salt-water, and cause uplift and settlement in both buildings and underground utilities. Uplift is an upward pressure effect that causes buoyancy. Settlement is the sinking effect of soil losing its capacity to bear a load.

TIDAL INUNDATION

An impact of sea level rise. Tidal inundation refers to the regular, persistent impacts from a higher tide on a coastal area.

CLIMATE EVENTS

STORM SURGE

Refers to the temporary increase in the height of the sea at a particular location, due to extreme meteorological conditions, often a coastal storm such as a hurricane or nor'easter. The storm surge is defined as being the excess above the level expected from tidal variation alone at that time and place.

EXTREME PRECIPITATION

Extreme precipitation is defined in this report as one inch of rainfall or more during a period of 24 hours. The NPCC studies extreme precipitation events at 1 inch, 2 inches, and 4 inches or more of precipitation in a 24 hour period. Extreme precipitation events can overwhelm stormwater management systems and lead to **Combined Sewer Overflow (CSO) events**, where rainwater is combined with sewer water and discharged into local waterways when the volume of water exceeds the combined sewer system's capacity to carry both sewer water and rainwater. Sea level rise in the future may compromise the system's ability to discharge, which then leads to flooding in the streets and backups into building basements.

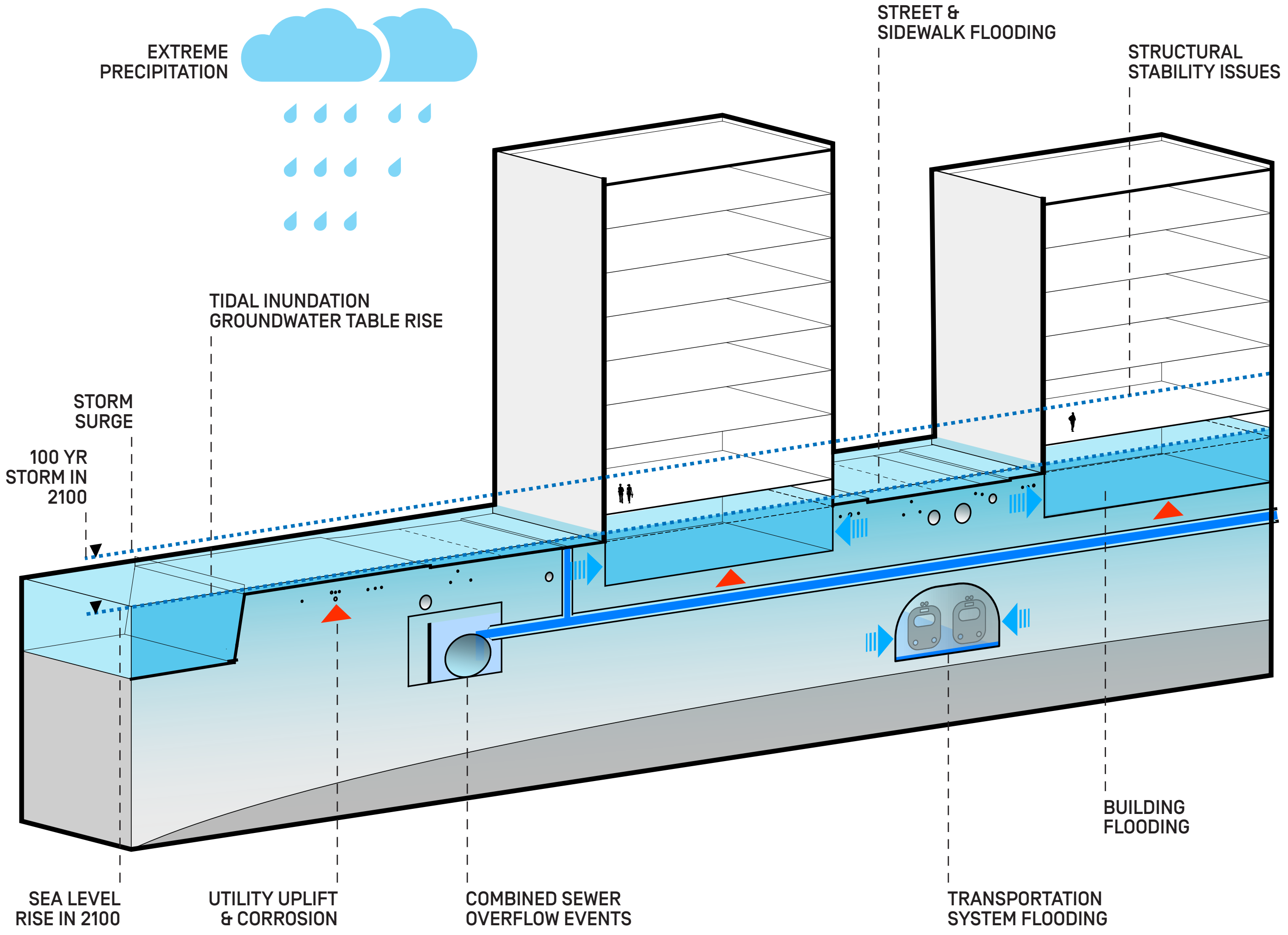
HEAT WAVES

A heat wave is a period of three consecutive days with maximum temperatures at or above 90°F. In Lower Manhattan, heat waves are exacerbated by the urban heat island (UHI) effect, which is the tendency for higher air temperatures to persist in urban areas as a result of buildings and asphalt absorbing and emitting heat. A relative lack of vegetation, dark rooftops, dense human activity, and waste heat also contribute to the UHI effect. This effect tends to make cities hotter than surrounding suburban and rural areas.

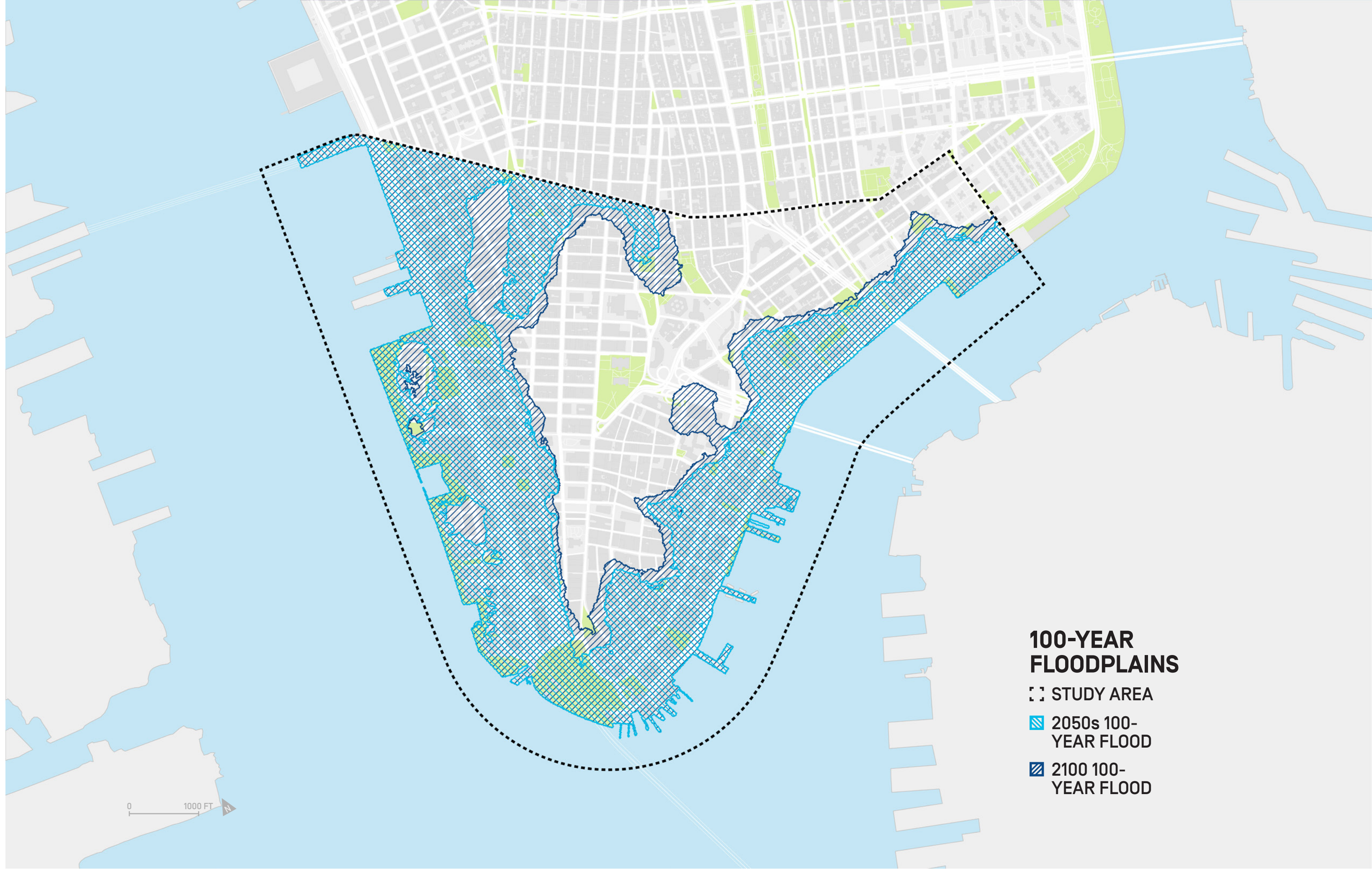
SUMMARY OF FINDINGS

This study's findings demonstrate a need to protect the District comprehensively from a wide range of climate hazards – not only low frequency, extreme events, but also high frequency, lower intensity events and chronic conditions.

Impacts in this chapter are organized by the climate hazards of storm surge, tidal inundation, groundwater table rise, extreme precipitation, and heat waves, and by the timeframes of 2050s and 2100. The analysis shows that Lower Manhattan is at risk of multiple types of flooding due to both climate events and chronic conditions. Adapting the District requires a comprehensive approach, tackling hazards with a wide range of solutions that are explored in following chapters.



Illustrative section showing the intersections of risks and exposure to multiple climate hazards.



STORM SURGE

Increasingly severe coastal storms, coupled with a rise in sea level, may produce more extreme storm surges across Lower Manhattan.

By the 2050s, 100-year storm surge could put 37% of the District's properties with a combined assessed value of $13 billion (2018 dollars) at risk. By 2100, there is a more than 50% chance that intense hurricanes could increase in frequency. Surge heights are projected to reach between 9 and 16 feet throughout the District, with the highest surge heights expected near the Battery and along the District's east side. A 100-year storm surge in 2100 could put 47% of the District's properties with a combined assessed value of $14 billion (2018 dollars) at risk.

These impacts may be greatest for buildings that cannot implement retrofits or dry floodproofing measures, due to lack of financial capacity or structural integrity. Over 150 of the District's buildings may be unable to adapt due to their age – buildings that are less than six stories tall and were built before 1938, when the City's first modern building code was implemented, are unlikely to have been built on piles that reach bedrock, and may lack the structural integrity required for retrofitting and dry floodproofing. In 2100, over two-thirds of the buildings in the District that are landmarked or located in a historic district are projected to be within the 100-year floodplain.

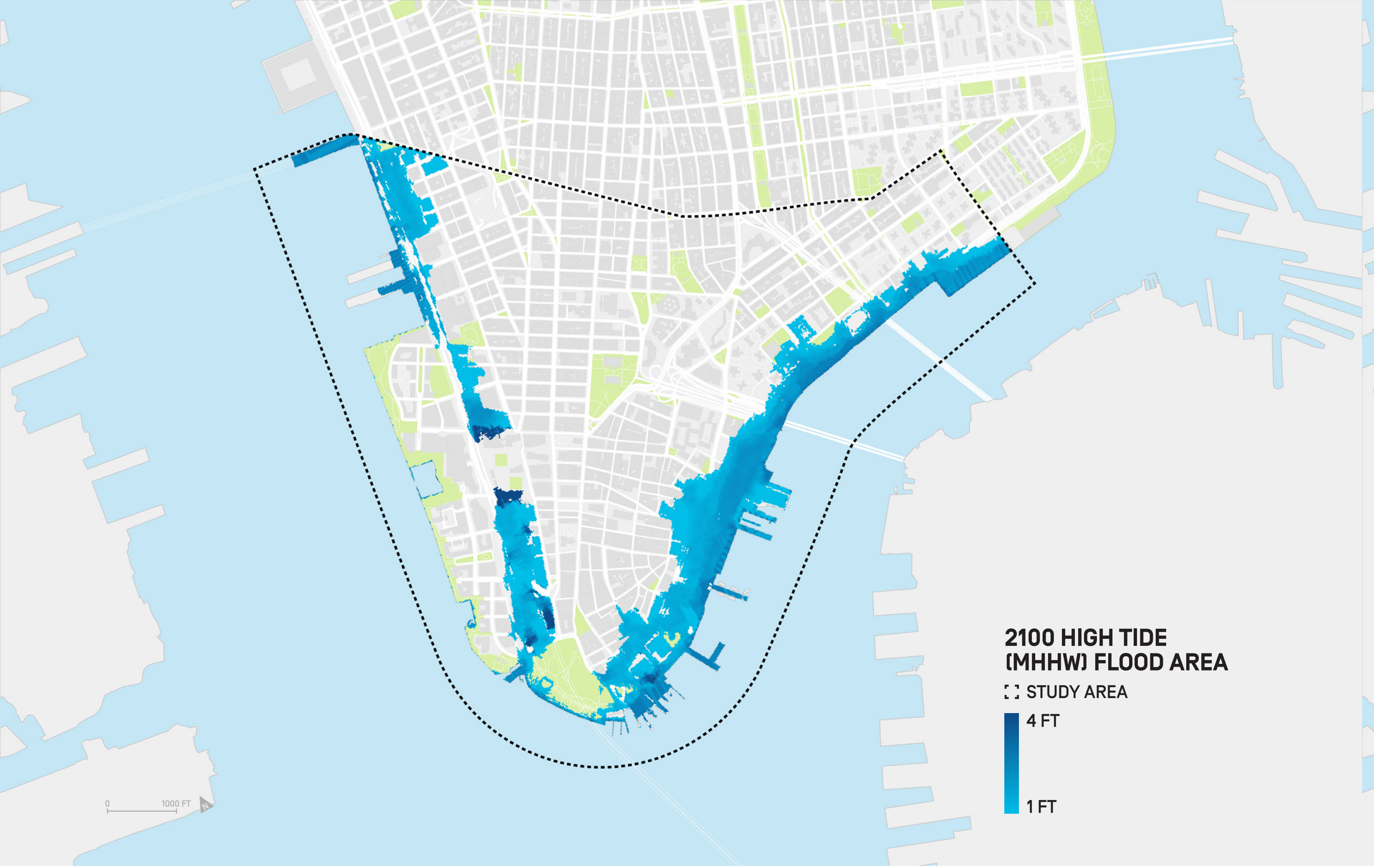
KEY IMPACTS

BY THE 2050s...

- 37% of properties with a combined assessed value of $13 billion (2018 dollars) at risk from 100-year storm surge

BY 2100...

- Surge heights of 9-16 feet projected
- Nearly 50% of properties with a combined assessed value of $14 billion (2018 dollars) at risk from 100-year storm surge, including over two-thirds of buildings that are landmarked or within a historic district



TIDAL INUNDATION

Portions of the District's edge are projected to be flooded on a daily basis due to tidal inundation.

Future projections for sea level rise in New York City exceed the global average, and observed climate trends since 1900 show that sea levels at the Battery have risen nearly two times as much as the global average. By 2100, tidal inundation, an impact of sea level rise, is expected to submerge portions of Lower Manhattan's edge in up to 3 feet of water on a regular basis, and flood up to 4 blocks inland in certain portions of the Financial District and the Seaport. Daily tidal inundation is expected to impact 20 percent of the District's streets and over 10 percent of its properties, with a combined assessed value of $4 billion (2018 dollars). The baseline data used for this analysis represent a twice-monthly occurrence (MHHW), but all areas shown on the map are projected to be affected by tidal inundation on a daily basis, with varying degrees of intensity from day to day.

In the absence of adaptation measures, some transportation nodes, such as Whitehall Terminal and Bowling Green, may become inaccessible at certain times due to tidal inundation. The regular frequency of flooding due to tidal inundation may prevent businesses from being able to operate in certain areas. Impacts are projected to be especially severe on the eastern edge of the District, where the bulkhead is low-lying.

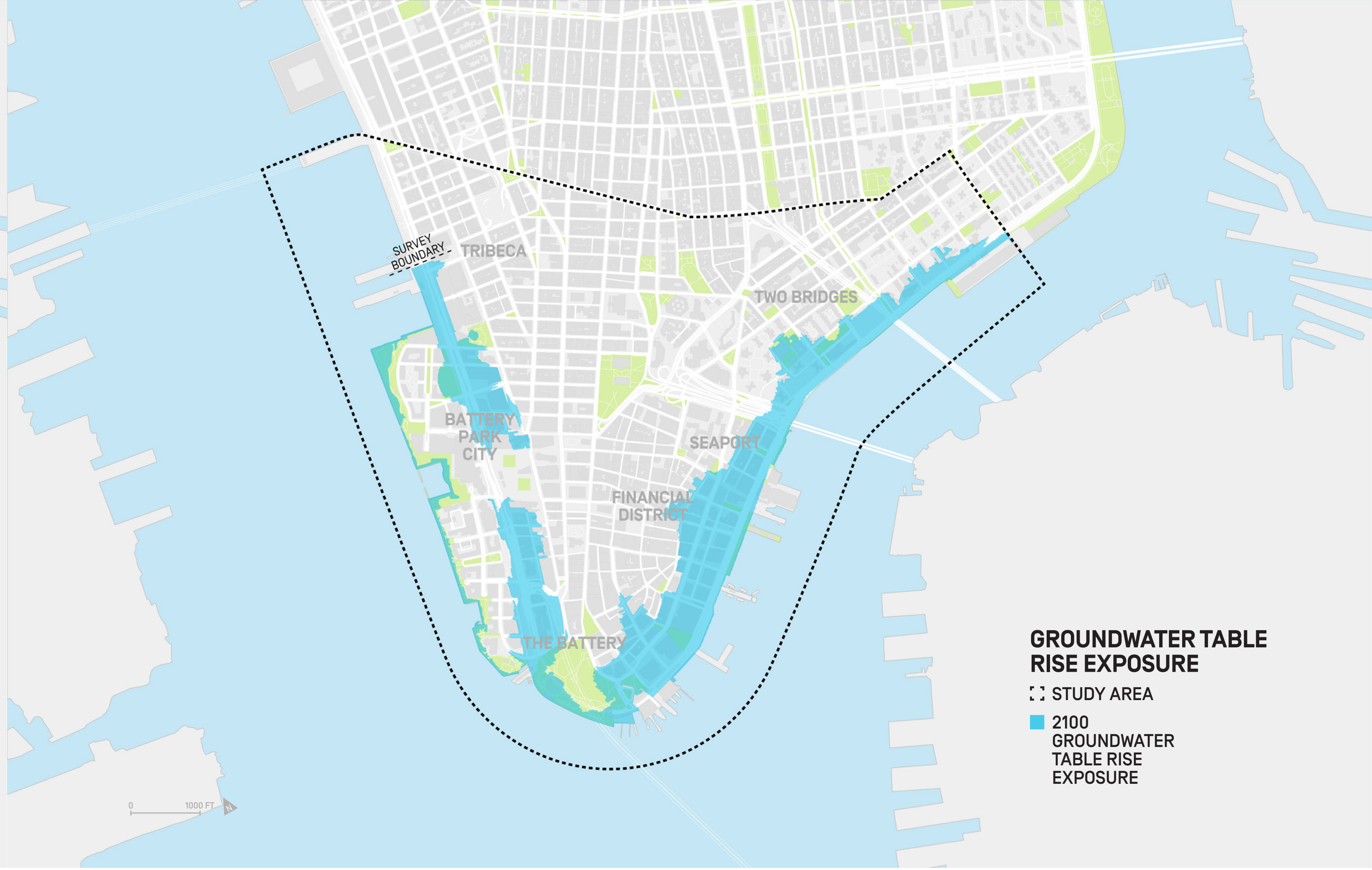
KEY IMPACTS

BY THE 2050s...

- No significant impacts projected

BY 2100...

- Daily tidal inundation up to 3 feet in depth projected around the District's edge
- Over 10% of properties with a combined assessed value of $4 billion (2018 dollars) at risk from daily tidal inundation



GROUNDWATER TABLE RISE

Groundwater table rise, caused by a rise in sea level, has the potential to expose buildings and underground utilities to corrosion, destabilization, settlement, and uplift.

The NPCC projects almost 3 feet of sea level rise by the 2050s and over 6 feet by 2100. Sea level rise may also cause the groundwater table in Lower Manhattan to rise, impacting both buildings and underground infrastructure. At the building level, a rising groundwater table would result in increasing saturation of the soil, which could cause settlement—a sinking effect where the soil loses its bearing capacity to support infrastructure and buildings—or uplift—where infrastructure and building basements become buoyant with upward pressure.

Over 450 buildings in the District could be exposed to groundwater table rise by 2100. Groundwater table rise has a higher potential to destabilize buildings with foundations that are not secured to bedrock. Of these 450 buildings at risk of exposure, over 150 of the District's buildings, built to less than six stories tall and before 1938—when the City's first modern building code was implemented—are unlikely to have been built on piles that reach bedrock. These buildings account for 7 percent of all buildings in the District and would be particularly vulnerable to destabilization.

Groundwater table rise could also have damaging effects on underground infrastructure. By 2100, almost 40 percent of Lower Manhattan's streets are expected to have underground utilities and other infrastructure exposed to corrosion, settlement, uplift, and other water infiltration. These impacts may necessitate more frequent pumping to keep water out of underground subway tunnels and maintenance to address damage.

KEY IMPACTS*

BY 2100...

- Over 150 buildings (about 7% of the District's buildings) at risk of destabilization due to their age and condition
- Almost 40 percent (or 17 miles) of streets could have underground utilities at risk of corrosion, settlement, and uplift

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*Analysis of 2050s impacts outside of study scope.

STORMWATER FLOODING

⬚ STUDY AREA

🟦 2050s 10-YEAR RAINSTORM FLOODING

EXTREME PRECIPITATION

Increasingly frequent extreme precipitation events, combined with sea level rise, may overwhelm the City's stormwater management system, causing sewer backups into buildings and street flooding.

By the 2050s, the NPCC projects that extreme precipitation events could occur with approximately 30% more frequency than they occur today. When rainwater exceeds the capacity of Lower Manhattan's combined sewer system, which carries both rainwater and sewage, it functions by discharging excess flow in the receiving water bodies in what is known as a Combined Sewer Overflow (CSO) event. CSO events can negatively impact water quality in the receiving bodies of water due to the presence of untreated sanitary sewage in the discharge. The combined sewer system's ability to discharge into the river is dependent on the difference between water elevation in the river and water elevation in the system. Higher sea levels may increase water elevation in the river, causing tidegates to close outfalls for a longer period of time, thereby reducing or even reversing the flow of this discharge. In effect, sea level rise may compromise the combined sewer system's ability to discharge when it is over capacity in the event of extreme precipitation.

KEY IMPACTS

BY THE 2050s...

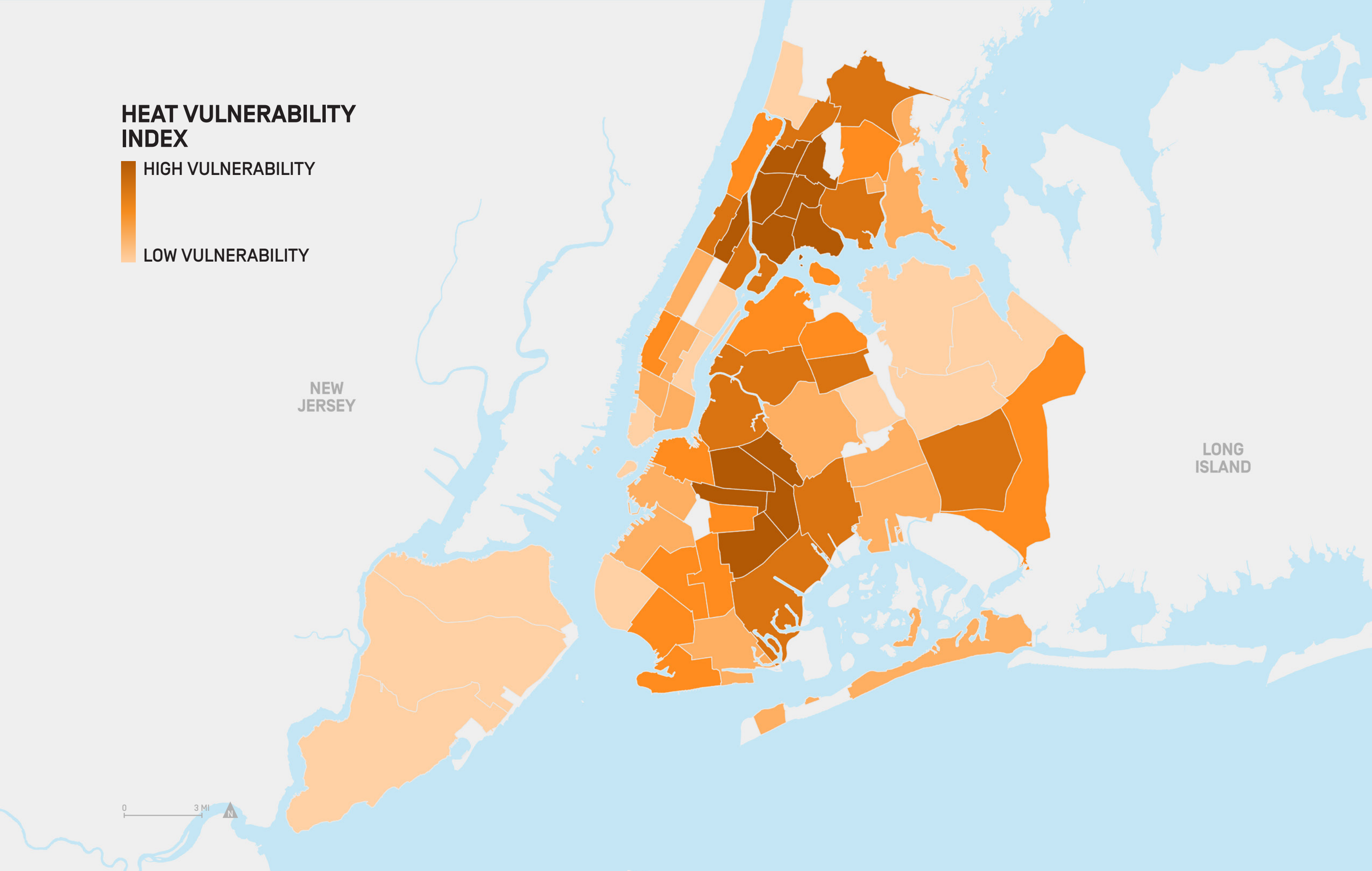
- Increased frequency of street flooding and sewer backups into building basements projected
- Reduced combined sewer system drainage capacity due to increased water pressure from higher sea levels projected

BY 2100...

- Impacts of extreme precipitation to the combined sewer system expected to be more severe in the absence of significant action

The system's reduced capacity to drain into the waterways could result in increased street flooding, as well as sewer backups into building basements.

This Study conducted modeling of a 10-year rainstorm event with the existing combined sewer system. Combined with sea level rise, 10-year rainstorm events by the 2050s are expected to have a high risk of overwhelming the current system. By 2100, these impacts are expected to be more acute due to additional sea level rise and potentially more frequent extreme rain events, absent significant action to slow these trends or investments to upgrade stormwater capacity.



HEAT VULNERABILITY INDEX

HIGH VULNERABILITY

LOW VULNERABILITY

HEAT WAVES

Average citywide temperatures are projected to rise and heat waves may become longer and more frequent, impacting the livability of the District and the health of its residents.

KEY IMPACTS*

BY THE 2050s...

- Heat waves projected to be 250% more frequent and 50% longer
- Average citywide temperatures projected to rise by up to 5.7°F

The NPCC projects that heat waves could increase in frequency by approximately 250% and increase in length by 50% by the 2050s. Average citywide temperatures could increase by up to 5.7°F.

Extreme heat has a profound effect on quality of life and human health, causing dehydration, heat exhaustion, heat stroke, and mortality. In New York City, extreme heat is the number one cause of deaths due to extreme weather. Today, New York City experiences an average of 450 heat-related emergency department visits, 13 heat stroke deaths, and 115 deaths from natural causes that are exacerbated by extreme heat. More frequent and longer heat waves have the potential to aggravate these health impacts. Health risks are disproportionately borne by New Yorkers from high-poverty neighborhoods, of older age, with poor health, and without access to air conditioning.

Like other cities, New York City is more vulnerable to extreme heat and rising temperatures due to the UHI effect, which contributes to cities being up to 22°F hotter than rural and suburban areas. Within the city, some areas may be more at risk than others. Lower Manhattan has a relatively low risk compared to the rest of the city. In 2015, the NYC Department of Health and Mental Hygiene and Columbia University developed a Heat Vulnerability Index (HVI) combining social and physical indicators of heat risk. Battery Park City, the Financial District, and the Seaport were found to have a low HVI, while Two Bridges and Tribeca have a moderate HVI.

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*No NPCC projections for heat waves available for 2100.

CHAPTER 4

CLIMATE ADAPTATION TOOLKIT AND APPROACHES

CLIMATE ADAPTATION TOOLKIT

INTERVENTION
●

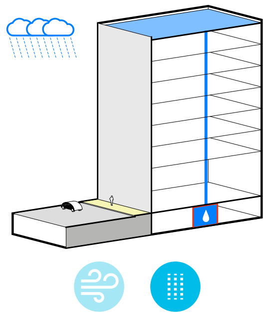
LEVEL OF PROTECTION
● HIGH
● LOW

CLIMATE HAZARD
STORM SURGE
TIDAL INUNDATION
PRECIPITATION
GROUNDWATER TABLE RISE
HEAT

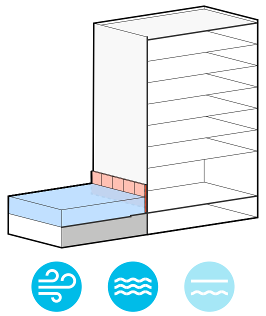
Given the vulnerability of Lower Manhattan to multiple climate hazards and the diverse neighborhood contexts across the District, a wide set of tools is needed for comprehensive adaptation and protection.

This study drew from an array of global precedents and best practices for adapting to increased storm surge, rising sea levels (and its impacts of tidal inundation and groundwater table rise), increased precipitation, and longer and more frequent heat waves. From these precedents, an adaptation toolkit was assembled and analyzed for climate resilience in Lower Manhattan, focusing on interventions that could be sited within or close to Lower Manhattan and excluding measures at the regional scale. We studied over twenty adaptation measures, or 'tools,' that address different climate hazards and offer different levels of risk reduction. They are organized here by scale of implementation, from individual buildings and utilities, to the public realm and coastal edge. This range provides a variety of options to be evaluated and matched with different physical contexts in Lower Manhattan.

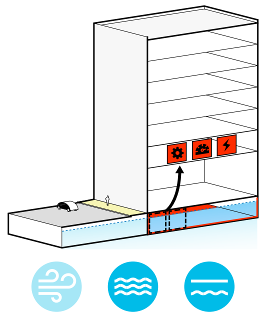
BUILDINGS



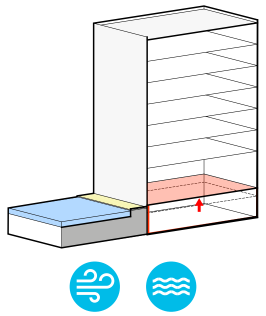
STORMWATER RETENTION & DETENTION
Storage of stormwater in tanks within buildings or on building roofs, i.e. 'blue roofs' that temporarily store and regulate the drainage of stormwater, reducing the risk of inland flooding during extreme precipitation and storm events.



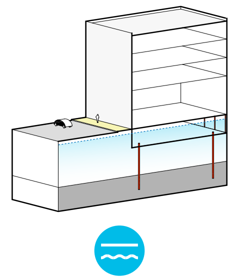
DRY FLOODPROOFING
Deployable barriers around buildings or hardening of buildings to protect them from tidal inundation flooding and storm surge flooding. Basements can be waterproofed to address groundwater table rise.



WET FLOODPROOFING
Lower levels of buildings adapted to allow flooding. Utilities relocated to higher levels. Damage from groundwater table rise and tidal flooding mitigated by abandoning lower levels.

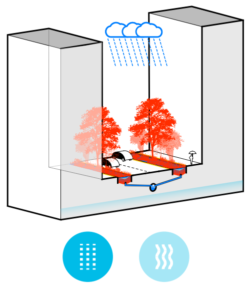


ELEVATED PROPERTY
Entire buildings or just ground floors elevated above flood level. Can be raised to future high tide or storm surge levels.

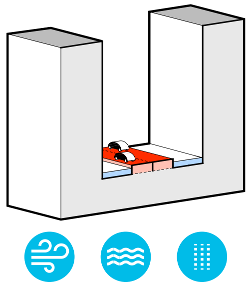


BUILDING STABILIZATION
Reinforced basement walls and floors for old buildings and tall buildings lacking structural piles tying into bedrock.

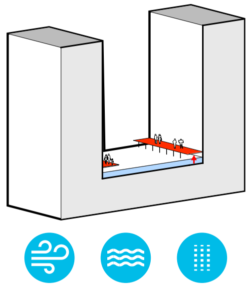
STREETS



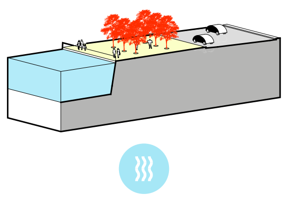
GREEN STREETS
Planted bioswales and permeable surfaces capture stormwater and lower urban temperatures.



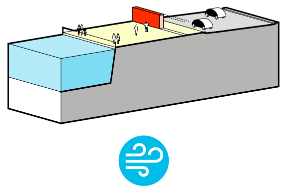
ELEVATED STREETS
Streets raised above future high tide and floodplain to ensure accessibility during extreme precipitation and storm events. Typically elevated using fill.



ELEVATED PEDESTRIAN REALM
Sidewalks raised above future high tide and floodplain to ensure pedestrian mobility during extreme precipitation and storm events. Elevated using fill or decking.

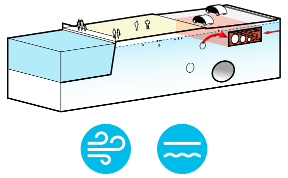


INCREASED TREE CANOPY
More trees and greenspace planted to reduce urban temperatures.

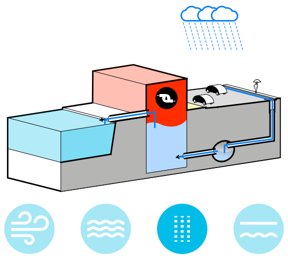


DEPLOYABLE PROTECTION
Operable barriers within the public realm deployed prior to storm surge events. Can be stored in-place or off-site.

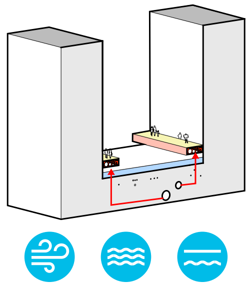
UTILITIES



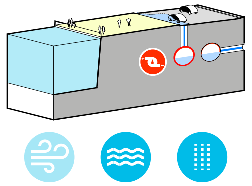
UTILITY BOX
Waterproofed tunnel running under streets to protect against damage from storm surge and groundwater table rise. Utility mainlines relocated into the tunnel for protection and connections rerouted.



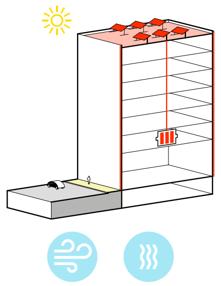
ADDITIONAL PUMPING CAPACITY
A pumping system to remove inland stormwater and flooding from future high tide, extreme precipitation and storm events. Constant pumping can address groundwater table rise behind a seepage barrier.



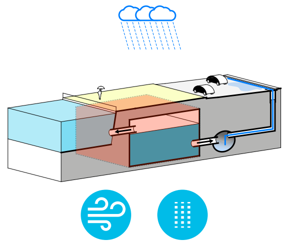
RAISED UTILITIES
Utilities relocated above flood level for protection from water damage.



PARALLEL STORMWATER SYSTEM
A new stormwater system running parallel to the existing combined waste and stormwater system to prevent system back-up. The existing system would be decoupled to only manage wastewater.

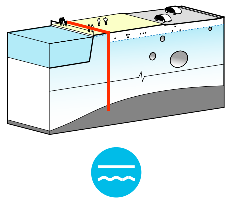


LOCAL ENERGY ASSURANCE
Energy savings measures and energy production measures by building owners. Reduces the risk of brown-outs due to high demand during heat waves and electrical loss in emergencies such as storm events.

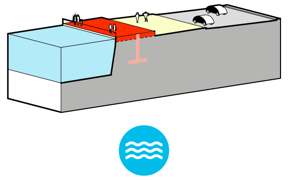


STORMWATER TANK
Stormwater storage tanks located within the public realm, reducing the risk of inland flooding during extreme precipitation and storm events.

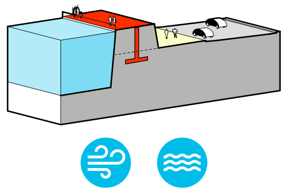
EDGE



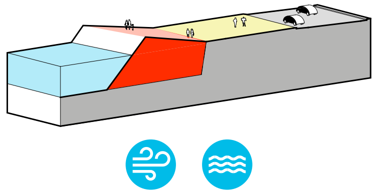
SEEPAGE BARRIER
Waterproof barrier reaching to bedrock, preventing inland groundwater inundation. Typically a cofferdam or grout injection.



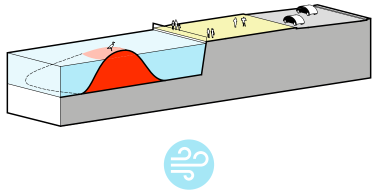
RAISED EDGE – SEA LEVEL RISE (SLR)
Low-level barrier or raised grade along the waterfront, preventing future high tides from flooding inland.



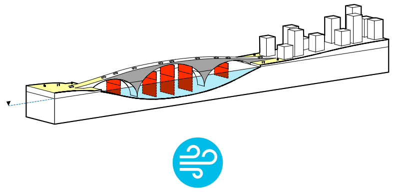
RAISED EDGE – SLR + SURGE
High raised barrier along the waterfront, preventing flooding from future high tides and storm surges.



RAISED OUTBOARD EDGE – SLR + SURGE
Sloped raised barrier on reclaimed land in the river, preventing flooding from future high tides and storm surges.



WAVE BREAK ISLANDS
Infilled islands in the river, reducing the height of waves during storm surges, but not blocking flooding.



STORM SURGE GATE
Barrier in the water with operable gates that close during storm surges.

ADAPTATION APPROACHES

Because no single tool can adapt the District to respond to the broad range of climate hazards, tools from the toolkit were grouped into illustrative approaches that show how climate adaptation can be achieved at five different scales.

Tools must be combined in order to achieve comprehensive adaptation to a variety of climate hazards in varied contexts. These adaptation approaches were developed by grouping different tools according to scale of implementation. All approaches are conceptual and illustrative for analyzing and evaluating different pathways toward adaptation, not actual projects grounded in real places.

Lower Manhattan contains a broad range of building typologies, topographies, infrastructure assets, community needs, and other characteristics across its different neighborhoods. None of these approaches can be uniformly applied to the whole of Lower Manhattan, or even to any one neighborhood. Rather, New York City's approach in reality must be tailored from a range of tools to each unique neighborhood context. The process of evaluating theoretical approaches laid the groundwork for the next phase of identifying projects for real geographies based on constraints, feasibility, context, and scale.

All of the approaches protect against the same set of climate hazards: storm surge, tidal inundation, groundwater table rise, and flooding from precipitation. However, each approach would achieve protection from these climate hazards differently according to the scale at which they are implemented. These illustrative approaches to adaptation range from the level of individual buildings and the public realm, to District-wide protection through a variety of interventions at the District's coastline.

The adaptation approaches were evaluated and analyzed on the following criteria:

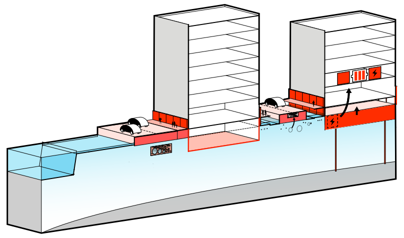
- **Technical Difficulty:** Challenges and complexities to implementation from a technical standpoint, e.g. constructability, ability to phase implementation without large-scale disruption, permitting
- **Neighborhood Considerations:** Specific neighborhood contexts in which the approach, or certain measures within the approach, would be particularly complex, burdensome, or infeasible; potential impacts the approach would have on District reputation
- **Sectoral Responsibility:** How the responsibility and resources for implementing solutions would be divided between the public sector, defined as all government agencies at the City, State, and Federal levels, and the private sector, defined as all non-governmental individual citizens, businesses, property owners, and other actors
- **Potential Co-Benefits:** Potential for approach to be integrated with other public benefits, such as enhanced streets, new open space, new development, and other changes in the built environment needed to meet policy goals such as affordable housing and economic development; conversely, how the approach may negatively impact the public realm and limit the potential for other public benefits.

BUILDING-LEVEL MEASURES

DISTRICT-WIDE MEASURES

1

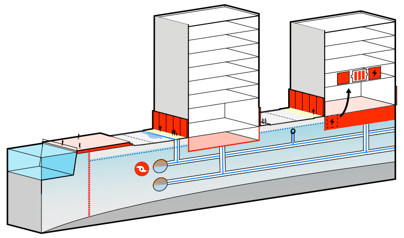
BUILDING AND PUBLIC REALM APPROACH



Let all water in, raise streets, and waterproof utilities and buildings.

2

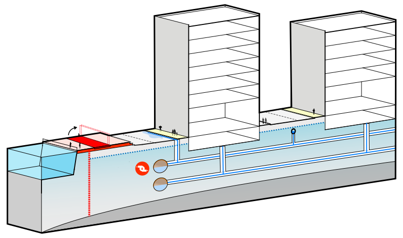
BUILDING AND LOW EDGE APPROACH



At water's edge, protect against sea level rise and groundwater table rise by moderately raising and reinforcing the edge. Let storm surge in and waterproof buildings to protect them. Upgrade stormwater system capacity to address flooding due to extreme precipitation and storm surge.

3

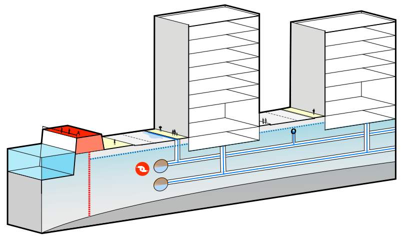
DISTRICT DEPLOYABLE AND LOW EDGE APPROACH



At water's edge, protect against sea level rise and groundwater table rise by moderately raising and reinforcing the edge. Use deployables to protect against storm surge. Upgrade stormwater system capacity to address flooding due to extreme precipitation.

4

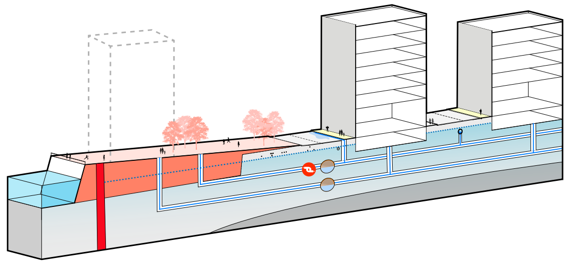
HIGH EDGE APPROACH



At water's edge, protect against sea level rise and storm surge by using a high physical barrier. Protect against groundwater table rise by reinforcing the edge. Upgrade stormwater system capacity to address flooding due to extreme precipitation.

5

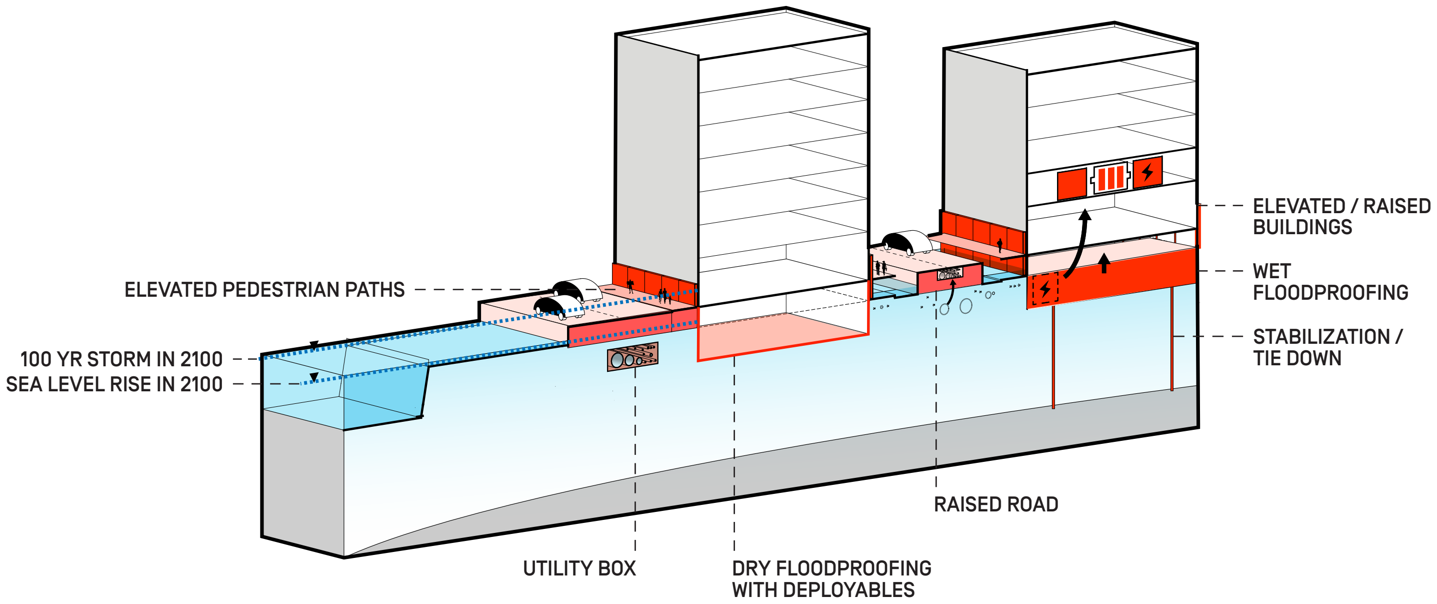
OUTBOARD APPROACH



Protect against sea level rise, storm surge, and groundwater table rise through land reclamation. Upgrade stormwater system capacity to address flooding due to extreme precipitation.

APPROACH 1

BUILDING AND PUBLIC REALM



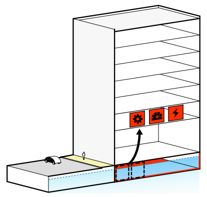
APPROACH OVERVIEW

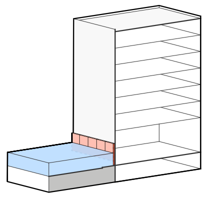
Approach 1 achieves climate adaptation by letting all water flood into the District while protecting individual buildings, streets, and utilities from damage. Properties would be protected from storm surge, groundwater table rise, and tidal inundation by a variety of mechanisms: floodproofing (wet and dry), stabilizing through installation of deeper foundations, and elevation. Streets and sidewalks would be elevated to achieve protection. Underground utilities would be rerouted and enclosed in a waterproof utility box.

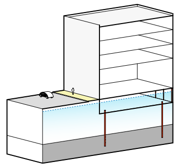
Although this approach in theory protects buildings, streets, and utilities, allowing the regular tidal inundation projected by 2100 into the District would likely have a negative impact on people's livelihoods and quality of life. This could have the potential to diminish the District's reputation, its attractiveness to businesses and residents, and economy activity over time. Using this approach, protection of all the District's buildings would also be dependent on piecemeal implementation by all property owners. Although certain property owners in some neighborhoods of Lower Manhattan have already begun to implement their own adaptation measures, it is unrealistic to expect all property owners throughout the District to do so. Piecemeal, scattered implementation by many individual actors would also produce potential conflicts between building owners and introduce more uncertainty in the timeline by which climate adaptation for the District would be complete.

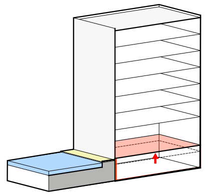
TOOLS

BUILDINGS

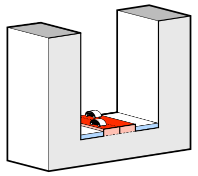

WET FLOODPROOFING

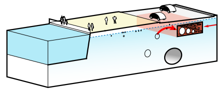

DRY FLOODPROOFING


BUILDING STABILIZATION


ELEVATED PROPERTY

PUBLIC REALM


ELEVATED STREETS


UTILITY BOX

APPROACH EVALUATION

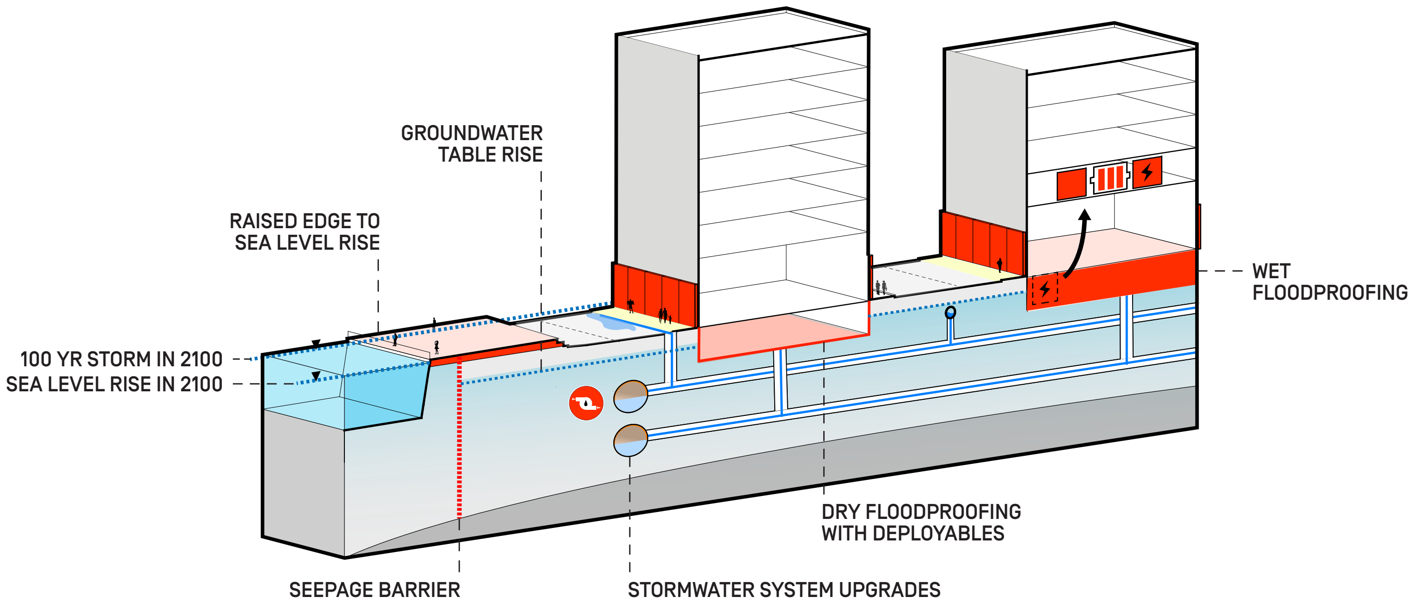
TECHNICAL DIFFICULTY	NEIGHBORHOOD CONSIDERATIONS	RESPONSIBILITY BY SECTOR	POTENTIAL URBAN CO-BENEFITS
Relocation of utilities to a utility box at this scale would require complicated phasing and would cause significant disruption to businesses in the District. This approach relies on the implementation of building-level protections by individual property owners to achieve District-wide protection. It is unlikely that all property owners would implement these measures, in part due to limited financial and technical capacity for some owners. Piecemeal implementation across the buildings has the potential to create conflicts and coordination issues between individual owners and may increase length in time for achieving climate adaptation. Elevating streets and sidewalks to high elevations would be disruptive and may create unsafe or infeasible street networks.	Older, smaller buildings may be challenging to adapt, due to their age and lack of structural integrity required for retrofitting. There is a high concentration of older buildings in Tribeca and the Seaport, including historic landmarked buildings. Adaptation of larger, newer buildings, such as those in high concentration in the Financial District, would be more feasible. Neighborhoods with low topography would require the street network to be raised to a higher elevation, making this approach less feasible. This approach lets water into the District. The inundation of water could still have a negative impact on individual livelihoods and on the collective quality of life and long-term reputation of the area.	Implementation of building-level measures would primarily fall on the private sector and individual property owners. Regulated utility companies would be responsible for relocation of utilities to a utility box. The public sector would be responsible for implementing the elevation of the public realm.	Piecemeal implementation, conducted mostly by private owners, has limited potential for district-wide co-benefits to be integrated with protection. Some investments in the public realm may be integrated with elevation of streets and sidewalks.

APPROACH EXAMPLE


Example of dry floodproofing of a building in Lower Manhattan.

APPROACH 2

BUILDING AND LOW EDGE



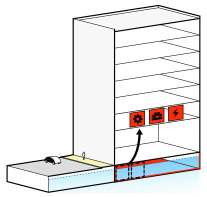
APPROACH OVERVIEW

Approach 2 achieves climate adaptation by protecting from storm surge at the building level, while protecting from the impacts of sea level rise at the coastal edge. Individual buildings would be floodproofed (wet and dry) to mitigate the impacts of high-intensity storms. A seepage barrier and raised edge at the coastline would offer protection from the impacts of sea level rise, groundwater table rise and regular tidal inundation respectively. While tidal inundation would be addressed at the coastal edge, additional capacity would be needed in the stormwater system to reduce the risk of flooding in the event of both storm surge and extreme precipitation. This would be addressed through emergency pumping capacity, a parallel stormwater system, or other measures.

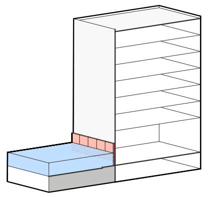
A modest elevation of the coastal edge to achieve District-wide protection from sea level rise may be desirable in areas where a higher elevation is infeasible and a high proportion of buildings have the capacity to adapt to storm surge. However, as with Approach 1, this approach depends on the implementation of storm surge adaptation measures by all property owners to achieve adaptation for the whole District. It is unlikely that all individual actors across the District would implement these measures due to varying levels of financial and technical capacity.

TOOLS

BUILDINGS

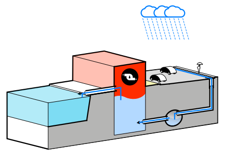


WET FLOODPROOFING

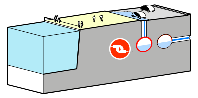


DRY FLOODPROOFING

STORMWATER SYSTEM

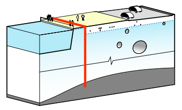


ADDITIONAL PUMPING CAPACITY

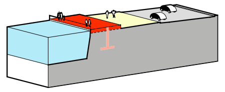


PARALLEL STORMWATER SYSTEM

COASTAL EDGE



SEEPAGE BARRIER



RAISED EDGE - SEA LEVEL RISE

APPROACH EVALUATION

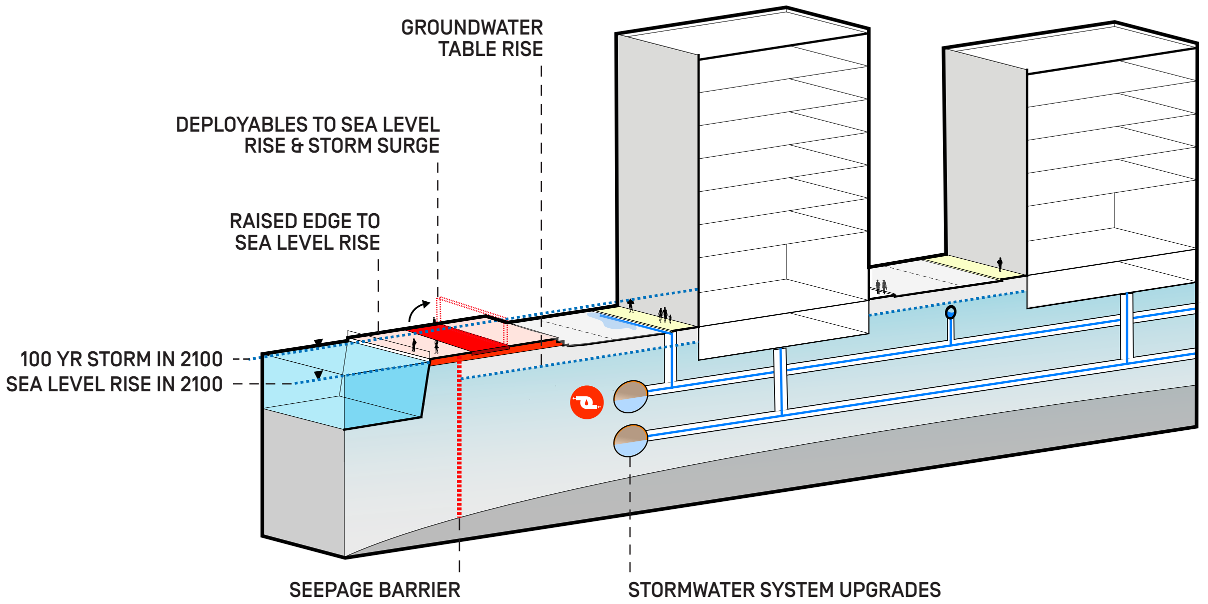
TECHNICAL DIFFICULTY	NEIGHBORHOOD CONSIDERATIONS	RESPONSIBILITY BY SECTOR	POTENTIAL URBAN CO-BENEFITS
As with Approach 1, this approach relies on the implementation of building-level protections by individual property owners, and it is unlikely that all owners would do so, in part due to the limited financial and technical capacity of some owners. However, the scale of the work to be implemented by individual property owners would be less compared with Approach 1. As with Approach 1, piecemeal implementation across the buildings may be impeded by conflicts between individual owners and may introduce uncertainty in the timeline by which climate adaptation would be achieved. Raising the edge requires a deep, large below-ground foundation that is difficult to build in areas that are highly concentrated with existing underground infrastructure, or areas without enough available space at the coastal edge.	As with Approach 1, it would be challenging to adapt older buildings like those in the Seaport and Tribeca. Building-level adaptation would be more feasible for newer, larger buildings in the Financial District. However, in contrast to Approach 1, the impact for individual buildings where measures are not implemented would be limited to the effects of high-intensity storms. Implementation of a raised edge is practical where there is sufficient open space along the water's edge.	As with Approach 1, implementation of building-level measures would primarily fall on the private sector and individual property owners. The public sector would be primarily responsible for adaptation of the coastal edge to tidal inundation and groundwater table rise and for upgrades to the stormwater system.	This approach does not offer significant potential for co-benefits for the District as a whole, especially with the piecemeal implementation of building-level measures. Raising the District's edge could be implemented in conjunction with modest improvements to existing waterfront open space in some areas.

APPROACH EXAMPLE

Example of a low raised edge using revetment.

APPROACH 3

DISTRICT DEPLOYABLE AND LOW EDGE



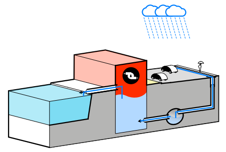
APPROACH OVERVIEW

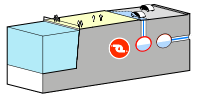
Approach 3 achieves climate adaptation primarily at the District's coastal edge, with a combination of passive interventions to protect against sea level rise, and deployable interventions to protect against storm surge. As with Approach 2, a seepage barrier and raised edge at the coastline would offer protection from the impacts of sea level rise, groundwater table rise and tidal inundation respectively. District-wide deployable protection would be installed on top of the raised edge to provide protection from storm surge. While both tidal inundation and storm surge would be addressed at the coastal edge, additional capacity would be needed in the stormwater system to reduce the risk of flooding in the event of extreme precipitation. This would be addressed through emergency pumping capacity, a parallel stormwater system, or other measures.

The combination of passive and deployable interventions along the edge allows for District-wide protection from coastal hazards while also preserving neighborhood character, waterfront access, and views. However, deployable flood barriers are technically complex and require a significant amount of underground space and above-ground clearance along the edge, as well as public resources, to implement. Deployable protection also requires public resources and planning to operate and maintain over the long-term.

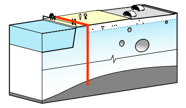
TOOLS

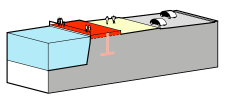
STORMWATER SYSTEM

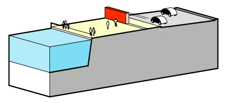

ADDITIONAL PUMPING CAPACITY


PARALLEL STORMWATER SYSTEM

COASTAL EDGE


SEEPAGE BARRIER


RAISED EDGE - SEA LEVEL RISE


DEPLOYABLE PROTECTION

APPROACH EVALUATION

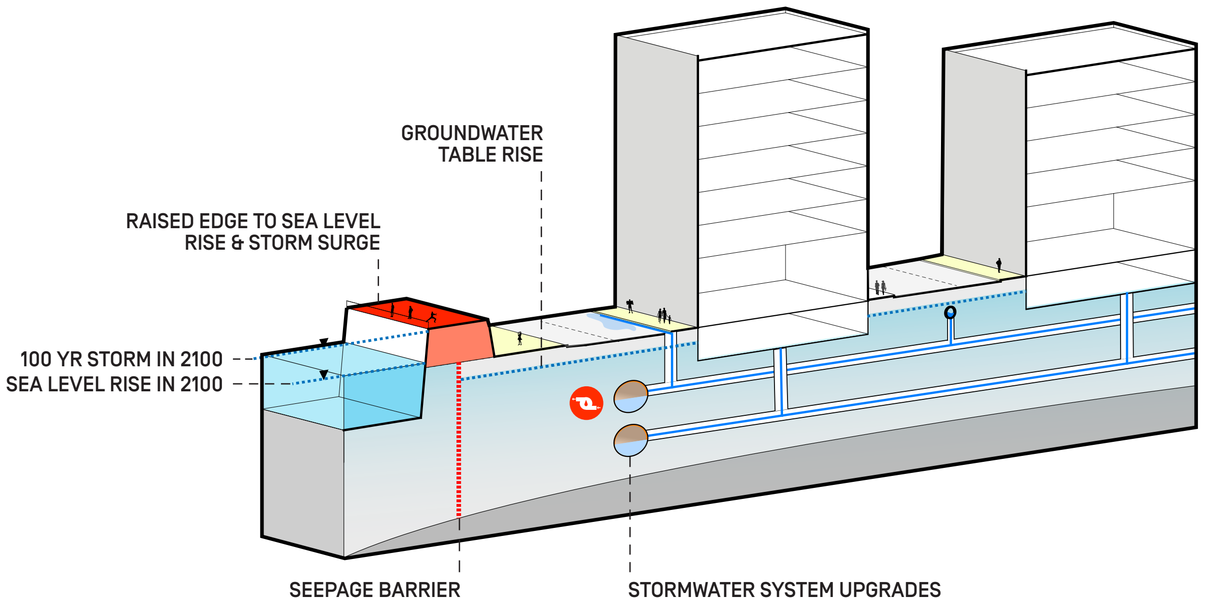
TECHNICAL DIFFICULTY	NEIGHBORHOOD CONSIDERATIONS	RESPONSIBILITY BY SECTOR	POTENTIAL URBAN CO-BENEFITS
Implementing deployables at this scale is challenging to coordinate around existing infrastructure, both above- and below-ground, and would require complex relocation of utilities and infrastructure. Deployables and raising the edge require deep, large below-ground foundations that are difficult to build in areas that are highly concentrated with existing underground infrastructure, or areas without enough available space at the coastal edge. The height and number of deployables that would be needed to protect Lower Manhattan is unprecedented and may push the limits of deployable technology. Deployables also require resources, planning, and coordination for operations and maintenance. Adapting deployables at the edge to future climate risk would be challenging. Augmenting the height of the deployables would require a deeper and larger foundation.	The elevated FDR Drive in Two Bridges, the Seaport, and the Financial District takes up a considerable amount of space along the coastal edge of these neighborhoods. It represents a significant constraint on the implementation of deployables and a raised coastal edge, which cannot touch the viaduct's columns or foundations because of State-required 3' offset. In the Financial District where the FDR slopes down to street level, the clearance underneath may not be sufficient for the height of deployables or a raised edge. Pile-supported structures along the waterfront in the Financial District and the Seaport may not be able to support the additional weight of deployable foundations on top. Critical tunnels, like the A/C subway tunnel that runs through the Seaport and the Battery tunnel that cars enter from the FDR in the Financial District, also cannot support the additional weight of deployable foundations on top. Neighborhoods with low topography require taller deployables, which push the feasibility of this approach, particularly under the FDR Drive. This approach is most desirable where the required relocation of above- and below-ground infrastructure is manageable and where preserving access to and views of the waterfront is a high community and public priority.	Implementation of these interventions, as well as the long-term operation and maintenance of the deployable barriers, would likely be the public sector's responsibility.	Because deployables are hidden from view except in event of a storm, they can offer District-wide protection while preserving access to waterfront open space and views. However, fixed elements of deployable infrastructure, such as wing walls to seal flip-up barriers or posts to hold stop log barriers, may negatively impact waterfront access. Deployables also have the potential to be integrated with outdoor public amenities and waterfront recreation uses.

APPROACH EXAMPLE


Example of small-scale deployable protection in the form of flip-up barriers. In normal conditions, flip-up barriers would be flipped down and hidden.

APPROACH 4

HIGH EDGE



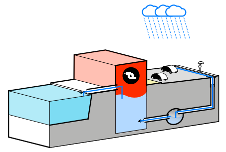
APPROACH OVERVIEW

Approach 4 achieves climate adaptation through entirely passive, permanent protection along the District's coastal edge. The edge would be raised permanently to an elevation that would protect from both tidal inundation and storm surge. This elevation would be achieved with either raised permeable landscaping, or a raised impermeable seawall along the waterfront. A seepage barrier along the edge would protect against the impacts of groundwater table rise. While both tidal inundation and storm surge would be addressed at the coastal edge, additional capacity would be needed in the stormwater system to reduce the risk of flooding in the event of extreme precipitation. This would be addressed through emergency pumping capacity, a parallel stormwater system, or other measures.

Passively elevating the coastal edge to such a height is likely to limit people's ability to access and see the waterfront. In areas where there is enough space to accommodate passive protection along the edge, this height could be reached at a gradual slope and integrated with open space to mitigate this negative impact to the public realm. In order to incorporate this gradual slope, more physical space on existing land as well as public resources than those required in Approach 3 would be needed to implement this approach.

TOOLS

STORMWATER SYSTEM



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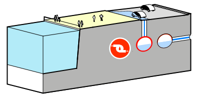
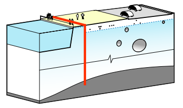
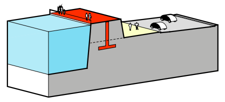


PARALLEL STORMWATER SYSTEM

COASTAL EDGE



SEEPAGE BARRIER



RAISED EDGE – SEA LEVEL RISE + STORM SURGE

APPROACH EVALUATION

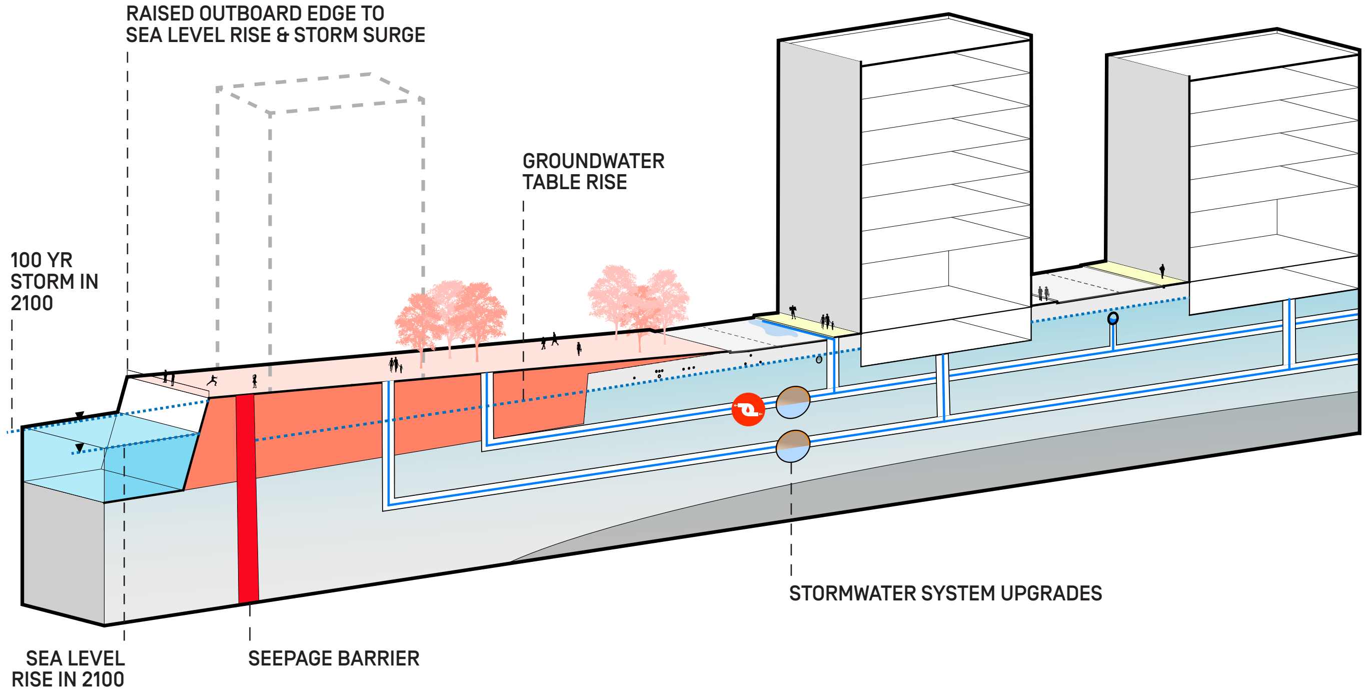
TECHNICAL DIFFICULTY	NEIGHBORHOOD CONSIDERATIONS	RESPONSIBILITY BY SECTOR	POTENTIAL URBAN CO-BENEFITS
Implementing a raised edge at such a height would require deep foundations and significant relocation of both above- and below-ground infrastructure, such as transportation networks and utilities, at the coastal edge. Adapting to future climate risk would be more feasible with this approach than in Approach 3. The raised edge offers the potential to augment with passive or deployable interventions in the future.	Space for implementation along the east side of the District, particularly in the Financial District and the Seaport, is limited due to the concentration of critical infrastructure, both above- and below-ground. This infrastructure includes the elevated FDR Drive, the A/C subway tunnel, the Con Edison Substation and utility corridor, and the Battery tunnel. The elevated FDR Drive in Two Bridges, the Seaport, and the Financial District represents a significant constraint on the implementation of this approach. In areas where the FDR slopes down to street level, the clearance underneath may not be sufficient space for a raised edge that is tall enough to protect against storm surge. This approach is more feasible to implement in areas where there is ample open space along the waterfront, such as in the Battery or Battery Park City. Waterfront assets and ferries may be impacted if the edge is raised to a height that blocks boat access.	Implementation of these interventions, as well as the long-term maintenance of the raised edge, would likely be the public sector's responsibility.	Integrating the raised edge with open space would offer some limited opportunity for co-benefits. The high edge has the potential to be integrated with outdoor public amenities and waterfront recreation uses. This approach has the potential to negatively impact views, existing open space and waterfront access, especially in areas where available space is limited and the edge would need to be raised at a steep incline. Whereas Approach 3 offers protection that only temporarily inhibits waterfront access and views in event of a storm, the high edge in this approach would have a permanent impact. However, in areas with sufficient space for implementation, the high edge can be achieved at a more gradual incline, which would mitigate impacts on the public realm.

APPROACH EXAMPLE

Rendering of East Side Coastal Resiliency project, a resilient park along East River that will be elevated to protect against 2050s storm surge.

APPROACH 5

OUTBOARD



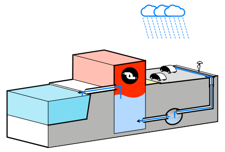
APPROACH OVERVIEW

Approach 5 achieves climate adaptation by raising the coastal edge to protect against tidal inundation and storm surge on reclaimed land, as opposed to existing land. New land creation using landfill would extend the edge into the water and raise it at a gradual slope to an elevation that would protect from both tidal inundation and storm surge. A seepage barrier along the new edge would protect against the impacts of groundwater table rise. While both tidal inundation and storm surge would be addressed through a new coastal edge, additional capacity would be needed in the stormwater system to reduce the risk of flooding in the event of extreme precipitation. This would be addressed through emergency pumping capacity, a parallel stormwater system, or other measures. Additional pumping capacity would potentially be located on reclaimed land.

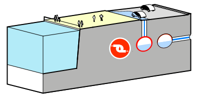
Outboard, or in-water, protection along the coastal edge would involve a highly complex permitting and public coordination process to implement. Comprehensive and complex planning would be needed to integrate new land creation and potential new development with the fabric of the existing edge, including infrastructure, built environment, and neighborhood context. This approach would be desirable in areas where space on existing land is so limited and constrained that other adaptation measures are extremely constrained and would lead to undesirable outcomes. Of the five approaches, this approach is the only one with the potential for a partial financing mechanism through the creation of development sites. Outboard protection could also be integrated with a range of urban co-benefits and fulfill additional policy objectives such as housing, job growth, and open space.

TOOLS

STORMWATER SYSTEM

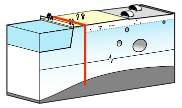


ADDITIONAL PUMPING CAPACITY

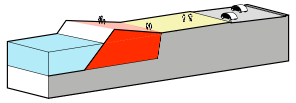


PARALLEL STORMWATER SYSTEM

COASTAL EDGE



SEEPAGE BARRIER



RAISED OUTBOARD EDGE – SEA LEVEL RISE + STORM SURGE

APPROACH EVALUATION

TECHNICAL DIFFICULTY	NEIGHBORHOOD CONSIDERATIONS	RESPONSIBILITY BY SECTOR	POTENTIAL URBAN CO-BENEFITS
The permitting and regulatory approval process for new land creation would be more complex than for any of the other approaches studied. Approvals may be needed from the state and federal governments. Coordination of new land creation with existing sewer, drainage, and transportation infrastructure would be complex and difficult. Phasing of construction would also be highly complex, and the timeline needed for implementing this approach would likely be longer than that of the other approaches.	The outboard approach could comprehensively address climate hazards in neighborhood contexts where there are a large number of physical constraints. Land reclamation would offer protection at a District-level where there is no available space or existing land to implement other interventions. Permitting and issues surrounding navigable waters will define scope of outboard, which would greatly vary by neighborhood. Comprehensive, intensive planning would be needed to understand the opportunities and limitations of implementing this approach in varying contexts. In Lower Manhattan, this approach would impact and change the historic waterfront nature and identity of some neighborhoods. Comprehensive planning would also be needed to appropriately integrate new land creation with the fabric of existing neighborhoods.	Implementation of this approach would require a strong integration of resources and coordination across multiple levels of government. This approach is the only one evaluated that offers the potential for a partial financing mechanism through proceeds from potential development sites on reclaimed land. Incorporating development sites would need to be evaluated and studied according to each particular context prior to any implementation. The extent to which such development on reclaimed land may be able to help finance the infrastructure needs associated with this approach would also need to be studied.	This approach has the highest potential of the approaches evaluated to be integrated with co-benefits. Land reclamation offers the potential to be integrated with a wide variety of public amenities and benefits, including but not limited to new open space, transportation connectivity, development, affordable housing and job creation.

APPROACH EXAMPLE

Precedent of land reclamation, or outboard, for Battery Park City (1973), not incorporated with resilient design at the time.

CHAPTER 5

STRATEGY FOR THE CLIMATE RESILIENCE OF LOWER MANHATTAN

STRATEGY FOR THE CLIMATE RESILIENCE OF LOWER MANHATTAN

The Lower Manhattan Climate Resilience Study lays the groundwork for short- and long-term investments and planning efforts to adapt Lower Manhattan to the impacts of climate change.

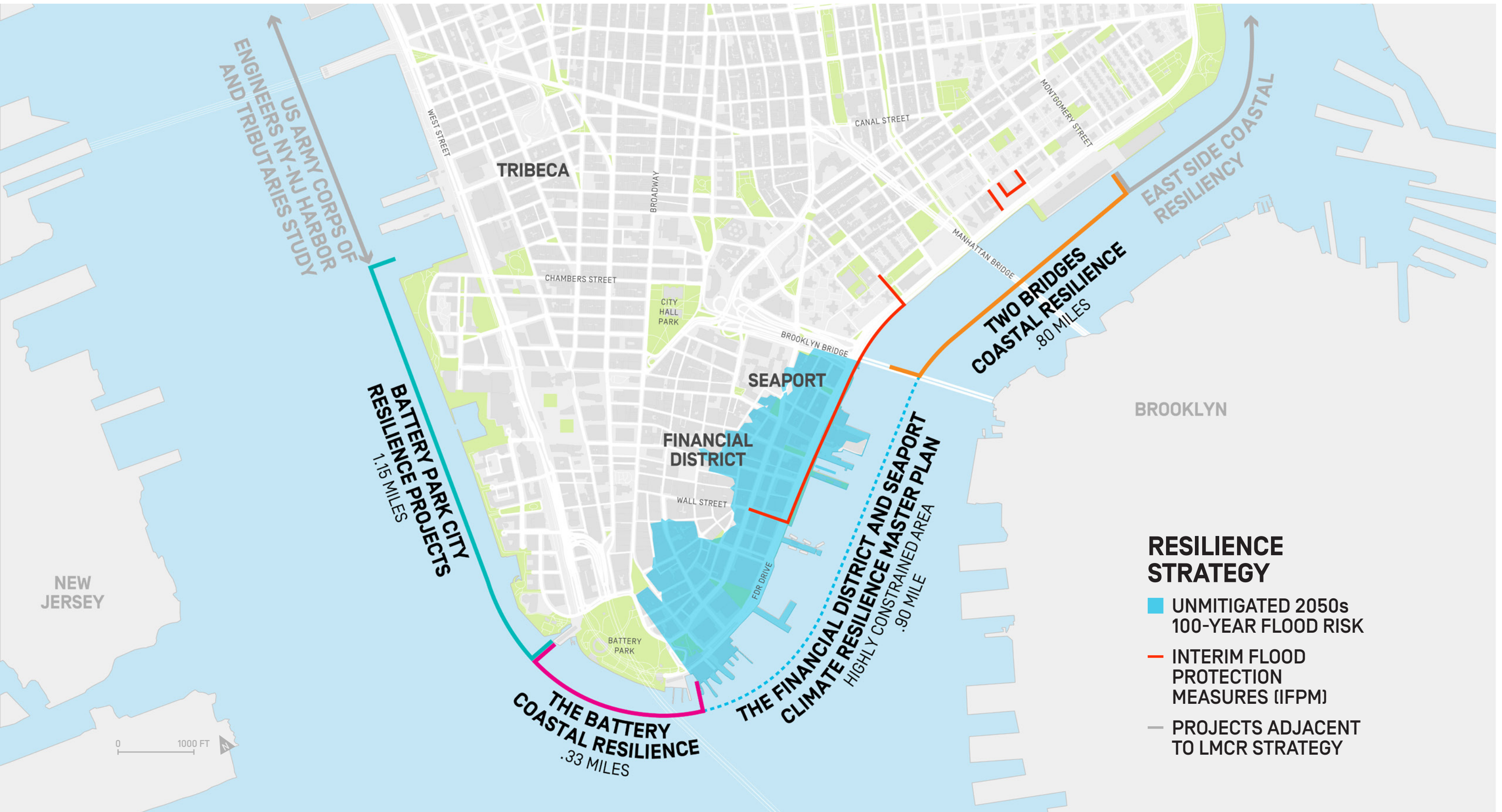
Surrounded on all sides by water, Lower Manhattan represents one of the most vital as well as vulnerable districts of the city. This study examined the complex and existential threats that climate change will bring to the District. The City is already making strides not only to assess the future impacts of climate change, but also to plan for them proactively. With the findings of this study, the City is advancing an overall climate resilience strategy for Lower Manhattan. This strategy integrates necessary actions to adapt to climate risks in the near term, with the innovation and flexibility needed to continue preparing for climate change into New York City's long-term future.

The City's resilience strategy incorporates targeted, ambitious investments that will deliver significant climate adaptation for key neighborhoods of Lower Manhattan – Two Bridges, the Battery, Battery Park City, and the Seaport – in the near future. These projects prioritize achieving protection from climate hazards while also mitigating negative impacts on the public realm and integrating co-benefits for the residents and workers of Lower Manhattan. In addition, the City will conduct further planning for the Financial District and Seaport, where implementation of more conventional adaptation measures is extremely constrained by the physical contexts of these two neighborhoods.

The US Army Corps of Engineers is conducting its own comprehensive regional study of the harbor, called the New York-New Jersey Harbor and Tributaries Study (NYNJHATS). As part of the NYNJHAT Study, they are further examining shoreline-based resilience measures in Tribeca.

The City's strategy identifies investments in climate resilience and in the District's future that total approximately $500 million. The City is advancing several coastal adaptation projects in Two Bridges, the Battery, Battery Park City, and the Seaport to respond to the hazards identified in this study. These projects were identified and developed in conjunction with the climate adaptation toolkit and approaches and were shaped by analyses of technical feasibility, implementation considerations, and potential co-benefits. Project concepts took the toolkit and adaptation approaches into account, matching them with the complex realities and constraints of each unique neighborhood, including available budget and the built environment. This tailored, neighborhood-specific approach has been designed to integrate within the existing contexts to maximize co-benefits where possible.

These investments represent the City's commitment to adapt to climate change and charts the course for Lower Manhattan to continue thriving as a District into the future.



RESILIENCE STRATEGY PROJECTS

TWO BRIDGES COASTAL RESILIENCE

Using elements of Approach 3, this project will be a combination of permanent deployable and passive flood protections along .80 miles of coastal edge to protect the neighborhood from a 100-year storm surge in the 2050s. This project will protect thousands of residents, including many living in affordable housing, while continuing to promote access to waterfront open space. Deployable flood walls will be maximized at the end of the neighborhood's many view corridors to preserve views and access to the water. These deployables will be permanent underground infrastructure, hidden until they are flipped up in event of a storm. The location of the flood walls and posts was determined to minimize conflict with subsurface infrastructure to maximize integration with existing waterfront uses such as open-air seating, fitness, and athletic courts.

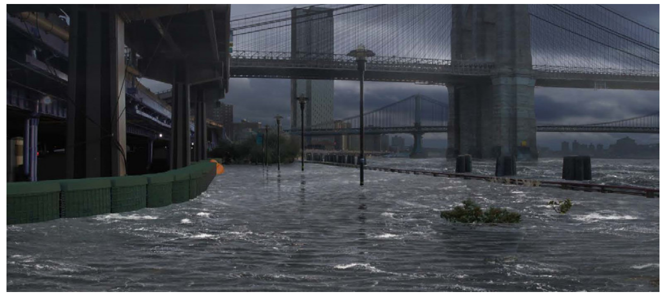
Climate Hazards: 100-year storm surge in the 2050s; extreme precipitation
Tools: Deployable Protection (Flip-up Barriers); Parallel Stormwater System
Status: EDC does final design, DDC does construction

THE BATTERY COASTAL RESILIENCE

In the Battery, the .33-mile waterfront esplanade will be rebuilt and raised to a height that would adapt this iconic New York City park to groundwater table rise and sea level rise in 2100. Using elements of Approach 4, this project leverages the urgent need to repair and harden the esplanade as well as the ample open space in the park for climate adaptation. The City will also coordinate with the Battery Park City Authority to create a seamless line of protection from Battery Park City into the park with an intervention at the back to protect the neighborhood from 100-year storm surge in the 2050s. This design concept integrates climate adaptation with preservation of the park's historic character and active waterfront uses.

Climate Hazards: 100-year storm surge in the 2050s; tidal inundation; groundwater table rise
Tools: Raised Edge – Sea Level Rise (Elevated Esplanade); Raised Edge – Surge (Flood Wall or other intervention); Seepage Barrier
Status: EDC does design and construction of esplanade in coordination with DPR

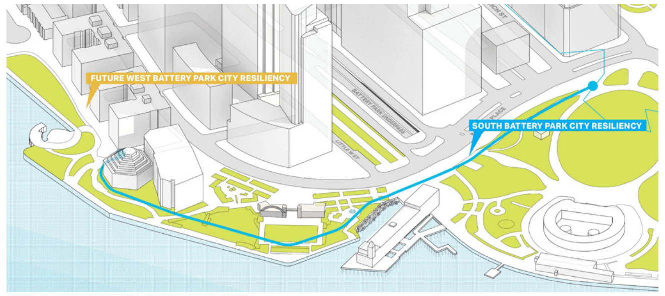
INTERIM FLOOD PROTECTION MEASURES (IFPM)



The NYC Office of Emergency Management (NYCEM) is planning IFPM to be implemented in the Seaport, Financial District, and Two Bridges areas. These temporary measures would include "just in time" water-filled dams to be deployed in event of a storm (Tiger Dams), and pre-deployed sand-filled barriers (HESCO Barriers) to remain in place. These interventions will be deployed along an alignment of just over a mile and protect against a 10-year flood.

Climate Hazards: Current 10-year storm surge
Tools: Deployable Protection (HESCO Barriers, Tiger Dams, other "just in time" deployables)
Status: NYCEM does design and implementation

BATTERY PARK CITY RESILIENCE PROJECTS



BPCA is advancing designs for three integrated resilience projects to adapt the neighborhood and the areas behind it to a 100-year storm surge in the 2050s. The City has approved bond financing for the design and construction of a resilience project in South Battery Park City, and the design of resilience projects in West and North Battery Park City. These capital projects will be coordinated with the Battery Coastal Resilience as part of the overall Lower Manhattan strategy.

Climate Hazards: 100-year storm surge in the 2050s
Tools: Deployable Protection; Raised Edge; Structure Hardening
Status: City approves bond financing for project, BPCA does design and construction

THE FINANCIAL DISTRICT AND SEAPORT CLIMATE RESILIENCE MASTER PLAN

In order for Lower Manhattan to continue thriving, the City's approach to climate adaptation must address the complex reality of a physically constrained District threatened by a wide range of climate risks. Although near-term interventions in Two Bridges, the Battery, and Battery Park City are critical to the future of Lower Manhattan, there remains a gap in adaptation for the District as a whole at the Financial District and the Seaport. Although short-term flood protection measures are advancing in the Seaport and part of the Financial District, these two neighborhoods remain at risk to the range of climate hazards. To close the gap and protect this area, the City will complete the Financial District and Seaport Climate Resilience Master Plan over the next two years to develop a comprehensive design for a shoreline extension in this area and to establish a public benefit corporation that will finance, construct, and manage it.

This Lower Manhattan Climate Resilience Study revealed particularly complex constraints and vulnerabilities in the Financial District and the Seaport, where high climate risk and few adaptation options converge. Both neighborhoods have low-lying topography, with an average elevation of 8 feet compared with 13 feet in Battery Park City. Low-lying topography requires taller interventions that require more space and push the technical feasibility of existing adaptation tools. Physical space on existing land is limited in these two neighborhoods due to critical above-ground and below-ground infrastructure being concentrated at the waterfront. This physical context is further complicated by the circulation needed for the mix of active waterfront uses in these areas. Unencumbered open space between the buildings and water's edge is less than ten feet in width throughout the Financial District and Seaport (compared with over 300 feet in Battery Park City, the Battery, and Lower East Side), and much of this space is often filled with residents, tourists, and workers. Our strategy for drainage of stormwater is also limited by the capacity of the existing combined sewer system and by the lack of available real estate for upgrades to the system. This study found that many land-based approaches in this context would be infeasible and have highly negative impacts to the public realm and waterfront.

In 2014, the City released the Southern Manhattan Coastal Protection Study, also known as the Multi-Purpose Levee Study, which investigated the feasibility of outboard coastal protection on the east side of Lower Manhattan. Since then, the field of climate science has evolved, demonstrating that severe impacts of climate change may be felt sooner and at a lower threshold of global temperatures rising than previously thought. Since Hurricane Sandy, the City's understanding of climate science has also evolved, with a more detailed and up-to-date understanding of both chronic climate risks and extreme climate change-related events. The City has also studied and evaluated all land-based options within the constrained realities of the Financial District and the Seaport, before identifying the critical need to develop a shoreline extension solution.

EXISTING CONSTRAINTS IN THE SEAPORT

The Seaport's topography is low-lying with an aging bulkhead, making it particularly susceptible to flooding. Unlike other areas in Lower Manhattan, the Seaport has a relatively high edge compared to the upland interior, creating a 'bowl' effect where water that enters the District gets trapped. This presents challenges with interior drainage and requires complicated elevated tie-ins stretching two to four blocks inland for coastal adaptation projects. The street network in the Seaport is dense and narrow, further complicating the alignments of large-scale interventions.

The Seaport is concentrated with an array of above- and below-ground critical infrastructure and utilities that leave limited amounts of physical space for resilience measures. A high concentration of utilities runs along South Street, along with the elevated FDR Drive and the Brooklyn Bridge at the neighborhood's northern end. The State Department of Transportation requires a 3-foot berth around the FDR Drive's columns and footings, to protect the structural integrity of the infrastructure and provide space for maintenance and repairs. Flood walls at the height required for protection in the future may be too tall and large to fit under the FDR. The Con Edison Substation and the A/C subway tunnel are also located in this neighborhood and likely cannot have flood protection infrastructure with deep foundations built on top. In some cases, aging structures built on piles in the Seaport's waterfront may also be unable to support the weight of flood protection infrastructure.

The Seaport is also home to a historic district and a significant portion of the District's older buildings, two factors that make building-level measures challenging. Buildings that are less than six stories tall and were built before 1938, when the City's first modern building code was introduced, are particularly vulnerable to destabilization. Their shallow foundations and age may make these buildings more difficult to adapt to flood risk. Historic district regulations must also be taken into account for any permanent adaptation fixtures on buildings.

Lastly, the Seaport contains a vibrant mix of existing structures and commercial and recreational uses for residents, workers, and tourists on the waterfront, as well as ongoing construction on public realm and commercial redevelopment projects. Any resilience measures must be coordinated with this construction and integrated with the complex circulation and access corridors that this active waterfront requires.

EXISTING CONSTRAINTS IN THE FINANCIAL DISTRICT

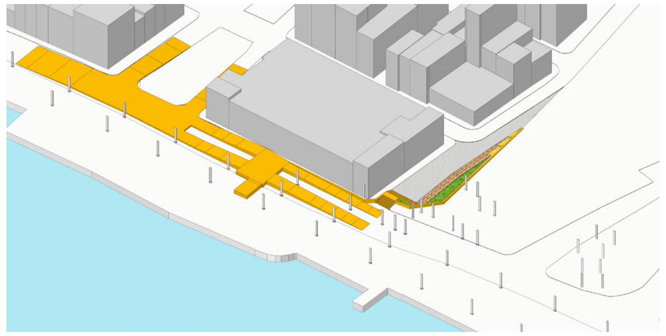
Like the Seaport, the Financial District's street network is dense and narrow, but packed with a higher concentration of large commercial office buildings. Open space and available real estate for implementing adaptation measures is especially limited in this neighborhood. South of Pier 11, the Financial District is even further constrained as the waterfront esplanade narrows and the elevated FDR Drive slopes down to street grade, leaving less available clearance and space for flood protection along the coastal edge. Further south, the FDR Drive becomes the underground Battery Park Underpass tunnel. This tunnel, like the subway in the Seaport, cannot have infrastructure with deep foundations built on top.

In addition to this complex network of vehicular transportation infrastructure, the Financial District also contains two important ferry terminals and transportation hubs, the Whitehall Terminal, where the Staten Island Ferry runs, and the Battery Maritime Building, where the Governors Island Ferry runs. The coastal edge is particularly complex where the entrance to the Battery Park Underpass intersects with pedestrian access to the Battery Maritime Building. Climate resilience projects must be integrated with the waterfront access and complex circulation patterns of cars and people that these ferry terminals require.

CONSTRAINED ON-LAND ADAPTATION

Within these complex constraints, many on-land adaptation projects in this area would have a negative impact on the public realm or be infeasible.

STREET RAISING



Raising streets over five feet high is extremely challenging and will result in the inaccessibility of many buildings along elevated streets and a negative pedestrian experience.

FLOOD WALLS

Low-lying topography requires taller interventions or flood walls of over 15 feet in height that would graze or even collide with FDR Drive where it drops down to street grade. Permanent flip-up deployable barriers would face a similar challenge, in addition to conflicts with subsurface infrastructure to accommodate the height of the wall and its foundations below ground.

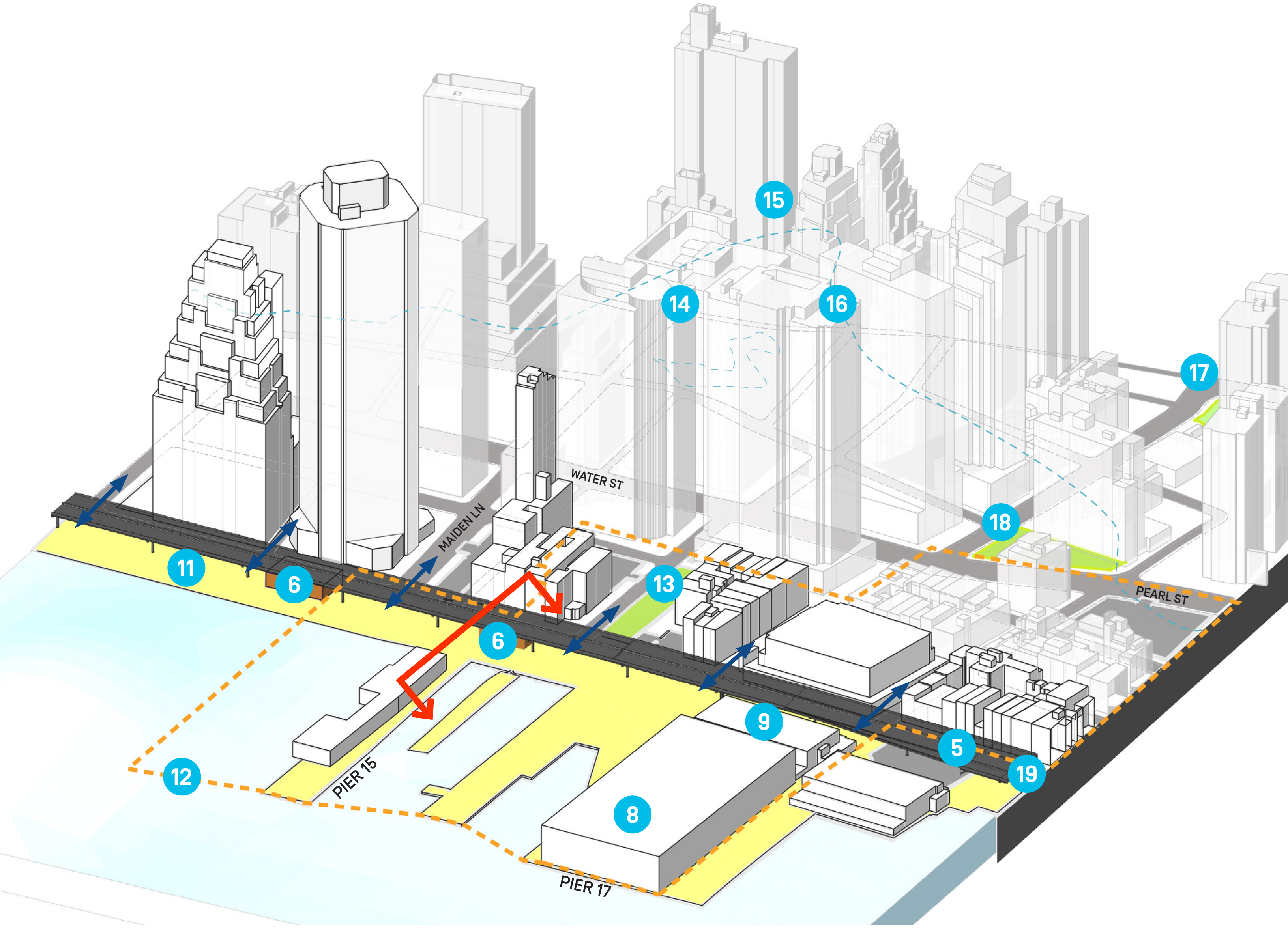
STOP LOGS

Other deployable measures, such as stop logs of up to 12 feet in height, would create an unpleasant experience for pedestrians near commercial uses along the waterfront and provide no public benefits.

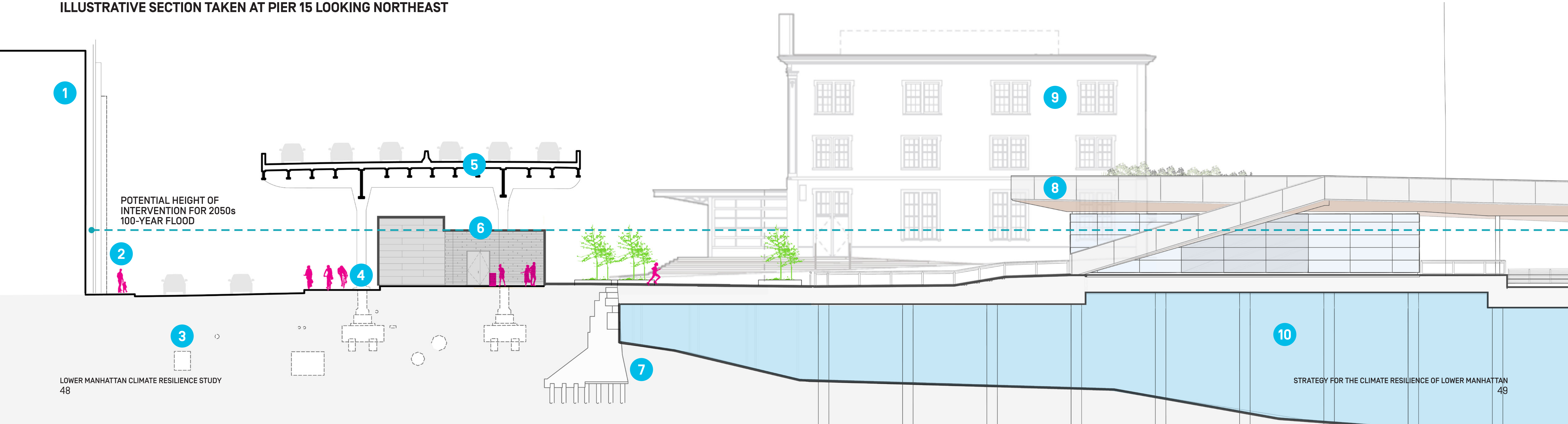
THE FINANCIAL DISTRICT AND SEAPORT CLIMATE RESILIENCE MASTER PLAN

EXISTING CONSTRAINTS IN THE SEAPORT

① HISTORIC BUILDINGS LESS THAN 6 STORIES TALL
② ACTIVE WATERFRONT ACCESS AND PEDESTRIAN CIRCULATION
③ EXISTING UTILITIES AND CRITICAL SUBSURFACE INFRASTRUCTURE
④ 3' OFFSET REQUIRED AROUND FDR COLUMNS AND FOOTINGS
⑤ ELEVATED FDR DRIVE
⑥ EXISTING STRUCTURES
⑦ VARYING BULKHEAD AND SUBSURFACE CONDITIONS
⑧ ACTIVE WATERFRONT COMMERCIAL AND RECREATIONAL USES
⑨ ONGOING CONSTRUCTION
⑩ PILE-SUPPORTED PIER
⑪ PILE-SUPPORTED STRUCTURES
⑫ HISTORIC DISTRICT BOUNDARY
⑬ WATERFRONT ACCESS AND VIEW CORRIDORS
⑭ LOW LYING TOPOGRAPHY
⑮ LARGE OFFICE BUILDINGS IN DENSE NETWORK OF NARROW STREETS
⑯ 2050s 100-YEAR FLOODPLAIN
⑰ FULTON STREET STATION (ONE BLOCK NORTH)
⑱ A/C SUBWAY TUNNEL
⑲ CONCENTRATION OF UTILITIES ON SOUTH STREET
↓↓ SECTION CUT
- - 2050s 100-YEAR FLOOD
🟨 ESPLANADE
🟩 PARK
⬚ HISTORIC DISTRICT
🟫 EXISTING STRUCTURES
↔ WATERFRONT CONNECTION



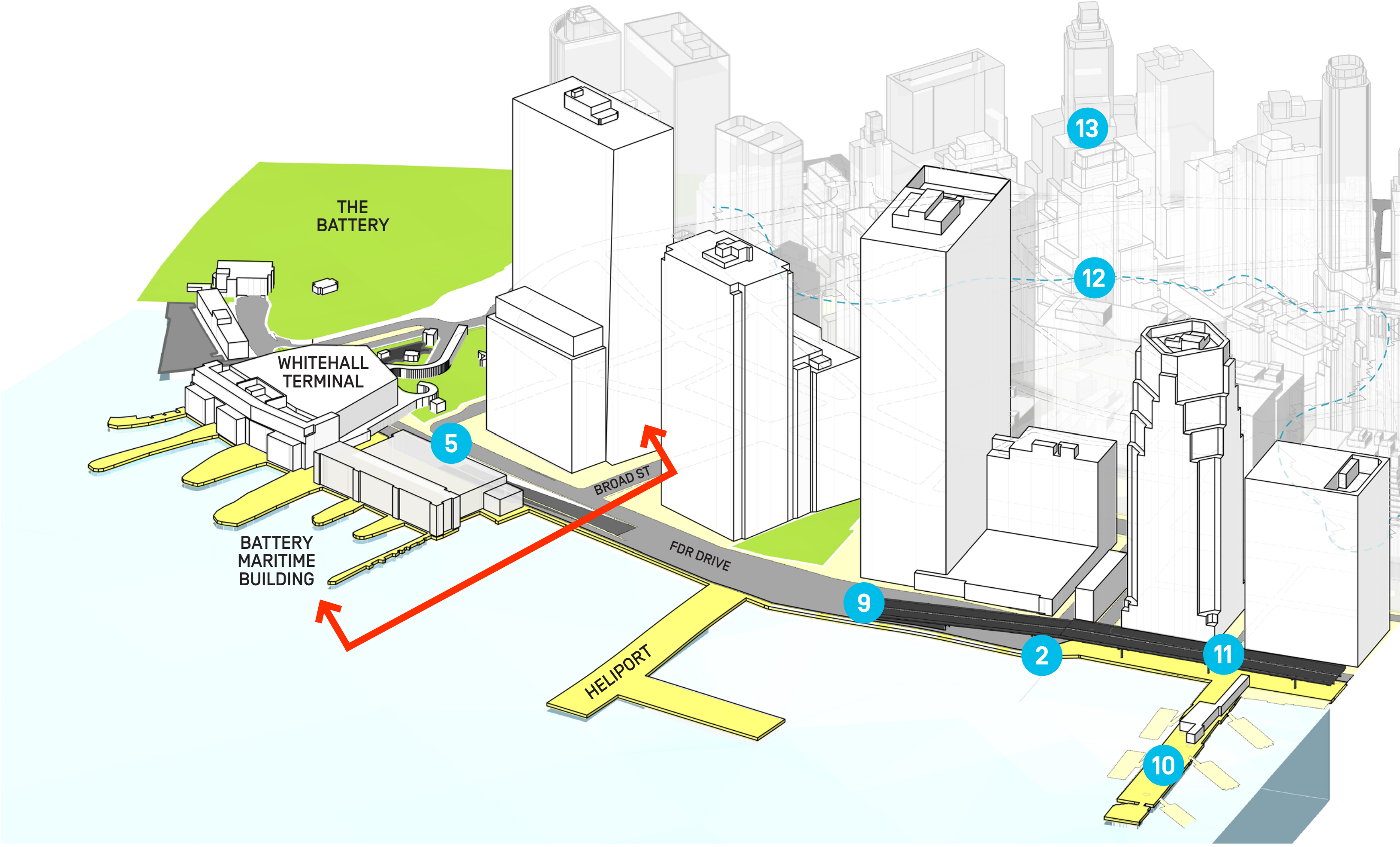
ILLUSTRATIVE SECTION TAKEN AT PIER 15 LOOKING NORTHEAST


POTENTIAL HEIGHT OF INTERVENTION FOR 2050s 100-YEAR FLOOD

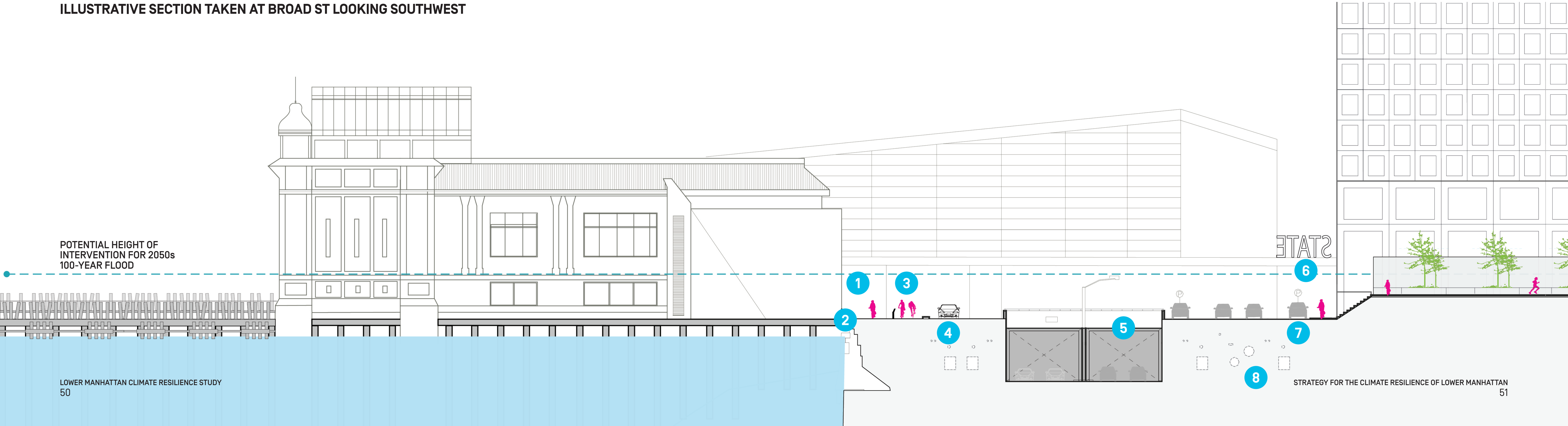
THE FINANCIAL DISTRICT AND SEAPORT CLIMATE RESILIENCE MASTER PLAN

EXISTING CONSTRAINTS IN THE FINANCIAL DISTRICT

① BATTERY MARITIME BUILDING ACCESS
② ESPLANADE NARROWING SOUTH OF PIER 11
③ PEDESTRIAN CIRCULATION
④ WHITEHALL AND BATTERY MARITIME BUILDING VEHICLE ACCESS LOOP
⑤ BATTERY PARK UNDERPASS
⑥ WHITEHALL FERRY TERMINAL PEDESTRIAN ACCESS
⑦ PARKING LANE
⑧ CRITICAL UTILITIES AND SUBSURFACE INFRASTRUCTURE
⑨ FDR GOING DOWN TO GRADE
⑩ PILE SUPPORTED STRUCTURES
⑪ ELEVATED FDR DRIVE
⑫ 2050s 100-YEAR FLOODPLAIN
⑬ LARGE OFFICE BUILDINGS IN DENSE NETWORK OF NARROW STREETS
↑ ↑ SECTION CUT
- - 2050s 100-YEAR FLOOD
🟨 ESPLANADE
🟩 PARK



ILLUSTRATIVE SECTION TAKEN AT BROAD ST LOOKING SOUTHWEST



THE FINANCIAL DISTRICT AND SEAPORT CLIMATE RESILIENCE MASTER PLAN

NEXT STEPS

More intensive planning is needed to protect the Financial District and the Seaport, both vulnerable and valuable to the city, from the full range of climate hazards and chronic stresses. As part of the overall strategy for Lower Manhattan, the Financial District and Seaport Climate Resilience Master Plan will bring a targeted focus to these two neighborhoods, closing a gap in climate protection for the District. The Master Plan will ground what has already been studied in more detailed, intensive planning to identify innovative solutions within the challenging constraints of the existing urban fabric.

In order to adapt to climate change within these constraints, the City must continue to study and include outboard development, or new land creation, in its toolkit. The outboard approach has the potential to comprehensively address sea level rise, storm surge, groundwater table rise, regular tidal inundation, as well as other climate impacts, in areas where other adaptation measures are infeasible to implement on existing land. The availability of new land also creates the potential to be partially financed through development, maximizing the integration of public-private resources and providing a critical funding source for implementation. The appropriateness of incorporating development sites would need to be carefully evaluated according to each specific location and neighborhood context. Where physical space is so limited that other adaptation tools may negatively impact the public realm, this approach could allow for more integration with co-benefits to the whole District, such as housing, open space, and job growth.

This resilience planning process will place priority on completion of a Master Plan for these two neighborhoods. The Master Plan will examine a range of outboard options, develop the design for an outboard solution, conduct deeper study of drainage management and other infrastructure, identify financing and governance strategies, and determine a first phase project to be implemented. The City will seek out innovative, ground-breaking ideas and technologies to develop a creative and implementable vision for the long-term future. The Master Plan will also outline a plan to establish a governance structure, which is critical for overseeing implementation of the project.

The City will continue to seek community and stakeholder input as it advances the design process for Interim Flood Protection Measures and individual capital projects in Two Bridges, the Battery, and Battery Park City. This study could not have been completed without many community stakeholders and leaders in Lower Manhattan with deep knowledge and expertise of climate change adaptation, who have advocated for innovative solutions and continued investment in climate resilience for the entire District. Building and sustaining a long-term coalition for resilience investment and shoreline extension in Lower Manhattan will be critical to delivering generational projects in this vulnerable and vital area of the City. As the City implements its overall strategy, it will continue to engage and partner with the communities of Lower Manhattan as a foundation for achieving climate resilience.

GLOSSARY

100-YEAR STORM	A storm that has a 1% probability of occurring in any given year.
10-YEAR RAIN EVENT	A very intense rain event that has a 10% probability of occurring in a given year.
2050S PROJECTIONS	Projections for climate impacts that will occur between 2050-2060.
2100 PROJECTIONS	Projections for climate impacts that will occur in 2100, the furthest date of available climate science.
BEDROCK	The solid rock that lies deep underground, beneath the loose deposits of soil that lie closer to the surface of the land.
BREACH POINT	An area along the coastal edge that, due to low elevation or aging infrastructure, allows water to easily flood inland.
BULKHEAD	A retaining wall along a waterfront.
CLIMATE CHANGE	Climate change refers to a significant change in the state of the climate that can be identified from changes in either the average state or variability of weather and that persists for an extended time period, usually decades, centuries, or longer.
CLIMATE VULNERABILITY	The degree to which systems and populations are affected by adverse impacts. It is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.
CO-BENEFITS	Added public realm benefits that come with climate adaptation measures, collectively improving quality of life and economic competitiveness of the area.
COMBINED SEWER OVERFLOW	The discharge of a mix of excess storm water and untreated wastewater into a waterbody (rivers, streams, estuaries, and coastal waters).
COMBINED SEWER SYSTEM	Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe.
DEPLOYABLE	Temporary flood barrier that can be installed in anticipation of a coastal storm and then removed thereafter.
DRY FLOODPROOFING	For non-residential buildings, a flood mitigation technique that results in the building resisting penetration of flood water, with walls substantially impermeable to the passage of water and structural components having the capacity to resist specified loads.
EXTREME EVENT	Unexpected, unusual or unpredictable weather or flooding compared to historical or future projected distribution. Extreme events include, for example, heat waves, cold waves, heavy rains, periods of drought and flooding and severe storms.
GROUNDWATER TABLE RISE	An impact from sea level rise. Groundwater table rise refers to the increase in the level of groundwater underneath a landmass. A rising and constantly shifting groundwater table can cause destabilization of building foundations, increase pressure and potentially infiltrate underground utilities with salt-water, and cause uplift in both buildings and underground utilities.
HEAT WAVE	A period of three consecutive days where temperatures rise above 90°F.
HYDROSTATIC PRESSURE	The pressure exerted by a fluid due to the force of gravity. Hydrostatic pressure increases in proportion to depth measured from the surface because of the increasing weight of fluid exerting downward force from above.
LAND RECLAMATION	The process of creating new land in a body of water from permeable fill, usually sediment from the ocean bed, riverbed, or lakebed.
MEAN HIGHER HIGH WATER (MHHW)	A tidal datum; the average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.
NEW YORK CITY PANEL ON CLIMATE CHANGE (NPCC)	The body of leading climate and social scientists charged with making climate change projections for the New York City metropolitan region.
OUTBOARD PROTECTION	Protection measures that are sited beyond, or as an extension of, existing land.
PASSIVE INTERVENTION	Protection measures that do not require the direct involvement of individuals to function properly once they have been implemented.
PILES	Vertical structural elements of a building foundation that are driven deep into the soil or bedrock for stability.
RESILIENCE	The ability to bounce back after change or adversity. The capability of preparing for, responding to and recovering from difficult conditions. The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner.
SEA LEVEL RISE (SLR)	An increase in sea level caused by a change in the volume of the world's oceans due to temperature increase, deglaciation (uncovering of glaciated land because of melting of the glacier), and ice melt.
SEEPAGE BARRIER	A waterproof barrier that is constructed in order to protect against the seepage of a liquid. In the context of this study, a seepage barrier is a deep wall that would be implemented underground to protect against the impacts of groundwater table rise.
STORM SURGE	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place.
STORMWATER DETENTION/ RETENTION SYSTEM	A structure designed to store an accumulation of stormwater runoff and release it at a controlled rate into an approved outlet sewer system of limited capacity.
STORMWATER MANAGEMENT SYSTEM	A series of practices and infrastructure used to collect, convey, detain, and retain stormwater.
TIDAL INUNDATION	An impact of sea level rise. Tidal inundation refers to the regular, persistent impacts from a higher tide on a coastal area.
URBAN HEAT ISLAND EFFECT (UHI)	The tendency for higher air temperatures to persist in urban areas as a result of heat absorbed and emitted by buildings and asphalt, tending to make cities warmer than the surrounding suburban and rural areas.
WET FLOODPROOFING	A flood mitigation technique designed to permit parts of the structure to intentionally flood, by equalizing hydrostatic pressures and by relying on the use of flood damage-resistant materials. With this technique, that parts of the building that are designed to flood are only to be used for parking, storage, building access, or crawl space.

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Recovery & Resiliency