# NYC'S RISK LANDSCAPE:

## A GUIDE TO HAZARD MITIGATION

MAY 2019

NYC Emergency Management

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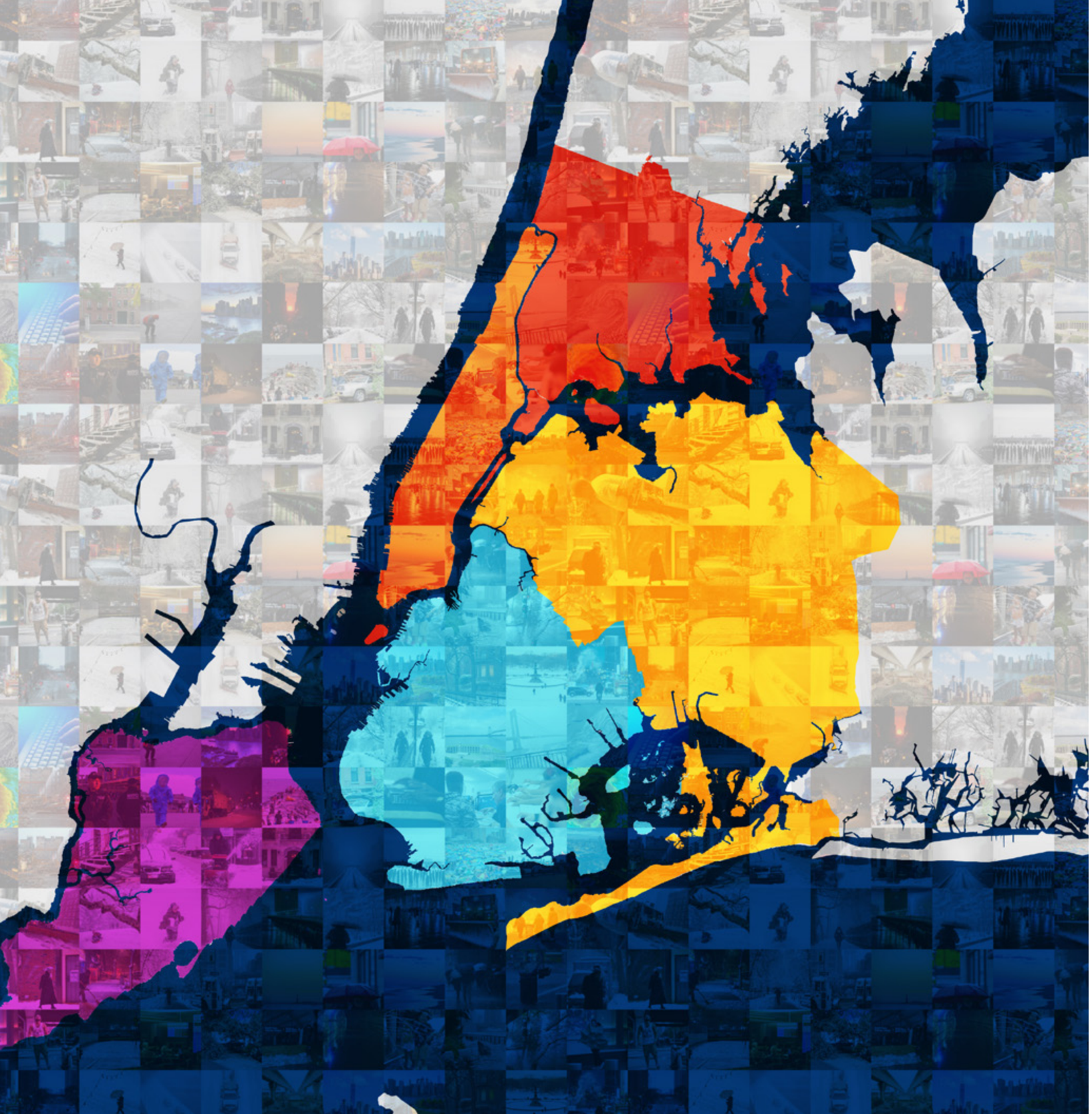


# FOREWORD

New York City is no stranger to disasters. Throughout its history, the City has been confronted with natural and man-made events. This includes fires, earthquakes, hurricanes, terrorism, and cyber-attacks. Each time we experience one of these events, we learn how to make our people, infrastructure and environment more resilient. These events underscore the need to assess and manage risk. We must learn from the past to shape the future.

Historically, the response-recovery and repeated damages cycle prevailed. This is changing. New York City has fundamentally shifted towards mitigation, the critical step that can break this cycle and reduce losses after a disaster. It is estimated that for every **$1 dollar invested** in hazard mitigation, an average of **$6 is saved** in the long-term.

This guide serves as an update to the *2014 New York City's Risk Landscape: A Guide to Hazard Mitigation* and builds upon New York City's continued efforts to create a resilient city. It represents a new chapter in the City's efforts to increase public awareness about the risks faced from a range of hazards and to help the City's partners invest in mitigation — now and in the future.

Prepared by New York City Emergency Management (NYCEM) in collaboration with a multitude of government agencies, organizations, private sector partners, and subject-matter experts, this guide includes:

- Key features of New York City's environment that makes it vulnerable to hazards; and
- Risk assessments for nine hazards discussing probability, location, and historic events; and
- Best practices and specific City-led strategies for managing risks associated with each of these hazards

*The 2019 Hazard Mitigation Plan (HMP)* website serves as the foundation for this Guide. However, this Guide is a communications tool to enhance public awareness about the risks that the City faces.

New York City will never be free from risk. However, by promoting awareness of hazards and encouraging New Yorkers to be better informed and prepared, we can create a safer city for ourselves and for generations to come.





# RISK LANDSCAPE OVERVIEW

# WHY WE WROTE THIS GUIDE AND WHAT IT OFFERS YOU

## AN OVERVIEW

New York City and New Yorkers have a reputation throughout the world as being resilient. Throughout its history, the City and its residents have lived through a host different disaster events both natural and manmade, yet we have worked hard to recover and became stronger because of these experiences.

This Guide represents the collaboration by the City with its many agencies, academic partners, private sector experts, community organizations, and federal and state partners to understand and address the hazards that can affect the community we have built over the past four centuries.

This Guide comes at a time when climate change, weather patterns, and general well-being is on everyone's mind:

- Will weather patterns get worse?
- Is my home prepared for the next storm?
- Are the most vulnerable people in my neighborhood safe?
- Are older buildings safe?
- Are there new and emerging threats I should be aware of?
- Is there any help or guidance on what I can do to keep my home or apartment building more habitable during extreme weather?

We developed this Guide to be a resource for New York City residents, businesses, and visitors that builds off a much bigger effort. The *2019 Hazard Mitigation Plan (HMP)* website is the foundation for this Guide. FEMA mandates that all jurisdictions create a Hazard Mitigation Plan (HMP) in order to be eligible for post-disaster funding, including Hazard Mitigation Grant Program (HMGP) funding. The plan must be updated every five years.

The 2019 HMP website is a living plan that ensures we can continuously identify, assess, and reduce our risk from an array of hazards threatening our city. Centralizing this information serves as a tool for businesses, communities, and government agencies. Due to its length and digital format, we wanted to create a hard copy of the website's salient concepts in a user-friendly document that serves as communications tool. This Guide draws heavily from the 2019 HMP website but for the sake of brevity, profiles a shorter set of hazards. It updates information. It adds information. And it is more reader friendly.

## WHAT CAN YOU GAIN FROM THIS GUIDE

This Guide is designed to deliver the following:

- A sense of the physical and social characteristics that may amplify the impacts of hazards;
- A deeper understanding of specific hazards, some of which are expected to worsen with climate change; and
- Familiarity with mitigation strategies implemented throughout the city to manage risks

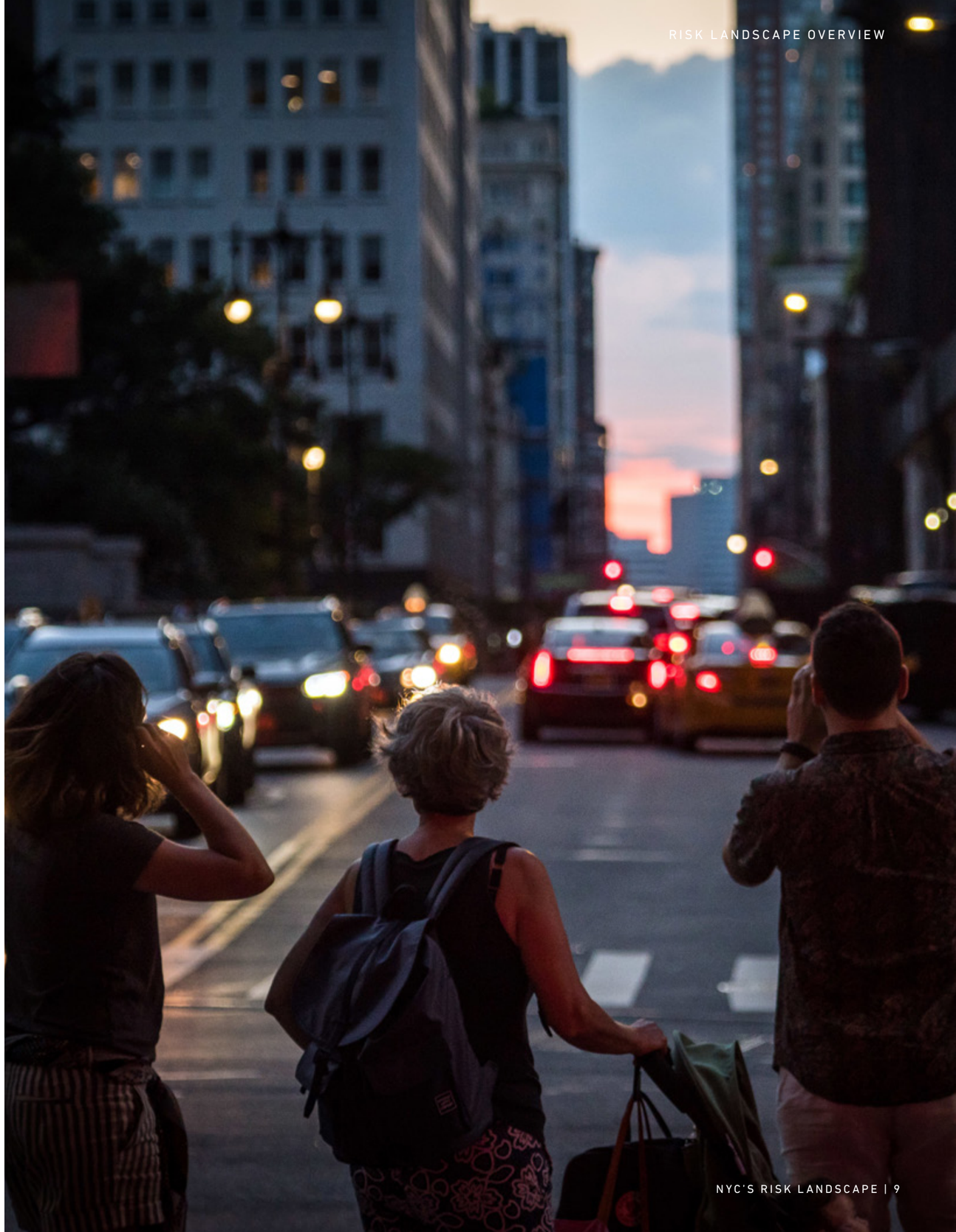
Like the 2019 HMP website, the Guide focuses on long-term hazard mitigation and not on short-term emergency response.

Hazards addressed in detail in this Guide are:

1. Coastal Erosion
2. Coastal Storms
3. Earthquakes
4. Extreme Heat
5. Flooding
6. High Winds
7. Winter Weather
8. Cyber Threats
9. Hazardous Materials Release: Chemical, Biological, Radiological, and Nuclear (CBRN)

Each hazard profile describes the nature of the hazard, identifies key risks it poses, and presents a sampling of strategies for managing the risks.





# HOW HAS MITIGATION EVOLVED IN NEW YORK CITY?

Historically, hazard events have led to the awareness and incentive to implement new mitigation strategies and capabilities. As displayed in the timeline, many changes to the Building Code and Zoning Resolution , creation of new laws and policies have come about due to major disasters. From the 1860s tenement fires resulting in required fire escapes in the First Tenement House Act, to the destruction of Sandy leading to the adoption of the Flood Resilient Text Amendment, we frequently invest in mitigation strategies after major events. Our hope is that plans such as this Guide, will help shift New York City's mentality towards pre-disaster mitigation — thereby breaking the response, recovery, repeated damage cycle.





## 1860

### TENEMENT FIRE TAKES 20 LIVES.

**1860:** The Building Code, the first comprehensive building regulations, enacted for the city.

**1867:** The First Tenement House Act requires fire escapes and one outhouse for every twenty occupants.

**1897:** The Second Tenement House Act ("Old Law") requires that all rooms open onto a street, rear yard, or air shaft.

**1899:** City enacts first citywide Building Code. Previous laws were enacted by the State.

TENEMENT FIRE
1860

## 1870–1900

### NEW YORKERS PROTEST LOSS OF LIGHT AND AIR FROM THE CONSTRUCTION OF TALLER BUILDINGS.

### NUMEROUS CHOLERA OUTBREAKS IN THE 1800S AND TUBERCULOSIS OUTBREAKS FROM 1900-1920

**1901:** Tenement House Act ("New Law") adds height restrictions on residential buildings, replaces airshafts with courtyards, and requires individual bathrooms in apartments.

## 1911

### TRIANGLE SHIRTWAIST FACTORY FIRE KILLS 146 PEOPLE, SPURRING ADOPTION OF MANY BUILDING SAFETY CODES

**1913:** The Labor Laws, strict fire safety and labor laws, established for factories.

**1916:** First Zoning Resolution (the first in the nation) established rules for "land use and build" to separate residential, commercial, and manufacturing districts, and control building heights.

**1929:** Multiple Dwelling Law replaces Tenement House Act. Establishes additional fire and health safety requirements for multi-family buildings.

TRIANGLE SHIRTWAIST FACTORY FIRE
1912

## 1915

### THE 42-STORY EQUITABLE BUILDING IS BUILT, BLOCKING LIGHT AND AIR FOR SURROUNDING ENVIRONMENT.

**1916:** Reactions to the Equitable Building completion, along with major shifts in population, transportation, technology, lifestyle changes, and government housing prompt the enactment of the Zoning Resolution. The Zoning Resolution uses the concept of incentive zoning, involving granting extra floor area in exchange for public amenities.

**1938:** Revisions to the Building Code address wind loads for skyscrapers and standards for multi-family buildings.

**1961:** Second Zoning Resolution focuses on reducing densities and requires open space. Introduces Floor Area Ratio, limiting building height based on size of lot.

**1968:** Building Codes of 1968 created. Revisions incorporate new technology and building practices, including performance criteria for building construction and design requirements for wind pressure (including buildings lower than 100 feet).

42-STORY EQUITABLE BUILDING
1915

The first building codes are implemented after the disastrious tenement fire in 1860. The outbreak of disease, the Triangle Shirtwaist Factory fire, and the insulated state of new buildings advised government officials to make more regulations to secure people's health.

1860 — 1880 — 1900

# 1969

**THE CUYAHOGA RIVER CATCHES ON FIRE IN CLEVELAND, OHIO AFTER CENTURIES OF POLLUTION FROM CLEVELAND'S STEEL MILLS AND FACTORIES.**

**1972:** The Nixon administration passes the Clean Water Act.

**1983:** Revisions to the New York City Building Codes of 1968 incorporate FEMA floodplain maps and mandate flood-resistant construction standards (for new or substantially improved buildings) that residents must meet to be eligible for the National Flood Insurance Program.

# 1984

**IN BHOPAL, INDIA, A PLASTIC PLANT, UNION CARBIDE, RELEASES 40 TONS OF METHYL ISOCYANATE (MIC) AND KILLS 5,000 PEOPLE AND INJURES 50,000 PEOPLE.**

**1984:** In reaction to the chemical release, the United States Congress passes the Emergency Planning and Community Right-to-Know Act.

# 1988

**QUEBEC EARTHQUAKE AND 1989 LOMA PRIETA EARTHQUAKE IN CALIFORNIA ARE WIDELY FELT.**

**1988:** Earthquakes prompt adoption of federal seismic guidelines for bridges and NYC seismic Building Code provisions and seismic Bridge Design guidelines.

**1995:** Local Law 17/19 of the Building Code update contains the first seismic provisions that consider soil and foundation conditions for new construction (effective February 1996)

**1998:** Department of Transportation Seismic Criteria Guidelines for bridges are adopted by all local bridge owners. Guidelines are revisited every 2 to 4 years.

**9/11 ATTACKS ON THE WORLD TRADE CENTER**
2001

**QUEBEC EARTHQUAKE**
1988

# 2001

**9/11 ATTACKS ON THE WORLD TRADE CENTER.**

**2001:** Collapse of World Trade Center reveals safety issues related to outdated 1968 Building Code.

**2008:** The Building Code is comprehensively revised after updated and retitled 'Construction Codes.' Modeled after International Code Council codes, City Code address natural hazards and include additional safety and emergency provisions. Must be updated every 3 years.

# 2003

**ON AUGUST 14, THE NORTHEAST REGIONAL BLACKOUT LEAVES 50 MILLION PEOPLE WITHOUT POWER.**

**2003:** City Council passes Executive Order 107 to implement Continuity of Operations (COOP) planning and programming for City agencies.

**2008:** The New York City Panel on Climate Change (NPCC), a body of leading climate and social scientists and risk management experts, convenes in 2008 to produce climate projections for New York City that would inform the City's decision-making as well as the public.

**2013:** Mayor Bloomberg convened the Second New York City Panel on Climate Change (NPCC2).

**NORTHEAST REGIONAL BLACKOUT**
2003

# 2012

**HURRICANE SANDY**

**2013:** Flood Resiliency Zoning Text Amendment encourages flood-resilient building construction throughout designated flood zones. Update requires that building be protected from flooding to a level 1 or 2 feet higher than the FEMA-designated flood elevation.

**2014:** 2014 Construction Codes: Effective Oct 1, 2014, they include new seismic standards for risk-based requirements and enhanced design requirements for soil liquefaction.

**GAS EXPLOSION IN EAST HARLEM**
2014

**GAS EXPLOSION IN EAST HARLEM**
2014

**HURRICANE SANDY**
2012

# 2014–2015

**A GAS EXPLOSION FROM A GAS LEAK AT AN APARTMENT BUILDING IN EAST HARLEM KILLS 8 AND INJURES 50.**

**A GAS EXPLOSION IN THE EAST VILLAGE CAUSED BY AN ILLEGAL TAP INTO A GAS MAIN KILLS 2 AND INJURES 22.**

**DURING THE SUMMER MONTHS, AN OUTBREAK OF LEGIONNAIRES RESULTS IN 133 PEOPLE CASES, WITH 16 FATALITIES.**

**2015:** City Council enacts 10 bills to enhance gas safety. The first set of bills bring into effect legislation that requires qualifications for those performing gas work and inspecting infrastructure, as well as institutionalizes transparency between utility companies and property owners with the Department of Buildings. The second set of bills creates requirements and penalties for homes building owners concerning emergency alert systems and gas piping defects.

**2015:** The NPCC releases the 2015 Report, stating that seven climate-change variables have the potential to affect the New York City area in the future.

**2015:** City Council passes bill that requires owners to register and quarterly inspect cooling towers. If a cooling tower tests positive for the bacteria that causes Legionnaires', the owner would have to follow DOHMH regulations to disinfect the system.

# 2016

**DURING A WIND EVENT, AN UNSECURED CRANE BEING OPERATED BY AN UNTRAINED OPERATOR, COLLAPSED IN MANHATTAN, INJURING 3 AND KILLING 1.**

**2016:** As a result, City Council passes bills to require the Department of Buildings to notify the Federal occupational Safety and Health Administration (OSHA) of any Construction Code violations, to increase the minimum and maximum fines for violations of the Building Code and Administration Code, to require that all cranes install anemometers, and to create an age limitations on cranes in NYC.

**CRANE COLLAPSE**
2016

Natural hazards and mad-made pollution prompt new building regulations and laws to advise civilians about imminent dangers.

1920 1940 1960 1980 2000 2020

## READERS WE WANT TO SERVE

New York City is a leader on issues related to disaster recovery, resiliency, and sustainability because our City government aggressively pursues those goals and because of the continued efforts of our community partners, researchers, policy makers, advocates, industry stakeholders, and concerned citizens. This Guide is intended for a broad cross-section of New Yorkers, and for residents ofther cities who are interested in risk reduction best practices.

While the work of updating the HMP and producing this Guide ended in 2019, the work of managing risk is ongoing, as we continue to implement strategies, assess them, learn, confer and then adapt and strengthen strategies as needed. This Guide serves as an abridged version of a much broader and comprehensive library of work that can be found through the HMP website at www.nychazardmitigation.com.

## WHO WAS INVOLVED AND WHAT WAS THE PROCESS?

In order to create this guide, NYCEM forged many partnerships and brought together a cross-section of government agencies, community members, and other stakeholders to share ideas, discuss current and future initiatives, and form a consensus on how to invest in long-term mitigation strategies.

## PLANNING TEAM

The Hazard Mitigation Planning Team (Planning Team), which served as the overall lead in updating New York City's Hazard Mitigation Plan (HMP), was comprised of New York City Emergency Management (NYCEM) staff — four planners from the Hazard Mitigation Unit, one specialist from the Geographic Information Systems (GIS) Unit, and additional staff from the Planning and Preparedness Division.

The Planning Team's responsibilities were to:

- Organize and manage working-group sessions with partners
- Develop and implement the community-involvement process
- Manage the identification, collection, and analysis of mitigation actions by the Hazard Mitigation Planning Partners
- Coordinate with Hazard Mitigation Planning Partners to identify and review relevant material for the HMP.

This labor intensive process involved working with nearly 40 agencies, private sector partners, community organizations that equaled nearly 200 individuals.

CLIMATE WORKING GROUP SESSION.





## FUTURE HAZARD MITIGATION PLAN REVISIONS

Although the HMP update and publication of this Guide concluded in early 2019, NYCEM and its partners continue to implement strategies, assess their effectiveness, conduct research, confer and adjust as required. The formal update of the 2019 HMP is scheduled for publication in 2024.





LEARN MORE ABOUT NYC

# INTRODUCTION TO NEW YORK CITY'S HAZARD ENVIRONMENT

When considering the hazards that put New York City at risk, the City's position as a global, coastal city and the sheer scale and diversity of its people, neighborhoods, buildings, and landscape illuminate why careful planning and hazard mitigation efforts are so important. This chapter examines New York City's most unique characteristics from several perspectives to describe how increased public awareness, creative planning, and actions taken today will prepare the City for the challenges in the future.

# THE NATURAL ENVIRONMENT

New York City's natural position on the water at the confluence of the Hudson River and Atlantic Ocean has had a powerful impact upon the City's history and prosperity.

Centuries of economic activity have altered the City's natural landscape, which has accelerated risk in some areas, but the wise maintenance of New York City's natural features and open spaces can also mitigate some of the harsher impacts of severe weather.

### FACTS: NYC SCALE AND SCOPE

- 520-mile coastline bordering ocean, rivers, bays, inlets, harbors, tidal straits
- 30,300 acres open space/parks managed by NYC Parks that covers 15 percent of the city
- 10,000 acres open space buffer inland areas from hazards of floods, high winds, and extreme weather

### KEY NYC RISK CONCERNS IN FUTURE

- Low-lying areas vulnerable to coastal storms, coastal erosion, flooding, and sea level rise
- Some areas more vulnerable to the impacts of earthquakes due to geology and artificial fill

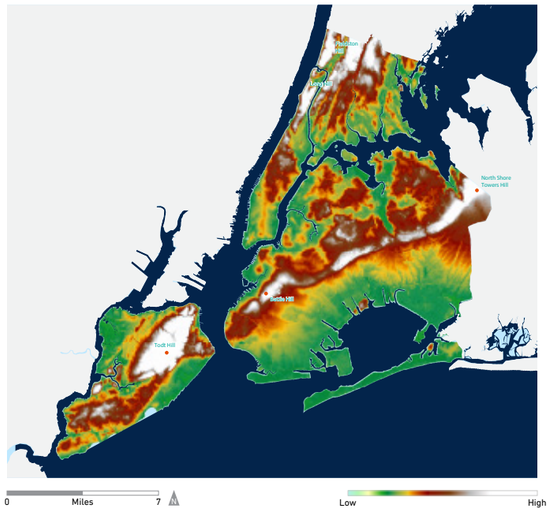
## TOPOGRAPHY

New York City's topography varies greatly across the five boroughs. The natural elevation ranges from less than 50 feet for most of Manhattan, Brooklyn, and Queens, to nearly 300 feet in northern Manhattan and the Bronx, and to 412 feet at the highest point, Staten Island's Todt Hill.

There are several barrier islands parallel to the Atlantic Ocean coastline, which serve as buffers against coastal storms. Beaches, dunes, and salt marshes absorb the most severe impacts of pounding waves and storm surges.

However, human intervention and land reclamation have altered the City's topographic landscape. Extensive stretches of very low-lying land constructed from landfills have been added over the years, making even more land along the coast vulnerable, particularly during coastal storms and other severe weather events.

**TOPOGRAPHY**
SOURCE: NYC DoITT




## A CITY SURROUNDED BY WATER

New York City's historic prosperity as a global and domestic trading center is due to its advantageous position on the water at the confluence of the Hudson River and the Atlantic Ocean. Together, New York City's five boroughs have over 520 miles of shoreline, touching numerous bays, rivers, and tidal straights including New York Harbor, Long Island Sound, the East River, Jamaica Bay, and the Harlem River.

Over the centuries, New York City's shoreline has been altered dramatically. Waterways have been dredged to accommodate larger ships, and piers and bulkheads have been built, and then later removed or modernized.

Landfills have been used to increase the acres of land that can be developed along shorelines. The extent of reclamation in Lower Manhattan, for example, is significant where Battery Park City and other big developments were built atop landfill.

This development approach has had significant economic benefit, but has an environmental cost — natural features that keep marine ecosystems healthy and buffer shorelines from the impact of coastal erosion and storms are lost, leaving people and property more exposed to the hazards of severe weather.

## OPEN SPACE AND THE NATURAL ENVIRONMENT

Coastal land preservation is important. The NYC Department of Parks and Recreation (NYC Parks) manages a vast amount of open space — 4,200 sites spanning over 30,300 acres, which represents about 15 percent of the City's land.

Beaches, boardwalks, and waterfront parks occupy 40 percent of this open space, over 30 percent (160 miles) of New York City's coastline.

Grasslands, wetlands, streams, and other natural areas comprise about one-third of the area managed by NYC Parks. These 10,000 acres serve a beneficial role to protect New York City by absorbing stormwater runoff and buffering inland areas from the impact of floods, high winds, and other extreme weather events.

## GEOMORPHOLOGY AND TERRAIN

Understanding New York City's terrain and geomorphology is critical to knowing why certain areas of New York City are so vulnerable to coastal storms and earthquakes.

New York City sits on land shaped thousands of years ago by a giant glacier known as the Wisconsin Ice Sheet. The Wisconsin Ice Sheet pushed south to this area about 20,500 years ago, carrying chunks of gravel, pebbles, and sand. It began to melt about 18,000 years ago, depositing rock debris at its edge and as it retreated, forming a terminal moraine — today's hilly area stretching through Staten Island, central Brooklyn, and Queens. Streams from the melting glacier formed outwash plains of sand, silt, and clay — today's low-lying areas along Staten Island's East Shore and areas in southern Brooklyn and Queens. During recent coastal storms, these areas were vulnerable to storm surges and will become even more vulnerable if sea levels rise in the future.

The City's unique geological characteristics also heighten an earthquake's seismic effects. As shown on the map, geologic conditions range from solid bedrock at ground surface (green) to artificial fill (blue). The sharp contrast between the soft artificial fill and the extremely hard bedrock amplifies shaking during an earthquake, increasing the risk of damage to many buildings.

Over the centuries, large areas in New York City have been filled in, covering soft sediments and marshes, to create acres for new building development. For example, Manhattan's Chinatown is on land created by filling the Collect Pond in the early 1800s. Buildings constructed atop artificial fill are at greater risk from earthquake hazards than those built in other areas.

**TOGETHER, NEW YORK CITY'S FIVE BOROUGHS HAVE OVER 520 MILES OF SHORELINE.**

# THE SOCIAL ENVIRONMENT

Every day, over 8.6 million residents go about their lives in New York City, a nonstop hub of commerce, culture, and opportunity that draws commuters, tourists, and immigrants from all over the world.

Hazards that threaten New York City, like Hurricane Sandy, put everyone at risk — resident and visitor alike. Although rebuilding commenced after Sandy, many New Yorkers still feel the emotional, financial, and physical repercussions.

The density of the City and the magnitude of the population are uppermost in the minds of planners and emergency managers, who also know that certain populations, such as the elderly, people with disabilities, the poor, and children, have a harder time recovering from storms, extreme weather events, and other hazardous events.

### FACTS: NYC SCALE AND SCOPE

- 8.6 million residents
- 400,000 daily commuters and visitors
- 5.5% population growth since 2010
- Density of 44 people per acre
- Large population of seniors, people with disabilities, low-income people, and others considered at-risk

### KEY NYC RISK CONCERNS IN FUTURE

- Millions of people at risk in dense urban area
- Population increase will put more people at risk, including segments who are vulnerable
- Climate change and socio-economic disparity could result in severe impacts upon low-income neighborhoods or more vulnerable population segments.

## POPULATION AND THE ECONOMY

More people than ever before are living in, working in, and visiting New York City.

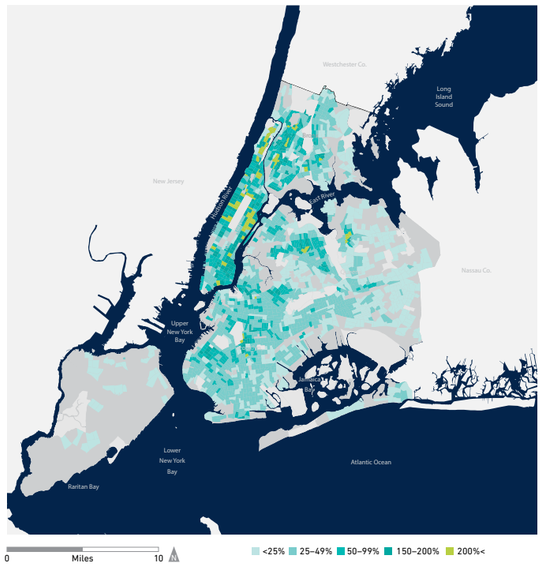
People continue to move here from around the country and the world because they see New York City as a mecca for opportunity and advancement.

New York City is one of the global financial capitals of the world. In fact, the City has the highest concentration of *Fortune* 500 and *Fortune* 1,000 headquarters in the United States; is home to top securities and law firms and international banks; and serves as a global center for the arts, fashion, media, and information technology. Major publishing houses, universities, and medical centers are also magnets.

Tourists are similarly drawn to New York City. Over the last ten years, visitor spending increased by over 50 percent, reaching a record of $43 billion in spending by 60.5 million visitors in 2016. Tourism provides jobs for 383,000 New Yorkers.

An average of 9 million people may be in New York City on any given day — a significant, densely packed population that must be kept safe in the face of hazardous threats, such as nor'easters, heat waves, and coastal storms.

**POPULATION DENSITY**
SOURCE: U.S. CENSUS 2010








## DEMOGRAPHICS AND VULNERABLE POPULATIONS

Although all New Yorkers are potentially at risk from severe weather and hazards, some segments of the population are more vulnerable than others. Recent population statistics show an increase in the number of seniors and children in New York City two population segments that could be more vulnerable to extreme weather events and hazards.

Other highly vulnerable groups are people with disabilities or others with access and functional needs, serious health conditions, people who are socially isolated, and households with limited English proficiency. In addition, low-income populations may have a harder time recovering from the impacts of hazards.

The following explains why these population segments are considered to be more vulnerable to the range of hazards detailed in the following chapters.

### Seniors

Seniors, one of New York City's fastest-growing demographic groups, face many challenges during severe weather events and other emergencies. Between 2000 and 2016, New York City's senior population increased by 17 percent, reaching 1.1 million or 13 percent of total population.

Almost 48 percent of senior New Yorkers are foreign-born and approximately 31 percent live alone — two factors that increase a person's vulnerability if they lack English-language proficiency or are socially isolated during emergencies.

Seniors are generally at higher risk during severe weather events or other emergencies if they have chronic health conditions or disabilities, rely heavily on medical services, hospitals, and nursing homes, or have limited access to emergency care. Seniors with mental health conditions, such as dementia, anxiety, or depression, are also at higher risk during these times. Seniors with limited mobility might require accessible transportation, or help with refilling prescriptions and other basic tasks.

Power outages during an emergency can endanger seniors who need elevators to reach their apartments, keep medications refrigerated, or use oxygen tanks, motorized wheelchairs, or other power-dependent medical equipment. Where seniors live contributes to their vulnerability. Approximately 8 percent of New York City's seniors with disabilities live within the 1 percent annual chance floodplain — the area commonly known as "100-year floodplain" that has a one-percent-or-greater chance of experiencing coastal or riverine flooding in any given year — in communities such as the Rockaways, Coney Island, and Brighton Beach. This percentage does not include seniors living in nursing home, adult care facilities, and other institutions.

As shown in the table, nearly 18 percent of adult care facilities in New York City are located within the floodplain — a situation that puts a significant number of the most vulnerable people at risk during extreme weather events.

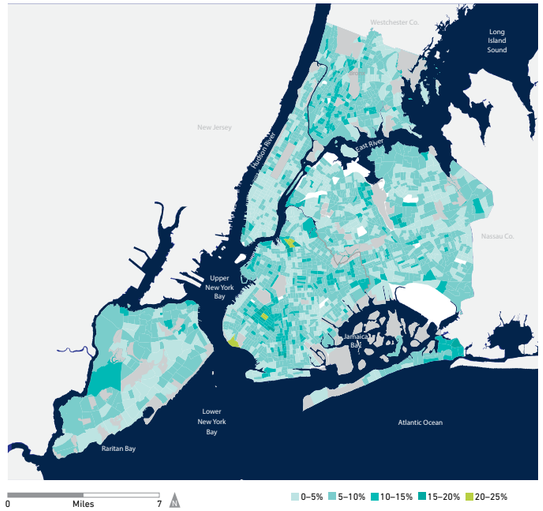
SOURCE: UNITED STATES CENSUS, 2012-2016 AMERICAN COMMUNITY SURVEY — SUMMARY FILE

| VULNERABLE DEMOGRAPHIC GROUP | % OF NYC POPULATION | % OF GROUP DISABLED | % OF GROUP LIVING BELOW FEDERAL POVERTY LEVEL |
|---|---|---|---|
| **Seniors (over 65)** | 13% | 36.7% | 18.7% |
| **Young People (under Age of 18)** | 21.2% | 3.4% | 29% |

NEW YORK CITY HEALTHCARE FACILITIES LOCATED IN THE 1 PERCENT ANNUAL CHANCE FLOODPLAIN
SOURCE: NYS DOH, NYCEM, FEMA

| FACILITY TYPE | NUMBER | NUMBER IN 1 PERCENT ANNUAL CHANCE FLOODPLAIN | PERCENT IN 1 PERCENT ANNUAL CHANCE FLOODPLAIN |
|---|---|---|---|
| **Adult care facilities** | 76 | 14 | 18% |
| **Adult care facility beds** | 10,968 | 2,203 | 20% |
| **Nursing homes** | 171 | 14 | 8% |
| **Nursing home beds** | 47,982 | 3,648 | 8% |

NEW YORK CITY POPULATION UNDER THE AGE OF FIVE BY CENSUS TRACT
SOURCE: U.S. CENSUS 2010.




## Children

Approximately 30 percent of all New York City households have children under the age of 18, which is also a growing segment of the population. Children are particularly vulnerable to hazards because they depend on parents and other adult caretakers for food, shelter, transportation, and guidance. In addition, the emotional stress that follows a hazard event may linger longer in children than in adults, according to the Federal Emergency Management Agency's mental health experts.

Children who are poor or have disabilities are at even greater risk. In New York City, approximately 29 percent of people under the age of 18 live below the federal poverty level, with over 150,000 of these children being under the age of five. About 3 percent of New York City's children under the age of 18 have some form of disability.

## Low-income Population

Approximately 1.7 million people, or 20 percent of New York City's population, live below the federal poverty line. Of this 1.7 million, over 30 percent are children under 18 years old. The greatest concentrations of low-income populations are in the South Bronx and Upper Manhattan, and in scattered neighborhoods in Brooklyn.

The New York City Housing Authority (NYCHA), the largest landlord in the City and the largest public housing authority in the United States, houses over 400,000 low-income tenants. During severe weather events and other emergencies low-income tenants are often vulnerable if building infrastructure fails.

## Affordable, Resilient Housing

When New York's economy booms, rents and home prices often rise. In recent years, the number of people seeking affordable housing coupled with the loss of homes that were damaged by Hurricane Sandy in 2014 have put additional pressure on New York City's tightly constrained housing market. Housing units are being added, but the supply may not be growing fast enough to meet the demand among middle- and lower-income families and new arrivals.

In the future, the number of housing units added is expected to grow significantly, and New York City has made access to affordable housing a policy priority. In 2014, New York City's Housing New York (HNY) set its goal to create and preserve 300,000 affordable units by 2026. As of May 2019, the administration has financed 109,767 affordable homes for 275,000 residents.

## Rental Housing

Most New Yorkers rent their housing. According to estimates from the 2017 New York Housing and Vacancy Survey, approximately half of New York City's renter households are considered "rent-burdened" — spending more than 30 percent of the household's pre-tax income on rent, unassisted by public housing or other housing vouchers. Rent-burdened households have a very limited margin to cope with unexpected financial expenses — a margin that shrinks if people in the household also lose income due to a hazard event.

If someone's rental home or apartment is damaged by an extreme weather event or other hazard, finding an affordable place to stay while repairs are being made — even temporarily — can be a serious challenge, given New York City's limited supply of affordable housing. To avoid paying higher rent for temporary shelter or being homeless, some people choose to remain in their damaged homes — a choice that comes with its own health hazards.

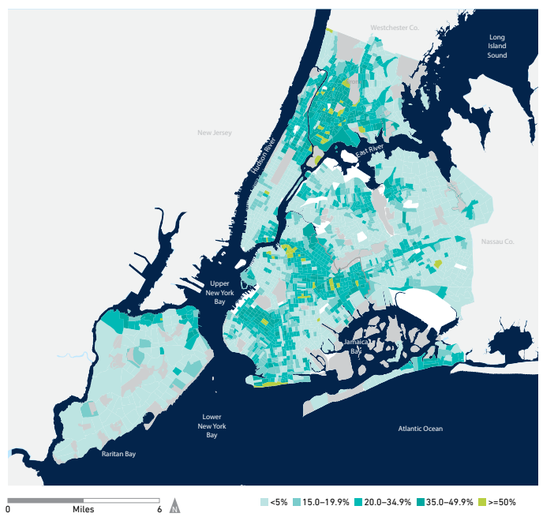
### FACTS: NYC SCALE AND SCOPE

- Housing units: 3.5 million
- Rental units: 2.1 million
- 2010-2017 growth: 141,000 units
- 30% of new units in Brooklyn
- Growing neighborhoods — Long Island City, Williamsburg, Hudson Yards/Chelsea, Hell's Kitchen, Downtown Brooklyn
- New permits: 79,000 units

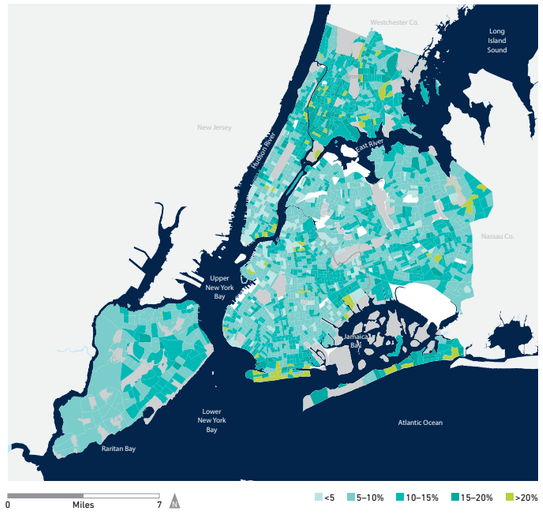
### KEY NYC RISK CONCERNS IN FUTURE

- City rental vacancy rate: 3.6%
- 50% of rental households pay over 30 percent of income on rent
- Climate change and socio-economic disparity could result in severe impacts upon low-income neighborhoods or more vulnerable population segments

POPULATION UNDER POVERTY LEVEL
SOURCE: U.S. CENSUS 2010



PERCENT OF NON INSTITUTIONALIZED RESIDENTS WITH A DISABILITY
SOURCE: U.S. CENSUS 2010




## Language

New York has one of the most diverse populations of any major city in the United States. In 2012, New York City was home to the largest foreign-born population in the United States — 3.1 million people, an historic high that represented 37 percent of the City population. For example, in 2012, nearly half of all residents in Queens were foreign-born.

Over 200 languages are spoken in New York City and nearly half of all New Yorkers speak a language besides English at home. According to the 2012-2016 American Community Survey, an estimated 23 percent of New Yorkers had limited English-speaking proficiency. Limited English-proficiency can put individuals at higher risk during an emergency because they might not be aware of or fully understand evacuation orders, instructions on how to access critical City services, directions from first responders, or other warnings.

## Populations with disabilities

According to the 2012-2016 American Community Survey, approximately 11 percent of all New Yorkers, 37 percent of its seniors, and 3 percent of young people under the age of 18 have at least one disability. New York City's population with a disability increases with age.

As shown in the chart below, there are four major categories of disabilities among groups that the United States Census assesses.

FOUR MAJOR CATEGORIES OF DISABILITIES
SOURCE: U.S. CENSUS

| DISABILITY CATEGORY | DEFINITION |
|---|---|
| **Sensory disabilities** | Blindness, deafness, or severe vision or hearing impairment |
| **Physical disabilities** | Long-lasting conditions that substantially limit one or more basic physical activities, such as walking, climbing stairs, reaching, lifting, or carrying things |
| **Self-care disabilities** | Conditions lasting six or more months that make it a challenge to dress, bathe, or move around inside the home |
| **Go-outside-the-home disabilities** | Conditions lasting six or more months that make it difficult for people to shop or to visit a doctor's office by themselves |





# THE BUILT ENVIRONMENT
## BUILDINGS

New York City's building stock encompasses approximately one million structures that vary by construction type, age, and use — everything from super-tall skyscrapers to brownstones and beach bungalows.

These buildings occupy an extremely large area and reflect a wide variety of uses and construction types — single-family, freestanding wood frame structures; attached masonry row houses; public housing developments; mid- and high-rise apartment complexes; low-rise retail districts; and massive commercial buildings and skyscrapers. Although New York City's assets have become safer and more structurally sound as building codes and land use laws have improved, the built environment remains vulnerable to a variety of natural and non-natural hazards. For example, buildings located within the floodplain or the storm-surge zone are susceptible to flooding and/or coastal storms. Buildings along the coastline are also vulnerable to the impact of long-term coastal erosion. New York's many older, unreinforced masonry buildings are at a higher risk of damage during earthquakes than other buildings made from sturdier materials or buildings that have been recently reinforced.

### FACTS: NYC SCALE AND SCOPE

- 145,000 acres of usable land
- 1 million buildings
- $2.4 trillion market value
- High percentage of older wooden and masonry buildings

### KEY NYC RISK CONCERNS IN FUTURE

- Structures could be at risk if intensity and severity of natural events increases due to climate change
- Older buildings at greater risk from high wind, heat, winter weather, earthquakes, and floods

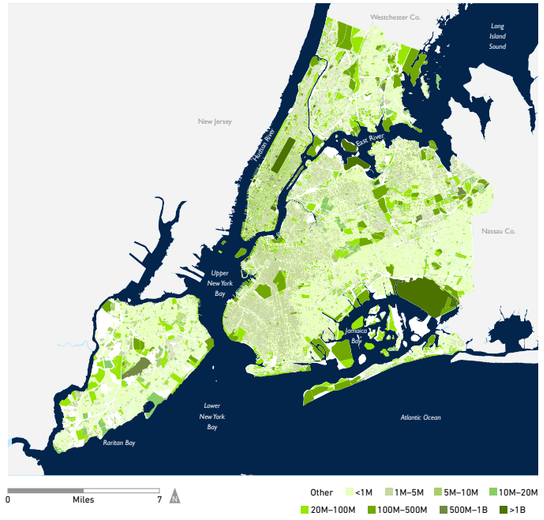
Each building has a unique set of characteristics that may amplify its vulnerability to hazards.

The following are examples of how risk-mitigation teams think about New York City's building stock to keep property and people safe.

## Market Value

To illustrate the value of what mitigation efforts seek to protect, according to the most recent data from the New York City Department of Finance, New York City's total building market value is $2.4 trillion dollars. By applying the Hazards U.S. Multi-Hazard (HAZUS-MH) formula for determining the content value within these buildings (percentage of the building value by land use), it is estimated that New York City's total content value is approximately $967 billion, an increase from $708 billion in 2014. Manhattan accounts for the largest proportion with approximately 40 percent of the City's building value and 45 percent of its contents value.

MARKET VALUE OF PROPERTIES IN NYC
SOURCE: MAPPLUTO 17V1 AND DEPARTMENT OF FINANCE



## Construction Codes, Safety, and Other Regulations

New York City's Construction Codes and Zoning Resolution control the way buildings are designed, built, occupied, and maintained. The Zoning Resolution regulates building size, use, location, and density to shape the character of New York City's neighborhoods and maintain residents' quality of life. The Construction Codes specify standards for design, construction, and maintenance of individual buildings to protect public safety, health, and welfare.

Over the years, New York City's built environment has become safer and more structurally sound over the years as zoning laws and Construction Codes have evolved and modernized. However, much of the City's building stock was built before modern codes were adopted and this building stock is therefore potentially more vulnerable to certain hazards.

In 2008, New York City adopted and applied its Construction Code to all new construction. These codes are modeled after the International Code Council codes and are updated every three years. Many of the most recent code provisions address natural hazard mitigation, including new standards to protect buildings from earthquakes, extreme temperatures, flooding, wind, and winter weather. The City has actively incorporated resiliency into its building regulations since 1983, when FEMA first released its Flood Insurance Rate Maps (FIRMs) for New York City, setting the boundaries of the 100-year floodplain. Today, New York City has further specified these requirements in Appendix G of its Building Code.

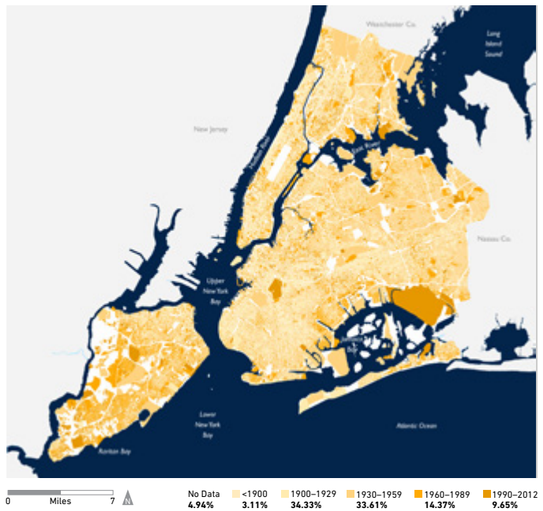
## Materials and Age

A building's age can be indicative of its structural vulnerability to certain hazards, because older buildings that were constructed according to less stringent codes are more likely to sustain more structural damage during a severe weather event than newer buildings.

Newer buildings using engineered materials like steel, concrete, and reinforced masonry are more capable of resisting significant environmental events, particularly if they were designed to meet modern standards such as those contained in the Building Code of 1968 or more recent iterations. New York City's stock of one- and two-story, low-rise buildings are usually wood-framed and are more likely to sustain structural damage from water and electrical-short fires during floods. Unreinforced masonry buildings also have a higher risk of earthquake damage than newer buildings.

Retrofitting older buildings to current, safer standards is a solution, but this can be an expensive option for owners and may not completely eliminate risk to the building from some types of hazards.

**NEW YORK CITY BUILDINGS BY AGE**
SOURCE: MAPPLUTO 17V1 AND DEPARTMENT OF FINANCE




## Fire Code

Fire is the most common and lethal hazard for city dwellers. New York City's fire regulations have significantly influenced the way that buildings are sited, designed, and constructed, as the regulations have evolved from a focus on protecting property to protecting people. Fire protection provisions, which are part of New York City's Construction Codes, were enacted to limit the potential for fire to develop in an enclosed space, to protect against fire spreading between floors and between buildings, and to ensure that people can evacuate safely.

## Density

Row houses, brownstones, and other buildings that are connected to one another have greater stability during severe weather events than isolated buildings. When vacant lots are interspersed among unreinforced masonry buildings, buildings are at higher risk of collapse.

## Maintenance

For any building in New York City, lack of adequate maintenance can increase its vulnerability. A light-frame building constructed decades ago according to less stringent codes is more likely to sustain structural damage during a moderate wind event than a newer building made from the same materials. Proper maintenance of older buildings is an important mitigation initiative.





Prolonged exposure to weather — daily and seasonal temperature changes, driving rains, repeated ice and snow cycles — affect most materials used in a building's exterior. The longer a material is exposed to the weather, the higher the risk of degradation.

Most building envelopes combine several materials that weather at different rates. Damaged, rusted, or cracked façade material may fall and injure pedestrians. Lack of sufficient or timely façade repair and maintenance can endanger the public, even without a weather-related hazard or fire.

**FOR ANY BUILDING IN NEW YORK CITY, LACK OF ADEQUATE MAINTENANCE CAN INCREASE ITS VULNERABILITY.**

### FACTS: NYC SCALE AND SCOPE

- 22 million people in greater metro region rely upon interdependent infrastructure.
- NYC has a significant number of critical systems that supply energy, telecommunications, transportation, and water

### KEY NYC RISK CONCERNS IN FUTURE

- Critical infrastructure must be maintained in top operational condition.
- Infrastructure disruptions from natural and manmade events in one sector could disrupt other sectors.
- Much of this infrastructure is aging and requires continued, extensive maintenance.

# INFRASTRUCTURE

A vast network of critical infrastructure enables millions of people to live in, work in, and travel around the City — a complexity of New York City's built environment that is unique due to its extremely large scale. The following sections describe a high level overview of the energy, telecommunications, transportation, and water-supply systems.

## ENERGY INFRASTRUCTURE

New York City's energy infrastructure, one of the most complex and reliable in the world, provides electric, natural gas, and steam to power a City of 8.6 million people. The following sections describe how these networks are vulnerable to hazards, how operators are minimizing risks from those hazards, and New York City's efforts to increase reliance upon sources of renewable energy.

## ELECTRIC

Two electric suppliers own and operate New York's in-city electric generation system:

- Con Edison, which has a 294 square-mile service area, distributes electricity to the 3.1 million electric customers, co-generates electricity at its East 14th Street Manhattan steam plant, has 46 area substations, and has one Westchester substation to supply the Edenwald network in the Bronx.
- PSEG-Long Island, which provides service to 32,757 customers on the Rockaway Peninsula in Queens, has three substations in Rockaway Beach, Arverne, and Far Rockaway.

These networks are robust, but they are still vulnerable to extreme weather conditions. High winds and icy winter storms blow down power lines or cause trees to fall and topple the wires affecting areas that have above-ground power lines including Staten Island and parts of Brooklyn, Queens, and the Bronx. Floods pose a risk to New York City's power generation plants located in the 1 percent annual chance floodplain. Extreme heat can push the power demand for air conditioning so high that it exceeds the grid's delivery capacity, risking disruptive power outages.

After Hurricane Sandy in 2012, Con Edison invested $1 billion in a four-year plan to insulate its infrastructure from future weather events. Con Edison has redesigned networks, underwater transformers, and reclosers, and is using stronger cables that release from utility poles if and when trees knock them down — an approach to cut the cost and time needed to bring the network back into service.

## Natural Gas

Natural gas meets approximately 65 percent of New York City's heating needs and fuels more than 98 percent of the in-city electricity production at power plants.

Four privately owned pipelines transport natural gas from the Gulf Coast, Western Canada, and elsewhere to local interconnection points (city gates). An intra-city transmission system delivers high-pressure gas to power plants.

Regulator stations reduce the pressure of the gas, channel it into a vast network of underground mains, and deliver the gas to customers. The two suppliers in New York City are:

- Con Edison supplies natural gas to 897,979 gas customers (as of January 1, 2018) in Manhattan, the Bronx, and northern Queens.
- National Grid supplies natural gas to 1.4 million customers in Brooklyn, Staten Island, and south Queens.

To keep New Yorkers safe, the utilities replace miles of aging cast iron and unprotected steel pipes each year with plastic and coated steel mains, and also monitor underground environmental conditions. Even a new pipe, for example, can be vulnerable if the ground underneath it is undermined by free-flowing water or constructed with inadequate backfill.

Gas explosions are rare, but occur either due to human error or from malfunctioning equipment. Utilities regularly use leak-detection surveys to monitor the gas system, respond to the public's reports of gas leaks, and replace leak-prone pipes as soon as they are reported.

To reach all segments of New York City's diverse population, the utilities use multilingual gas safety and leak-awareness campaigns to encourage people to call them or 911 if they detect any gas odor.

## Steam

In 2017, Con Edison supplied 23 billion pounds of steam to customers for heating, cooling, humidification, and sterilization. Con Edison operates five steam-generating plants in New York City — four in Manhattan and one in Queens. The Manhattan steam system is the largest in the United States — a 105-mile network of underground pipes that delivers steam to over 1,650 customers south of East 96th Street and West 89th Street.

Con Edison's steam customers are large building complexes, such as Rockefeller Center, the Metropolitan Museum of Art, and major hospitals. The service eliminates their need to own and maintain their own boilers — an attractive, cost-effective option that lowers the expense of operating large building complexes in Manhattan.

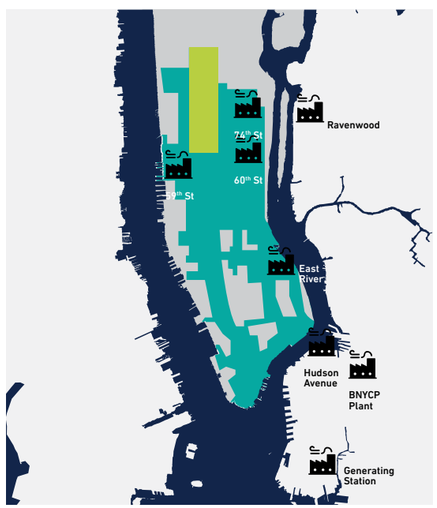
Steam pipe explosions, although infrequent, can happen if water hammers, or pressure surges, puncture pipes. These types of explosions, one of which occurred in Manhattan's Flatiron District in July 2018, could potentially endanger people, underground infrastructure, utility services, and nearby buildings, as well as result in asbestos releases.

## Renewable Energy

New York City has prioritized use of efficient energy sources to power City-owned buildings and to expand solar deployment. In 2018, New York City Council passed a bill stating that all City-owned buildings will be powered by green energy by 2050, with an interim goal of reaching 50% by 2030. Under Mayor de Blasio, New York City increased its solar production six-fold, through programs such as Solarize NYC and by adding solar equipment on rooftops of NYCHA buildings.

In 2015, the de Blasio administration announced its goal to reduce the City's greenhouse gas emissions 35 percent by 2025 and 80 percent by 2050. As of today, the City has reduced its emissions by 15 percent by creating more stringent energy-efficiency codes for buildings, investing $500 million in building energy efficiency improvements, investing in long-term efficiency improvements through the NYC Retrofit Accelerator program, and encouraging companies to reduce emissions through the NYC Carbon Challenge.

**CON EDISON STEAM NETWORK**
SOURCE: CON EDISON








# TELECOMMUNICATIONS INFRASTRUCTURE

New York City's telecommunications infrastructure supports broadband, mobile service, landline service, cable TV, and satellite services to 8.6 million residents, 4.5 million workers, 268,000 businesses, and over 60.5 million annual visitors. New York City's population density, volume of transactions, fast-paced business culture, and desire for the latest technology put extraordinary demands on the telecommunications infrastructure for connectivity, speed, and reliability.

Service providers include four major wireless providers (AT&T, Verizon, Sprint, and T-Mobile), several Mobile Virtual Network Operators (MVNO) that use these wireless networks and resell service, and several cable TV operators that also provide a mix of Internet and telecom services.

## Telecommunications Reliability and Risk

Keeping New York City's telecommunications systems running is a top priority for safety and security. Network operators are highly sensitive to the hazards that cause networks to go down — electricity power outages, damage to underground cables during excavations, and damage to overhead cables and antennas from high winds, lightning, fires, or human error. Network components are highly sensitive to heat, dust, and humidity, and any portion of a network situated within a flood zone is at risk during a flood.

New York City also identified the telecommunications regulatory regime as a risk factor. The telecommunications regulatory regime is considered a risk factor because no single entity regulates or enforces generally applicable rules to promote resiliency across the entire telecommunications sector. National, state, and local regulatory authorities have jurisdiction over some pieces of infrastructure and service, but not others. Recently, the FCC has taken action to preempt state and local regulatory authority in areas that are important to infrastructure resilience, such as the exercise of local authority following natural disasters and regulations pertaining to equipment siting.

# TRANSPORTATION INFRASTRUCTURE

The transportation infrastructure serving New York City is sprawling and complex, comprising large, interconnected rail, roadway, air, and waterway facilities that are all essential for daily travel, tourism, and commerce. Disruption of this system can separate families, thwart commutes, and disrupt critical business, government, healthcare, and other operations. Most importantly, disruption can also hinder emergency response. This section describes the risks posed to each component of New York City's transportation infrastructure.

## Rail Infrastructure

New York City's commuter and freight rail systems are among the most complex in the country. These interconnected subway and railroad networks carry two-thirds of all rail riders in the United States. New York City is served by three rail operators:

- The Metropolitan Transportation Authority (MTA), the nation's largest transit authority, is run by New York State. The MTA runs New York City Transit, an enormous subway system carrying 5.6 million riders daily within the City; Long Island Rail Road, which connects Long Island and New York City via trains operating out of Penn Station; and Metro-North Railroad, which connects New York, New Jersey, and Connecticut via trains operating out of Grand Central Terminal.
- The Port Authority of New York and New Jersey (PANYNJ) provides commuter rail service between New Jersey and New York City via PATH trains.
- Amtrak uses Penn Station, its busiest hub, to link New York City with Amtrak's national rail system.

All rail service is vulnerable to electrical power outages, which may cause a shutdown. New York City rail networks are also vulnerable to coastal storms and flooding, because much of New York City's rail and subway infrastructure is either near the waterfront or in low-lying areas.

High winds can derail or tip rail cars that operate above ground. Other hazardous weather conditions can also cause derailments. For example, steel tracks can shrink during extremely cold weather or buckle during periods of extreme heat.

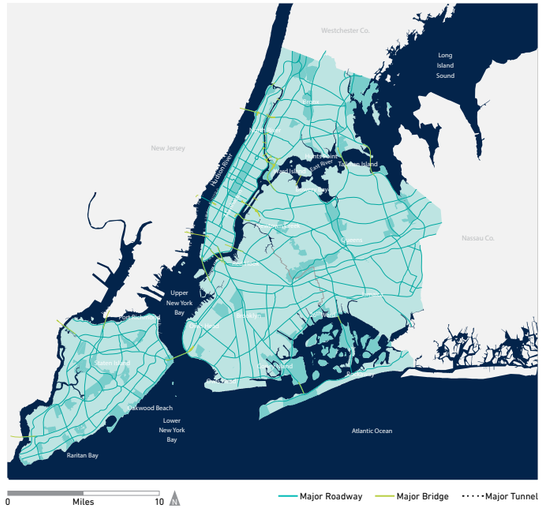
## Roadway Infrastructure

Three government entities are responsible for keeping all roadways safe in the New York City area:

- The New York City Department of Transportation (DOT) manages approximately 800 bridges and 4 tunnels, and maintains over 6,000 miles of streets, 12,700 traffic signals, sidewalks, and retaining walls.
- The MTA oversees 8 bridges and 2 tunnels used by more than 310 million vehicles each year, and operates 235 bus routes across New York City's roadways.
- The PANYNJ manages four bridges and two tunnels between New York and New Jersey, as well as two New York City bus terminals serving interstate commuters.

All roadway infrastructure is vulnerable to hazards such as heavy snow, ice, or rain. New York City's many tunnels and low-lying roads are particularly vulnerable to floods.

**MAJOR ELEMENTS OF THE NEW YORK CITY ROAD NETWORK**
SOURCE: NYC TRANSIT, NYC DOT, NYC DOITT, AND NYCEM




## Air Transportation

The PANYNJ operates all three airports in the New York City region — LaGuardia Airport and JFK International Airport in Queens, and Newark Liberty International Airport in New Jersey.

The combined traffic volume represents the world's largest air travel market. The two Queens airports play a significant role. In 2018, 132.3 million passengers traveled through LaGuardia Airport and JFK International Airport, contributing $64.4 billion to the regional economy and providing approximately 436,000 jobs.

Operations at LaGuardia Airport and JFK International Airport are at risk, because both of these important facilities are located in floodplains and subject to periodic flooding. In addition, both airports are built on artificial fill which could cause liquefaction (liquefied soil) during an earthquake.

## Maritime Transportation

New York City's waterfront activity includes commercial shipping, passenger ships, and local ferry service.

Marine terminals and waterfront facilities throughout the bi-state harbor are managed by both PANYNJ, the largest and busiest port complex on the East Coast of the United States, and the New York City Economic Development Corporation, on behalf of the City of New York. More than 50 piers, docks, and ferry terminals are owned by New York City agencies.

The economic impact resulting from this freight and passenger activity is significant, generating nearly 400,000 regional jobs. In 2017, PANYNJ moved 3.8 million shipping containers, approximately one out of every six containers moved annually in the United States. Cruise terminals in Manhattan, Bayonne, and Brooklyn served more than two million passengers.

Millions of commuters use private and public ferry service between New Jersey and New York City. The Staten Island Ferry, operated by the City's Department of Transportation, is the largest commuter ferry in the United States, making more than 23 million passenger trips a year. NYC Ferry operates a small fleet of 150- and 350-passenger ferries for commuters and tourists on other routes among the boroughs. By 2023, this fleet is expected to transport up to nine million passengers annually between Manhattan, Queens, Brooklyn, the Bronx, and Staten Island.

All commercial, commuter, and leisure waterfront operations are at risk from the hazards posed by high winds and coastal storms and from any power and telecommunications network outage.





# WATER SYSTEM INFRASTRUCTURE

The two components of New York City's water infrastructure are its extensive water supply system, which provides water to nearly half the residents in New York State, and its wastewater treatment system.

## Water Supply

New York City's drinking water is world-renowned for its high quality. Water is transported from large upstate watersheds more than 125 miles away to New York City through a complex network of aqueducts and tunnels to in-city reservoirs.

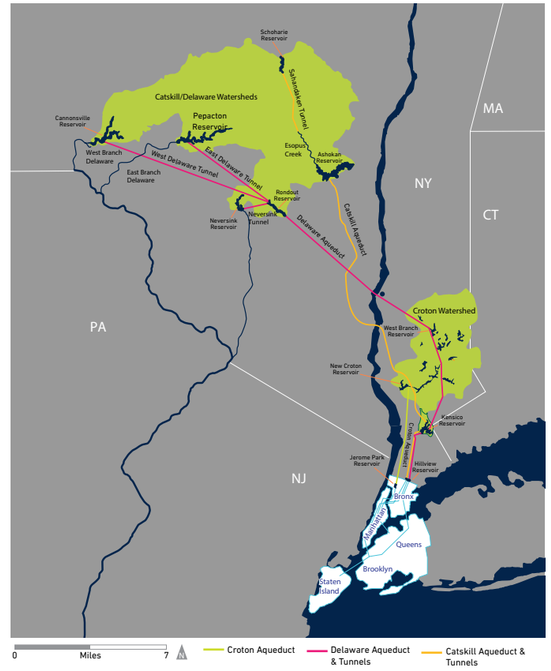
The Department of Environmental Protection (DEP) manages New York City's water supply system and ensures the safe, steady flow of clean drinking water. Upstate reservoir water is delivered via three aqueducts and Water Tunnels 1 and 2, which have been in continuous service since they were built. Water Tunnel 1, completed in 1917, is 18 miles long and carries between 500 and 600 million gallons of water daily. Water Tunnel 2, completed in 1936, is 20 miles long and carries between 700 and 800 million gallons of water daily. In 1970, New York City began constructing a third water tunnel, scheduled for completion in the 2020s, to increase system redundancy.

Within New York City, 7,000 miles of water mains and pipes, engineered for redundancy, distribute water throughout the five boroughs. To mitigate the risk of flooding, the mains and pipes are buried and pressurized.

Every day, more than 1 billion gallons of drinking water are delivered to the taps of 10 million customers throughout New York State, including 8.6 million people in New York City. The drinking water supply depends on adequate precipitation upstate to fill the reservoirs, continued good water quality, and continued reliability of this infrastructure.

The distribution system depends upon gravity to minimize the need for pumps. Water pressure is sufficient to reach the sixth floor of most buildings. For water to reach higher floors, high-rise buildings use rooftop water towers or electrical pumps. During a power outage, electrical pumps are unable to supply residents with water.

**NEW YORK CITY'S WATER SUPPLY SYSTEM**
SOURCE: NYC DEP




**EVERYDAY, MORE THAN 1 BILLION GALLONS OF DRINKING WATER ARE DELIVERED TO NEW YORK CITY RESIDENTS.**

### Wastewater Treatment

Like most old urban centers, New York City relies on a combined sewer system to collect sanitary and industrial wastewater, rainwater, and street runoff and to convey it all to wastewater treatment plants. The scale and capacity are enormous. Connections from buildings move approximately 1.3 billion gallons of wastewater from drains and toilets daily directly into the system. Catch basins for stormwater connect directly to this same system, although some neighborhoods have separate storm sewers that carry street water runoff into local streams, rivers, and bays.

New York City's 14 wastewater plants are situated at relatively low elevations along the waterfront. These low-lying waterfront locations are vulnerable to flooding. To address this risk, DEP developed the NYC Wastewater Resiliency Plan, which identifies cost-effective strategies to reduce flood damage to wastewater infrastructure and to safeguard public health and the environment.

Another risk concerns the capacity of the wastewater system to treat the combined volume of New York City's sewage and stormwater when the volume of heavy rain or snowmelt swells to more than double a plant's dry-weather capacity. When this happens, the *combined sewer overflows* (CSOs) — the mix of excess stormwater and untreated sewage — flows directly into the waterways.

New York City is addressing this risk through infrastructure improvement and green initiatives. Over many years, New York City invested billions of dollars in infrastructure to reduce CSO events. Annual updates to New York City's *Green Infrastructure Plan* document how natural and low-tech approaches are being used around the City to absorb rain and snowmelt. New York City's Bluebelt program is building natural drainage corridors to slow the water's flow and use vegetation or other natural elements to absorb and filter impurities.

## HEALTHCARE FACILITIES

New York City has one of the greatest concentrations of healthcare facilities in the country, which can be at risk during severe weather events and other emergencies. During and after emergencies, these facilities and pharmacies serve as critical assets to the community.

The scope of the healthcare infrastructure in New York City is vast, including New York City's Health + Hospitals Corporation (H+H), which operates almost a dozen hospitals, five post-acute/long-term care centers, seven community health centers, and 28 neighborhood health clinics. Daily, 1,400 residential-based providers are caring for more than 80,000 patients in nursing homes and other facilities, offering treatment, care, and supportive housing for individuals with substance abuse problems, developmental disabilities, and other behavioral or mental health challenges.

Hurricane Sandy demonstrated the vulnerability of patients, health-care institutions, and staff. The healthcare infrastructure is vulnerable during emergencies if transportation systems are disrupted and healthcare workers cannot get to work. Critical healthcare facilities had to be evacuated when storm surge from the East River flooded hospital backup generators, which were unable to supply power for medical equipment operation, sterilization units, hot water, heating, ventilation, lighting, refrigeration, or access to digital health records.

#### FACTS: NYC SCALE AND SCOPE

- 60 hospitals
- 170 nursing homes
- 76 adult care facilities
- 10,000 service sites for community-based healthcare
- 80,000 patients in nursing homes and other healthcare facilities

#### KEY NYC RISK CONCERNS IN FUTURE

- 18 percent of adult care facilities in 1 percent annual chance floodplain
- 8 percent of nursing homes in 1 percent annual chance floodplain
- Facilities could be at risk if intensity and severity of natural events increases due to climate change





## FOOD SUPPLY CHAIN

Most of the food New Yorkers consume is produced far beyond the City's borders, and its flow into and around the City is constant. The in-city supply chain is made up of centralized food distribution centers, where trucks carry food to retail outlets, restaurants, corporations, and institutions across the five boroughs.

The truck traffic across New York City's four bridges and two tunnels brings over 50 percent of New York City's food volume. The Hunts Point Food Distribution Center in the South Bronx, the largest produce market by revenue in the world, is the epicenter of New York City's food network and distributes 12 percent of New York City's food.

#### FACTS: NYC SCALE AND SCOPE

- 42,000 restaurants, cafes and other point-of-sale retail food locations
- 10,000 independent bodegas
- 99% of last-mile distribution via trucks
- Hunts Point distributes 12 percent of food
- 46% of food supplies are perishable

#### KEY NYC RISK CONCERNS IN FUTURE

- Highly reliant upon gas supply and roadway infrastructure
- Roadways, bridges vulnerable to heavy snow, ice, or rain
- Tunnels vulnerable to flooding
- Perishable food at risk of spoiling during power outages

According to the Five Borough Food Flow study, approximately 42,000 point-of-sale outlets, mostly independent restaurants and cafes, provide approximately 19 billion pounds of food to New Yorkers annually. New York City's institutional kitchens have a food budget estimated to be second only to the food budget of the U.S. military.

Because approximately 99 percent of the food being distributed relies upon trucks for the final delivery destination, the food supply chain is heavily dependent upon the smooth, uninterrupted operation of New York City's roads, bridges, and tunnels and the continuous availability of liquid fuel.

Severe weather or other emergency situations that create power outages put New York's food supply chain at extreme risk. Approximately 46 percent of the food supply is perishable, requiring either continuous refrigeration or freezing. Wholesale and retail food operations are also at risk if they lack power to run equipment, lighting, inventory systems, or other critical systems.

A steady power supply is required for telecommunications between distributers and retailers and for processing transactions for low-income residents who use New York City's Electronic Benefit Transfer cards to purchase food via the Supplemental Nutrition Assistance Program (SNAP, formerly called "food stamps").

# THE FUTURE ENVIRONMENT

Creating the most effective mitigation strategies requires understanding the trends that will shape New York City in the future. This section provides examples of factors that are guiding policies and actions by New York City today — how hazardous conditions could differ in the coming decades due to climate change, how population growth and demographic change affects planning, and how land use could be affected.

## Climate Change

Climate change poses several significant risks to New York City by changing the pattern and frequency of hazardous weather events, such as heat waves, torrential downpours, high winds, snow storms, and more frequent, severe coastal storms.

The New York City Panel on Climate Change (NPCC), a body of leading climate and social scientists and risk management experts, convened in 2008 to develop climate projections for New York City to inform the City's decision-making and the public's understanding of what changes potentially lie ahead.

According to the NPCC's 2015 report, *Building the Knowledge Base for Climate Resiliency,* seven climate-change variables have the potential to affect New York City in the next 30 to 60 years.

**NEW YORK CITY HEALTHCARE FACILITIES LOCATED IN THE 1 PERCENT ANNUAL CHANCE FLOODPLAIN**
SOURCE: NEW YORK PANEL ON CLIMATE CHANGE (NPCC), 2015

| CLIMATE CHANGE PROJECTIONS | NEW YORK CITY PROJECTIONS |
|---|---|
| **Average Temperature Increase** | · Mean annual temperatures projected to increase by 4.1 to 5.7°F by the 2050s and by 5.3 to 8.8°F by the 2080s |
| **Heat Waves** | · Frequency of heat waves projected to triple to six (up from two heat waves per year by the 2080s) |
| **Mean Sea Level Rise** | · Projected increase to between 11 and 21 inches by the 2050s, and between 18 and 39 inches by the 2080s |
| **Coastal Storm Surge with Sea Level Rise** | · Future sea height during coastal storms could potentially be above normal levels expected at that time and place based on the tides alone<br>· Projected increases in the frequency and height of 1 percent annual chance floods |
| **Extreme Hurricane Winds** | · Expected increase in the likelihood of extreme hurricane winds in the North Atlantic Basin |
| **Cold Snaps** | · Frequency of extreme cold events, defined as the number of days per year with minimum temperatures at or below 32 °F, are projected to decrease approximately 25 percent by the 2020s, over 33 percent by the 2050s, and approximately 50 percent by the 2080s<br>· Uncertainty in future projections of whether changes in the degree or frequency of extreme ice storms will occur |
| **Heavy Rainfall and Inland Flooding** | · Projected increase in annual precipitation (flash flood events due to heavy rainfall) to between 4 and 11 percent by the 2050s, and between 5 and 13 percent by the 2080s |

## Future Flood Maps

New York City worked with the NPCC to develop a series of "future" flood maps to guide local resiliency and mitigation efforts. They were created using a simplified bathtub model approach that combined the NPCC's "high end" sea-level-rise projections with FEMA's Flood Insurance Rate Maps (FIRMs). The future flood maps illustrate where the 1 percent annual chance floodplain could expand in New York City over the next several decades. Please see the Flooding chapter to view the *Current and Projected 1 Percent Annual Chance Floodplain* map.

# POPULATION GROWTH AND DEMOGRAPHIC SHIFTS

Several hundred thousand people move in and out of New York City each year — a trend that has continued since 1990. Based on the latest New York City Department of City Planning projections, by 2040, the population will grow by almost 10 percent and exceed 9 million residents — an important consideration for future risk to disasters because more people will be exposed to the impacts of emergency events. By 2040, the age demographics of New York City will shift.





## The Over-65 Population Trends

New York City has a large baby-boomer cohort that will be at least 75 years old by 2040. By then, the over-65 population segment is projected to increase 41 percent, which could potentially require significant resources and planning to mitigate risks during hazards that are expected to intensify and become more frequent. As a share of New York City's total population, the over-65 age group today is about 12 percent, but this is projected to increase to more than 15 percent by 2040. As mentioned in the social environment, seniors are more vulnerable to the impacts of major disasters.

This growth among the senior population is not expected to be spread evenly across the boroughs. The number of seniors living in Staten Island is predicted to grow 65 percent by 2040, growing from less than 13 percent in total population today to nearly 20 percent of Staten Island's population.

# RESILIENCY CONSIDERATIONS FOR FUTURE LAND USE AND DEVELOPMENT

Resiliency considerations for new development and existing buildings and infrastructure are necessary to meet the demands of population growth and climate change. Although it is hard to predict how New York City will change in the future, current resiliency and sustainability initiatives will better position the City to bounce back from future disasters and create more livable communities.

Since 2014, the City initiated 90 area-wide and targeted rezonings that represent one percent of the City's landmass. More recent rezonings have encouraged the development and preservation of housing affordability, investment in open space, and better access to transportation, infrastructure and education.

A key change since Hurricane Sandy is making sure new development and existing infrastructure are resilient in the face of future hazards and climate change. This is being accomplished by policy changes to help guide future development. This includes the Flood Resiliency Zoning Text Amendment that encourages flood-resilient building construction throughout the designated flood zones. The recent revisions to the New York City Waterfront Revitalization Plan also promotes climate–resilient designs and encourages public access to the waterfront. Other resiliency initiatives that will shape the future development of New York City's built environment include the Climate Resiliency Design Guidelines. The design guidelines help engineers, architects, landscape architects, and planners incorporate resiliency against sea level rise, extreme heat, and extreme precipitation events for a wide range of City facilities. To incorporate climate-change considerations in the future design of parks and open space, NYC Parks created Design and Planning for Flood Resiliency: Guidelines for NYC Parks.

The Build It Back program created by the Mayor's Office of Housing Recovery (HRO) helped New York City residents repair, rebuild, and elevate homes severely damaged by Hurricane Sandy. Currently, the program is helping 8,300 homeowners and landlords of one-to-four-unit homes, which house a total of 12,500 families. The recovery effort includes elevating or rebuilding over 1,300 homes and repairing more than 3,800 moderately damaged homes in New York City's hardest-hit coastal areas. The Build It Back Multi-Family Program, managed by New York City's Housing Preservation and Development (HPD), was created to help an additional 19,600 households in 143 developments with repairs, resiliency upgrades, and reimbursement services.

In addition to these resiliency initiatives, New York City is a leader on sustainable science-based actions and policies. Examples of key initiatives are:

- In 2015, the de Blasio administration announced its goal to reduce the City's greenhouse gas emissions 35 percent by 2025 and 80 percent by 2050.
- Following withdrawal by the United States from the Paris Climate Agreement in 2017, New York City became the first major city to declare that it would uphold the goals and advance its objectives to limit emissions at a local level.
- In 2018, New York City became the first major city to divest investments in the fossil fuel industry from its pension funds.
- In 2018, New York City Council passed a bill mandating that 100 percent of all City buildings will be powered by renewable energy by 2050, with an interim goal of achieving 50 percent by 2030.

New York City is unique and ever changing. Its size, location, natural environment, and role as a global city emphasizes the importance of hazard mitigation investments. Now that we've explored the key components that amplify our risk to future hazards, let's learn more about the specific hazards that New York City faces.





**LEARN ABOUT COASTAL EROSION**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 01 COASTAL EROSION

Coastal erosion plays a significant role in the retreat of New York City's coastlines. It also amplifies the city's vulnerability to coastal storms, leaving the city more at risk for natural resource depletion, infrastructure damage, physical harm, and economic hardship.

# WHAT IS THE HAZARD?

Coastal erosion is the loss or displacement of coastline land from the interaction of oceans, waves, and beaches, often coupled with the impact of human activity. Coastal erosion can occur rapidly or gradually, vary by location, and can be influenced by the amount of human intervention along specific areas of the coast.

Coastal erosion is described in two ways — as a rate of annual shoreline recession, and in terms of the volume of sand lost. Three factors contribute to coastal erosion in New York City:

- Coastal storms and severe weather events: Coastal erosion can be event-driven and happen fairly rapidly, with large sections of beaches, dunes, or bluffs being lost in a matter of days or even hours. For example, according to the U.S. Army Corps of Engineers (USACE), the force of Hurricane Sandy led to losses of 3.5 million cubic yards of sand on the Rockaway Peninsula and losses of 679,000 cubic yards of sand at Coney Island.
- Natural forces: Along New York City's 520 miles of coastline, long-term erosion rates vary significantly because of geology, the physical nature of different shoreline locations, and the varying intensities of wave action along the coast. Displaced sand and sediment shift from place to place and stay within the overall natural system unless sediment is dredged and permanently removed.
- Human intervention: Some coastal locations in New York City, such as Brooklyn's Seagate, have stabilized inlets or other engineered structures to protect property and prevent natural beach erosion. Hardened structures are used to disrupt the natural shifts of sand and sediment, but sometimes these are deployed without fully considering coastal erosion cycles or hydrodynamics and unintentionally increase erosion.

Areas along New York City's southern shore are at greatest risk, since they are exposed to increased wave action from the Atlantic Ocean and to the waters of many bays, including Lower New York, Gravesend, Raritan, and Jamaica Bay.

## COASTAL EROSION IN BROOKLYN'S SEAGATE, 1996–2018


These aerial photos of Seagate in Brooklyn display how certain hardened structures can alter the shoreline. Since its construction in 1995, the groin (extending into the water perpendicular to the shore) has worsened erosion on the western side, exposing property, while the beach on the east side has remained intact.Interestingly, the Seagate shoreline has changed again since the photo was taken in 2012; the USACE completed construction of groins in the Seagate area in 2017.

**LEFT TO RIGHT:**

**BROOKLYN SEAGATE, 1996–2018**
SOURCE: NYCEM, DoITT (IMAGERY)





## SEVERITY

Assessing the degree to which New York City's beaches are lost or gained through natural processes versus human intervention is difficult as natural erosion rates vary significantly from year to year.

New York City works with the New York State Department of Environmental Conservation (NYS DEC) to identify areas with high coastal erosion risk and to enforce guidelines to protect developments, people, and natural features.

### New York City's Coastal Erosion Hazard Areas (CEHAs)

The NYS DEC developed the Coastal Erosion Hazard Area (CEHA) program to limit coastal development in vulnerable areas such as by requiring permits for certain activities.

The NYS DEC has identified three distinct CEHAs within New York City, which collectively cover 0.7 percent of New York City (approximately 1,428 acres). The USACE monitors the coastal erosion rates of each of:

- **Rockaway Peninsula, Queens:** A 2016 USACE report determined that between 1975 and 2010 (the most recent values available), the Rockaway Peninsula's east and west end had the highest rates of shoreline increase — as much as 15 feet of additional shoreline per year. The middle section of the Rockaway Peninsula showed a small rate of erosion, losing up to 5 feet of shoreline per year.
- **Coney Island, Brooklyn:** According to the USACE, between 1966 and 1988, the most recent data available, along the ocean shore of Coney Island, the coastal erosion rate reflected a loss of 1.3 feet per year.
- **South Shore, Staten Island:** The south shoreline of Staten Island is generally stable except for the shorelines of Oakwood Beach and Annadale, which are eroding faster than the citywide average. The satellite map shows that parts of the Annandale shoreline retreated as much as 125 feet between 1924 and 2018.

### Coastal Erosion Hazard Area (CEHA) Maps

The boundaries of New York City's CEHAs are delineated on CEHA maps. Within each CEHA, NYS DEC maps also show the following designated areas:

- Natural Protective Feature Areas: Nearshore areas, beaches, bluffs, and dunes that protect New York's natural features. Alterations to these areas may reduce or eliminate their protective capabilities. Landward limits of the Natural Protective Feature Area are delineated on the CEHA maps.
- Structural Hazard Areas: Regulated areas landward of the Natural Protective Feature Areas, which are designated only along shorelines receding at an average rate of one foot or more per year. If applicable, the landward limits of the Structural Hazard Area are delineated on the CEHA maps.

Currently, NYS DEC is evaluating and updating the CEHA maps for New York State, which were last updated in the 1980s, to reflect changes to CEHA boundaries. The new maps will use LiDAR (Light Detection and Ranging) data, a remote-sensing methodology that provides greater precision and accuracy for three-dimensional shoreline mapping.

As of this publication, NYS DEC has not released an estimate of when its updated maps will be publicly available. New York City just released 2017 LiDAR data; however, including a new shoreline layer and Digital Elevation Model (DEM), which can be used to analyze coastal storm surge, sea-level rise inundation, and flood risks. This new data will help agencies to better monitor coastal erosion throughout New York City.

**SHORELINE CHANGE FOR ANNADALE, STATEN ISLAND: 1924–2018**
SOURCE: NYS DEC, NYCEM GIS, 2018

# WHAT IS THE RISK?

Coastal erosion poses many challenges to coastal communities — the loss of valuable real estate, personal property, recreational areas, and vital natural flood protection. Controlling beach erosion and restoring land are major concerns in New York City's coastal communities.

## PEOPLE AT RISK

Building owners and residents in coastal communities are primarily at financial risk from the threat of coastal erosion due to:

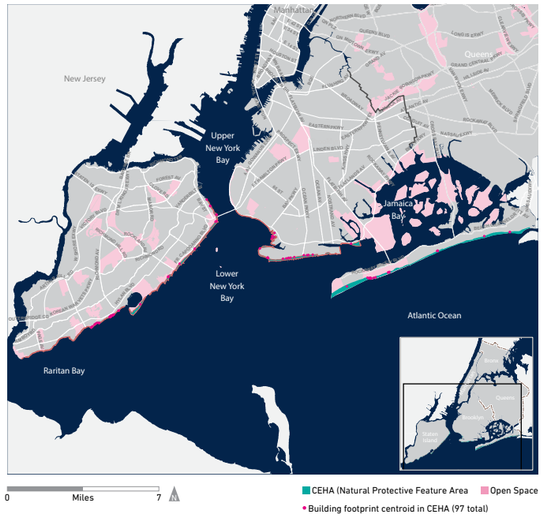
- Potential for necessary structural repairs or modification: If homes or property are compromised due to erosion, financing the repairs can be burdensome. Residents with waterfront property may be required to make structural changes such as bulkheads or rip-rap, which could financially stress lower- or middle-income homeowners. Structural improvements to existing accessible housing in coastal erosion areas for Individuals with disabilities or access and functional needs may not be possible because the required structural improvements could render the housing inaccessible.
- Relocation expenses: If businesses and residents need to relocate away from the waterfront, the low availability and high cost of housing in New York City may present a challenge. People with disabilities and access and functional needs may also face difficulty finding limited accessible housing in New York City or may have to pay prohibitively high costs for modifications to make housing accessible.

## BUILDINGS AT RISK

As coastal erosion reduces the distance between built structures and the water's edge, the risk of damage to public and private property increases.

New York City has 188 buildings with a footprint that intersect a CEHA — 97 are completely or predominantly within the CEHA, and 91 more touch a CEHA perimeter.

**NEW YORK CITY COASTAL EROSION HAZARD AREA (CEHA) BUILDINGS**
SOURCE: NYS DEC, NYCEM GIS, 2018




**ACREAGE AND BUILDINGS WITHIN NYS DEC-MAPPED COASTAL EROSION HAZARD AREAS (CEHAS)**
SOURCE: NYCEM GIS, 2018

| CEHA | ACREAGE EXPOSED | EXPOSED BUILDING FOOTPRINTS | EXPOSED BUILDING CENTROIDS |
|---|---|---|---|
| Coney Island, Brooklyn | 305 | 51 | 21 |
| Rockaway Peninsula, Queens | 708 | 29 | 21 |
| South shore, Staten Island | 415 | 108 | 55 |
| **Total** | **1428** | **188** | **97** |





## NATURAL ENVIRONMENT AT RISK

Under natural conditions, some beaches — particularly barrier islands like Rockaway Peninsula — are dynamic features of the landscape. Left in a natural state, some beaches and shoreline areas erode as others increase. Overall, however, these processes tend to be balanced, as long as human activities don't disturb them.

Shoreline stabilization structures can prevent longshore drift and help to protect public amenities and recreational assets. These physical structures need to be constructed properly however, to ensure that they do not increase coastal erosion by creating an imbalance in the cyclical process of natural erosion and accretion.

## FUTURE ENVIRONMENT

According to the New York City Panel on Climate Change, the sea level around New York City has risen 1.2 inches per decade since 1900 and is projected to rise as much as 21 inches by 2050. This will exacerbate coastal erosion, because coastal storms could hit New York City with increased frequency and ferocity.

The degree to which sea level rise alone affects coastal erosion is unclear. When viewed in terms of 30- to 50-year periods, the impact of sea level rise upon coastal erosion is less significant than other factors that change New York City's shoreline. Sea level rise is not expected to have a significant change upon the observed rate of shoreline erosion in the areas where it is most severe. These uncertainties emphasize the need to understand erosional patterns more precisely by building monitoring stations and increasing data collection along New York City's coastline.

**LIVING SHORELINE IN BROOKLYN BRIDGE PARK**
SOURCE:NYC DCP 2013

# HOW TO MANAGE THE RISK

Managing coastal erosion risks in New York City requires coordination with federal and state partners:

- USACE has jurisdiction over many water bodies, navigable rivers, and wetlands. Many of the waters surrounding New York City are subject to the USACE's regulatory authority.
- NYS DEC is often involved in regulation of projects that affect water bodies, freshwater or tidal wetlands, coastal areas, and threatened or endangered species.

## REGULATION AND POLICY

The NYS DEC enforces regulations within all State-designated Coastal Erosion Hazard Areas (CEHAs) and limits coastal development to protect areas at risk.

The State's Environmental Conservation Law regulates properties within CEHAs to limit coastal development in order to protect sensitive areas. The Coastal Erosion Management Regulations (6 NYCRR Part 505) require that all proposed construction in the CEHAs have a Coastal Erosion Management permit from NYS DEC. Permits are required for such projects as constructing or placing a structure on coastal land; altering the condition of coastal land, such as grading, excavating, dumping, mining, dredging, and filling; and other activities that disturb the soil.

Other types of regulation and policy measures used to mitigate coastal erosion include:

- **Construction permits,** which are often required to construct or modify existing structures, incorporate coastal-erosion management regulations to ensure that building activity will not accelerate shoreline erosion.
- **Setbacks or buffers** specify the minimum distance from the CEHA for certain types of land use or new development. Regulatory setbacks, which are identified on the State's CEHA maps, are only marked in areas having a long-term average erosion rate of one foot or greater per year.
- **Development restrictions** specify the types of zoning allowed in coastal areas or restrict the types of expenditures allowed. One example is the Coastal Barrier Resource Act (CBRA), which created federal regulations applicable to different categories of private and public land units along the shore.

The New York City Waterfront Revitalization Program (WRP), which is overseen by the New York City Department of City Planning (DCP), creates policies for waterfront planning, preservation, and development projects, and ensures they are implemented consistently over the long term.

## NATURAL/OPEN SPACE PROTECTION

Placing natural and nature-based buffers and protective features on the shore or in the water helps to keep the existing shoreline in place. Environmental control measures include:

- Beach nourishment, is the process of placing sand (typically dredged from nearby ocean bottoms) on beaches to increase the elevation and distance between the shoreline and upland areas. This creates a buffer that diverts storm and wave energy before this energy hits formerly eroding areas, reducing the risk of flood and dune erosion.
- Vegetation, is often planted on beaches, dunes, and unstable shorelines to anchor sand and/or soil in place.
- Living shorelines are made up of plants, sand, or soil, often in combination with hard structures, such as rip-rap or gabions, to stabilize the shoreline, prevent erosion, and maintain wildlife and marine habitats.
- Constructed wetlands are new or restored tidal wetlands using plants to anchor the soil in place, prevent erosion, and create wildlife habitat.
- Vegetated islands are either fixed or floating offshore structures, such as anchored mats or infill islands that provide ecological benefits and can minimize erosion from breaking waves.

**MANAGING COASTAL EROSION RISKS IN NEW YORK CITY REQUIRES COORDINATION WITH FEDERAL AND STATE PARTNERS.**





## BEACH RENOURISHMENT AT ROCKAWAY BEACH

Beach renourishment is the act of adding sediment to increase the strength of a beach. Renourishment protects structures, infrastructure, and natural areas near the coastline from storm surge and/or wave damage, and can help to retain coastline during sea level rise. Additionally, ancillary benefits to beach renourishment may include improved recreation, economic benefits, and social cohesion. Beach renourishment may be the best coastal resiliency option in densely built coastal neighborhoods in which it is not possible or practical to relocate buildings and infrastructure.

One way to accomplish beach renourishment is to use a dredge to scoop or suction sediment from the ocean bottom and place it where areas need protection from erosion and from wave action. While dredging has been done for thousands of years, onboard instrumentation of modern dredges is computer-assisted and can move millions of cubic yards of material.

An example in New York City is Rockaway Beach, where the USACE placed 3.5 million cubic yards of sand following Hurricane Sandy at a cost of $36.5 million. This renourishment increased the resiliency of the beach and the berm system, and protected the built area adjacent to the coastline.

Other related examples include "beneficial reuse" projects, in which New York City uses sand that the USACE has dredged to clear navigation channels to replenish local beaches instead of transporting the sediment away from the region. Such work is scheduled during spring 2019 at Rockaway Beach.

**TOP:**

**BEACH RENOURISHMENT AT ROCKAWAY BEACH**
SOURCE: USACE

COASTAL EROSION

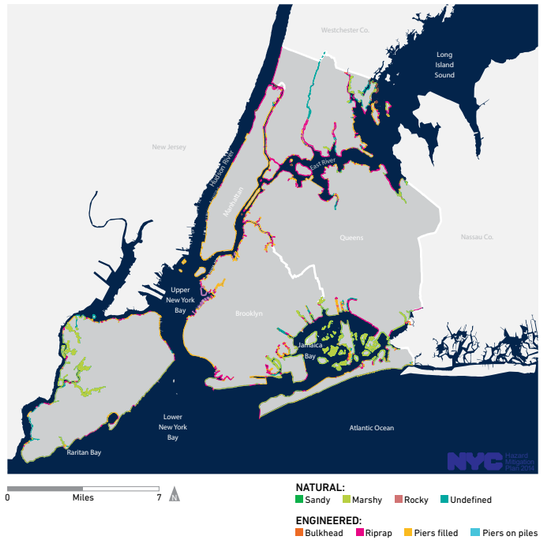
## BUILDING PROTECTION

To protect the urban environment, New York City built robust erosion-control structures throughout the five boroughs. Engineered structures on shore or in the water that are properly sited and sized can mitigate the forces of coastal erosion and hold the shoreline in place.

Choosing the most effective erosion-control structure depends on the specific features of the coastal location:

- Seawalls, which may also be considered a type of bulkhead, are massive stone, rock, or concrete structures built parallel to the shoreline and are designed to resist the force of waves that risk eroding the shore by holding the shoreline in place.
- Revetments are sloped structures typically made of stone or concrete blocks to protect the underlying soil from erosion and to minimize the energy of waves. Rip-rap and gabions are common types of revetments.
- Bulkheads are vertical retaining walls, typically made of wood or sheet steel, designed to hold soil in place and stabilize the shoreline.
- Groins are structures that extend perpendicularly from the shore into the water to trap sand, prevent erosion, and break waves.
- Jetties, which are similar to, but tend to be larger than groins, are designed primarily for sediment management and are typically located at the mouth of a river.
- Breakwaters are offshore rock structures situated parallel to the shoreline that break waves to reduce shoreline erosion.
- Artificial reefs are fully or partially submerged structures constructed of rock, concrete, or other materials to break waves, reduce erosive forces on the shoreline, and provide marine habitat.

**WATER EDGE TYPE**
SOURCE: NYC DCP, 2011




Currently, New York City, the NYS DEC, and USACE are collaborating on a recommended plan for the Atlantic Coast of New York, East Rockaway Inlet to Rockaway Inlet, and on the Jamaica Bay Reformulation Study. The plan will include a redesigned groinfield for Rockaway Peninsula to minimize coastal erosion from longshore drift.

**GROINS ALONG THE ROCKAWAY PENINSULA**
SOURCE: NYC DCP, 2013

**TO PROTECT THE URBAN ENVIRONMENT, NEW YORK CITY BUILT ROBUST EROSION-CONTROL STRUCTURES THROUGHOUT THE FIVE BOROUGHS. ENGINEERED STRUCTURES ON SHORE OR IN THE WATER THAT ARE PROPERLY SITED AND SIZED CAN MITIGATE THE FORCES OF COASTAL EROSION AND HOLD THE SHORELINE IN PLACE.**





**LEARN ABOUT COASTAL STORMS**

What is the Hazard?
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# 02 COASTAL STORMS

Coastal storms are a reality for New York City. Among cities in the United States, New York City's extensive, densely populated built coastline makes it one of the most vulnerable cities from coastal storms.

These storms can have a major impact upon millions of people in the greater region around New York City and potentially create a ripple effect throughout the country.

Climate change and rising sea levels are likely to worsen the impact of coastal storms that can threaten New York City, but hazard-mitigation teams in New York are taking steps now to keep people and property safe.

## CHARACTERISTICS OF COASTAL STORMS

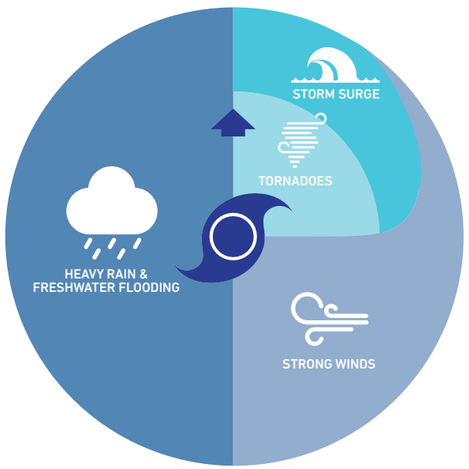
### TROPICAL CYCLONE

- Forms in tropics or subtropics
- Derives energy from warm ocean water
- New York City is most at risk between August and October
- Often associated with bands of severe thunderstorms and possibly tornadoes
- Forms over water
- Not associated with wintry precipitation (snow, sleet, freezing rain)

### NOR'EASTER

- Forms outside of the tropics
- Derives energy from temperature contrasts between cold and warm air masses in the atmosphere
- New York City most at risk between October and April
- Rarely associated with severe thunderstorms and tornadoes
- Forms and maintains strength over either land or water
- Often associated with wintry precipitation (snow, sleet, freezing rain)

**PRIMARY HAZARDS ASSOCIATED WITH HURRICANES**
SOURCE: NYCEM




## WHAT IS THE HAZARD?

Tropical cyclones and nor'easters are the types of coastal storm systems that threaten New York City. This section explains the differences and similarities of these potentially damaging weather systems that bring high winds, storm surges, and hazardous conditions at different times of the year.

### TROPICAL CYCLONES

Tropical cyclones are organized systems of thunderstorms that form over warm ocean waters — their primary source of energy. They are classified into three types:

- **Tropical Depressions:** an organized system of thunderstorms that produce circular wind flow with maximum sustained winds of 38 miles per hour (mph) or less.
- **Tropical Storms:** an organized system of thunderstorms with well-defined wind circulation with maximum sustained winds between 39 and 73 mph.
- **Hurricanes:** a strong, highly organized group of thunderstorms, with a well-defined low-pressure center ("eye") and having maximum sustained winds of 74 mph or more.

In the northern hemisphere, all systems rotate counterclockwise around a low-pressure center and gain in power if wind shear does not diminish them.

A hurricane has two specific areas where highly dangerous conditions arise — the turbulent area where thunderstorms surround the calm eye ("eye wall") and the right-front quadrant of the storm, as shown in the diagram, where the hurricane's high-speed forward motion worsens the impact of high winds and storm surge.

Tornadoes can spawn in the right-front quadrant of the storm, in the storm's eye wall, or in thunderstorms in rain bands far from the storm's center.

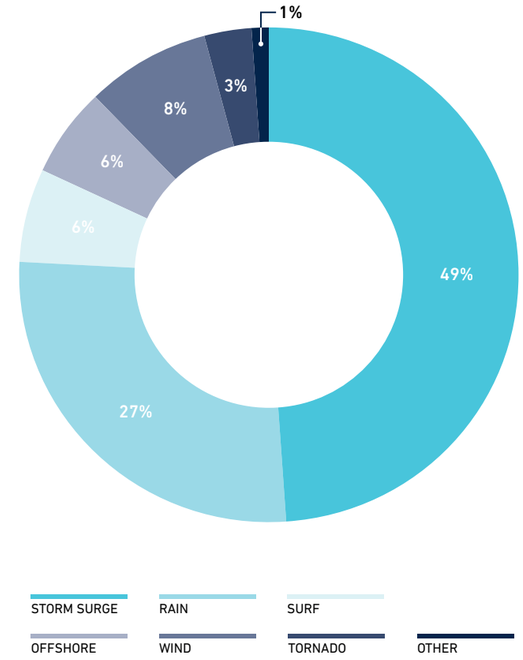
Heavy rain can fall throughout the duration of a tropical cyclone. The heaviest rain typically falls to the left of the storm's eye when it impacts the New York region.

Tropical cyclones that impact New York City originate along the coast of Africa, the Caribbean Sea, and the Gulf of Mexico, where warm, moist air, and low wind shears are prevalent. After tropical cyclones form over these warm waters, large-scale prevailing winds can push them toward New York City.

New York City's time of highest risk from tropical cyclones is when water temperatures are warmest, from August to October, with risk peaking mid-September. Water temperatures as far north as New York City may not be as warm as they are in the tropics this time of year, but they waters are warm enough to enable strong hurricanes to sustain their very high energy as they make landfall in the New York region.

When tropical cyclones make landfall, their primary hazards are storm surge, heavy rain, high wind, and tornadoes. Out of all these hazards, storm surge is the deadliest and most damaging. Storm surges occur when water washes onto shore by the force of the wind blowing across the ocean surface and the low pressure of the storm causing the water to bulge upward. This hazard is responsible for 49% of all deaths by tropical cyclones impacting the United States.

**U.S TROPICAL CYCLONE FATALITIES 1963–2012**
SOURCE: NATIONAL HURRICANE CENTER, 2012




### NOR'EASTERS

A nor'easter is a type of coastal storm that primarily threatens the Mid-Atlantic and New England states between October and April. Like tropical cyclones, they bring heavy precipitation and rotate counterclockwise around a low-pressure center.

Unlike tropical cyclones, nor'easters can form and sustain themselves over land, and typically form over the northwestern Atlantic, northern Gulf of Mexico, or central or western United States.

When these storms reach the Northeast or Mid-Atlantic coast, their counterclockwise circulation brings winds from a northeasterly direction—hence the name nor'easters. Although nor'easters are usually weaker than hurricanes, they may be larger and have durations lasting multiple tide cycles, creating the risk of more widespread impact. Nor'easters occur more frequently than hurricanes in the New York City area. Due to their frequency, the risk posed by hazards from nor'easters could be considered cumulatively greater than those from hurricanes.

The hazards posed by nor'easters are heavy precipitation, inland flooding, and winds normally intense enough to knock down trees and power lines, causing widespread power disruption and structural damage to buildings. Nor'easters may also create coastal flooding from storm surge and large waves.

A hurricane's impact upon a location varies according to the storm's size, its speed, its duration, the height of the storm surge, and the direction the storm is moving when it reaches New York.

The geography of the local coastline amplifies storm surge in the New York City region. The New York Bight — the nearly 90-degree relative angle formed by the shorelines of Long Island and New Jersey — can direct a storm surge into New York Harbor.

The worst-case scenario for New York City is a hurricane track making landfall just to the south along the coast of New Jersey. Note the illustration of this scenario, which would put the city is in the right-front quadrant of the storm as the westward bearing winds from the storm funnel the surge directly into Raritan Bay and New York Harbor.

This scenario happened in 2012 during Sandy and is why the storm had such a disastrous impact on New York City. In 2011, Irene made landfall over Brooklyn, but the conditions were very different. Irene's bearing at landfall was north-northeast, so the severity of direct storm surge that Sandy would later inflict did not occur during Irene.

# SAFFIR–SIMPSON HURRICANE WINDSCALE

Source: National Hurricane Center

## SEVERITY

Tropical cyclones and nor'easters hitting the New York City area vary in their severity. Although both types of storms can create serious hazards for New York City, their severity can vary by their intensity, size, direction, and the geography they traverse.

## TROPICAL CYCLONES

Tropical cyclones are formally categorized by intensity according to the Saffir-Simpson Hurricane Wind Scale, which assigns a value between 1 and 5 based on the storm's maximum sustained wind speed. Category 4 hurricanes in the New York City region are possible, but unlikely. Category 5 hurricanes are not meteorologically sustainable over the Atlantic Ocean north of Virginia.

### CATEGORY 1
74–95 MPH

Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roof, shingles, vinyl siding and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damange to power lines and poles likely will result in power outages that oculd last a few to several days.

### CATEGORY 2
96–110 MPH

Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.

### CATEGORY 3
111–129 MPH

Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numberous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.

### CATEGORY 4
130–156 MPH

Catastrophic damage will occur: Well-built framed homes can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

### Nor'easters

Annually, New York City typically experiences several nor'easters of varying intensity. Most are relatively weak but all have the potential to produce significant rainfall, snowfall, mixed precipitation, or storm surge that can cause minor-to-moderate damage across the region.

## PROBABILITY

### Tropical Cyclones

The National Hurricane Center (NHC) calculates return periods for hurricanes for different locations along the East Coast. NHC projects that New York City should experience on average at least a lower-category hurricane once every 19 years and a major hurricane (Category 3 or greater) once every 74 years.

### Nor'easters

The probability of severe nor'easters affecting New York City is low, but they do strike occasionally. New York City uses forecasts from the National Weather Service (NWS) and academic institutions to help anticipate when the consequences of nor'easters are expected to be severe.

**A HYPOTHETICAL STORM APPROACHING NEW JERSEY**
SOURCE: NYCEM


## LOCATION

Severe coastal storms threaten certain areas of New York City more than others. Different techniques are used to determine where and how the hazards associated with tropical cyclones and nor'easters will affect certain parts of the city.

### Tropical Cyclones

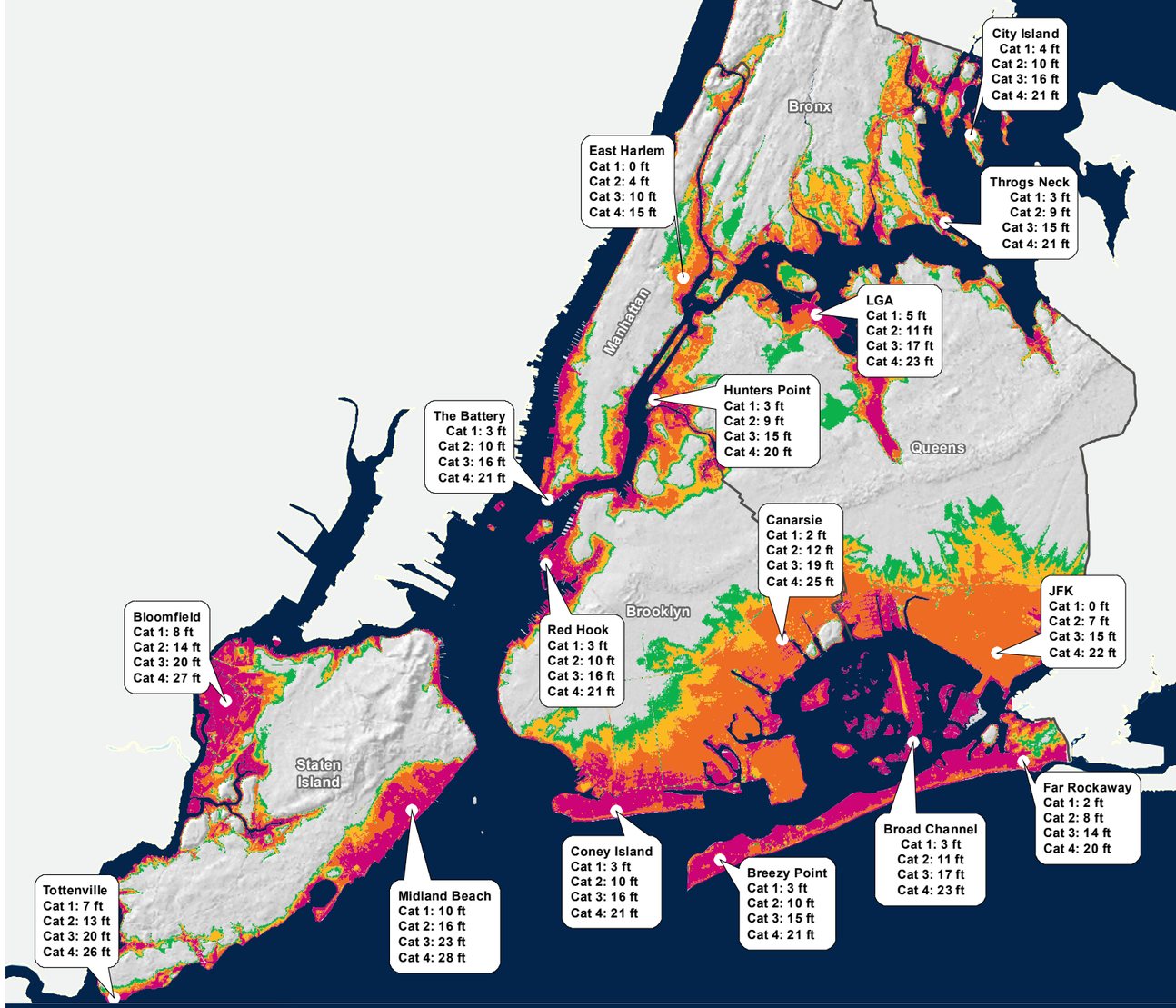
New York City Emergency Management (NYCEM) uses outputs from a National Hurricane Center computer model called SLOSH (Sea, Lake, and Overland Surges from Hurricanes) to predict storm surge for areas of New York City and to help take actions that protect people and property in these highly vulnerable areas from the hazards of tropical cyclones.

The SLOSH model calculates storm surge heights for areas of New York City under different scenarios — storms that move in different directions and range from Category 1 to 4 in strength. The model incorporates multiple factors that predict a storm's impact — varying wind speeds, the scope and distance of its maximum wind reach, its forward speeds, storm bearing, and the tides.

The SLOSH model assumes that each location is hit by the most intense part of a storm, so NYCEM is able to understand the worst-case scenario for storm surge at specific New York City locations.

The map shows the result: the four predicted storm surge inundation levels that different New York City neighborhoods may experience from hurricanes that range from Category 1 to 4. The red highlights locations expected to experience the highest inundation levels.

NYCEM used SLOSH data and an output called Maximum Envelope of Water (MEOW) to create evacuation zones for the New York City Coastal Storm Plan. NYCEM developed these evacuation zones presuming a universal worst-case scenario, as if a storm were to make landfall in all parts of the city at once and create the maximum amount of potential surge inundation in each location. Since Sandy in 2012, the City has updated its evacuation zones. In the June 2013 revision, the model gives more weight to the bearing (the direction a storm is moving) in the calculation of how various zones may be affected.




## STORM SURGE INUNDATION DEPTHS

Hurricane surge inundation areas and depths were produced by the U.S. Army Corps of Engineers in 2011 for NYC using the National Hurricane Center's 2010 NY3 Basin SLOSH (Sea, Lake, and Overland Surges from Hurricanes) MOM ( Maximum of MEOWS) at high tide. The inundation depth derived from the SLOSH MOM indicates a given location's worst case surge height (above NAVD88 bare earth ground elevation) for a particular storm category based on throusands of possible storm senarios at high tide. A Category 4 Hurricane is most severe.

- SLOSH MOM Category 1
- SLOSH MOM Category 2
- SLOSH MOM Category 3
- SLOSH MOM Category 4

**TOP:**

**STORM SURGE INUNDATION ZONES AND DEPTHS**
SOURCE: NHC, USACE

# NEW YORK CITY STORM SURGE INUNDATION AREAS CONTAIN NEARLY 2.5 MILLION CITY RESIDENTS.

### Nor'easters

SLOSH models are not used to predict where a nor'easter could threaten New York City. The National Weather Service (NWS) forecasts potential water levels associated with all impending nor'easters. This forecast is incorporated into NOAA's Office for Coastal Management Sea Level Rise Viewer and the NWS New York Impact Catalogs to determine the storm's potential impacts.

## WHAT IS THE RISK?

There are many factors that make New York City particularly vulnerable to major coastal storms and their secondary impacts. Based on SLOSH modeling, New York City storm surge inundation areas contain nearly 2.5 million city residents, a significant amount of extremely valuable real estate, and a vast network of critical, interconnected infrastructure. Because New York City is a global financial center and the hub of a large, complex regional economy, damage wrought by coastal storms have significant repercussions beyond the city's borders.

## PEOPLE AT RISK

Coastal storms can have a significant impact on the residents of New York City. Based on population figures from the 2010 Census, approximately 3 million New York City residents live within a Hurricane evacuation zone, putting them at increased risk.

The consequences of coastal storms can expose New York City's most vulnerable residents to significant safety and health risks:

- **Elderly:** Elderly people often lack mobility, have physical disabilities, need assistance, or pre-existing medical conditions that make it difficult to evacuate safely. If coastal storms create power outages, anyone relying on life-sustaining equipment or needing an elevator to get to the ground floor becomes vulnerable.
- **People with Disabilities:** People with disabilities or others with access and functional needs, who may be highly reliant on healthcare facilities and providers, may also have difficulty evacuating or getting assistance.
- **People Who Do Not Speak English:** New York City has a large population of immigrants, and many do not speak fluent English or understand it well. Language barriers could hinder these residents' ability to understand emergency warnings, move to safety, or take other lifesaving actions.

## FLASHBACK FEATURE: HURRICANE DONNA

**BEFORE SANDY, THE LAST HURRICANE THAT BROUGHT SIMILAR LEVEL FLOOD DEPTHS TO NEW YORK CITY WAS HURRICANE DONNA.** Hurricane Donna swept up the East Coast on September 19, 1960, causing 36 fatalities and property damage estimated at $100 million. Donna created an 11-foot storm surge in New York Harbor, caused a massive power outage, and cut telephone service to about 25,000 New Yorkers. The City incurred $20 million in damage. Residents of Coney Island and Sea Gate requested some form of hurricane protection. In 1972, the Army Corps of Engineers proposed building a 15-foot high seawall along the Coney Island peninsula—a $27.5 million construction project using concrete pilings and steel sheets. The reaction was mixed to negative. Some criticized the wall's height; others did not want limitations on their ocean access. Support from Federal and state agencies was also divided. Due to these challenges, the seawall was never built.

A HYPOTHETICAL STORM APPROACHING NEW JERSEY
SOURCE: NYCEM

| STORM SURGE EVACUATION ZONE | ESTIMATED POPULATION IN EVACUATION ZONE (2010 CENSUS) |
|---|---|
| Zone 1 | 370,000 |
| Zone 2 | 250,000 |
| Zone 3 | 400,000 |
| Zone 4 | 460,000 |
| Zone 5 | 760,000 |
| Zone 6 | 760,000 |
| **Total** | **3,000,000** |

Approximately one-third of New York City's hospitals and nursing homes are located in storm surge inundation areas. If backup generators and other types of critical equipment are housed on lower floors, equipment could be flooded and permanently destroyed by surging waters. Power outages affecting hospitals and nursing homes create extreme risk for anyone relying upon ventilators or other types of electrical life-support equipment.

People who do not evacuate during a coastal storm and, instead, shelter in place face risks, particularly if they must struggle through power outages. People living in high-rise buildings could be stranded without potable water if building systems do not have the power to pump water to upper floors. They can also be stranded if they live on high floors and there is no power to run elevators or other equipment. Under these circumstances, refrigerated food can spoil and air conditioning or heat can go out, creating hardship if temperatures are extreme.

Following a major storm, people who are directly affected may experience or suffer exacerbation of mental health conditions, such as post-traumatic stress disorder, anxiety, and mood disorders. These issues are most prevalent in the months immediately after a severe coastal storm, but individuals sometimes experience repercussions for a long time thereafter.

## BUILDINGS AT RISK

Buildings in New York City are at risk of experiencing significant damage from coastal storms due to several factors:

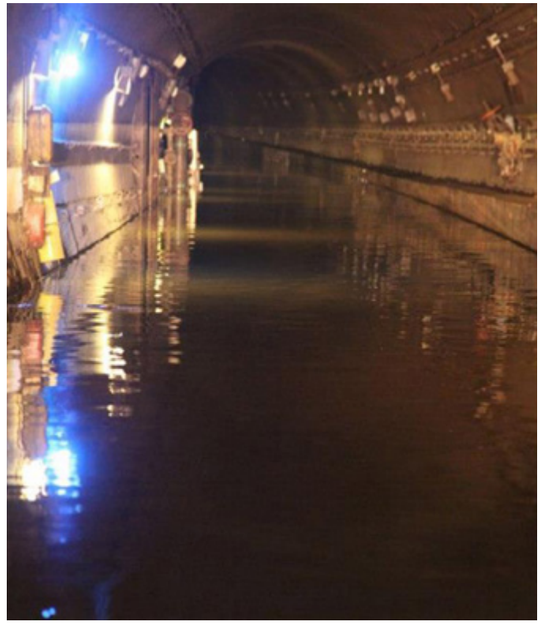
- Building Location: Buildings along the open coast are at greater risk of damage from high winds and destructive ocean waves, compared to buildings away from the coast, which might only be at risk from inland flooding.
- Building Age: Older buildings are more vulnerable to coastal storm damage than newer buildings, because they were constructed when zoning and building codes were less stringent.
- Tall Buildings: Facades of high-rises are very vulnerable to damage from high winds of coastal storms. Wind speeds can be up to one storm category higher for every 30 stories of a building, which can increase the risk of broken windows and falling debris. If electrical fires break out during a severe coastal storm, first responders may have more difficultly mounting a complex vertical response and evacuating everyone safely in a tall building.
- Low Buildings: Any building that is low to the ground and made of lightweight materials is vulnerable to significant damage from storm surge, high winds, and flying debris.

## TRANSPORTATION AND UTILITY INFRASTRUCTURE AT RISK

New York City's SLOSH model estimates that 35 percent of all critical facilities and key assets are located within storm surge inundation areas for Category 1-4 hurricanes.

A significant proportion of New York City's aging transportation and utility infrastructure is at risk of significant damage during severe coastal storms:

- Transportation: Any subway tunnel, subway station, passenger car tunnel, or bus depot is prone to flooding if it is situated in a low-lying area.
- Utilities: Parts of telecommunications networks, power lines, and electric substations are at risk of damage from high winds, flooding, falling trees, and flying debris during coastal storms. Underground power and telecommunications infrastructure are less exposed to the elements, but are vulnerable to flooding if they are situated in flood-prone areas.



FLOODED SUBWAY TUNNEL FROM HURRICANE SANDY

## NATURAL ENVIRONMENT AT RISK

Coastal storms can greatly affect natural areas and coastal ecosystems. Significant storms have the potential to erode and deform wetlands, cause barrier islands to narrow or split, destroy coastal marine habitats, and disrupt wildlife migration patterns. Losing any natural storm barrier exposes wooded areas and parks farther inland to the risks of damaging winds and storm surge.

Coastal storms can directly affect the health of the natural environment by causing damage to industrial facilities that release hazardous materials (HAZMAT) or cause overflow from sewers and wastewater treatment plants. If HAZMAT releases occur, remediating the natural environment is often a lengthy and costly process.

## FUTURE ENVIRONMENT

Climate change will affect the probability and severity of coastal storms in or near New York City due to an increase in coastal storm surge as sea level rises, higher storm surge, and more frequent flooding:

- Sea Level Rise: Increasing temperatures because of climate change contribute to sea level rise. As ocean water warms, it expands and increases in volume, causing rising sea levels. The New York City Panel on Climate Change (NPCC) projected that by the 2050s, the sea level around New York City could rise an additional 30 inches, or 2.5 feet. By 2100, it could rise 75 inches, or 6.3 feet.
- Higher Storm Surge: The sea height during coastal storms is above the normal level expected of tides alone. More extensive damage would occur because a storm can induce stronger storm surges from rising sea levels.
- More Frequent Flooding: Over the next several decades, both the frequency and the height of floods in New York City is projected to increase.
- More Intense Storms: Ocean surface temperatures are projected to increase as the global climate continues to warm, causing storms to intensify. Climate scientists generally agree that the frequency of the most intense hurricanes (but not the frequency of hurricanes in general) could increase in the North Atlantic Basin.





# HOW TO MANAGE THE RISK

New York City recognizes that climate change and warming oceans could increase the frequency and intensity of hurricanes, nor'easters, and other types of coastal storms. The city is implementing a wide range of policies and projects that protect New York.

## REGULATION AND POLICY

Different branches and levels of government play roles in managing risk from coastal storms. State and local government agencies coordinate to implement federal policies. A prime example is FEMA's policy on flood insurance for at-risk properties, which affects New York Citypolicy, and provides incentives and guidance for property owners:

- **National Flood Insurance Program:** FEMA's National Flood Insurance Program (NFIP) offers protection for property owners in the FEMA-designated 1 percent annual chance floodplain, which represent areas that have a 1 percent chance of flooding in any given year. To participate and maintain eligibility in NFIP, New York City is required to adopt building codes that meet FEMA standards for floodplain management. All owners of property within the 1 percent annual chance floodplain who hold federally-backed mortgages must purchase flood insurance.
- **New York City Construction Code:** The New York City Construction Code prescribes standards for flood-resistant construction in accordance with federal mandates. New buildings must be designed to withstand high winds in a dense, high-rise environment. The New York City Department of Buildings, the City's Floodplain Administrator, enforces flood-resistant construction standards, found in Appendix G of the New York City Building Code.
- **Climate Resiliency Design Guidelines:** The Mayor's Office of Resiliency (MOR) collaborated with City agencies to develop design guidelines that use a consistent methodology to incorporate climate data in the design of City infrastructure and buildings.
- **Flood Resiliency Zoning Text Amendment:** The text amendment encourages new and existing buildings to comply with the new, higher flood elevations specified by FEMA and the New York City Construction Code. Property owners that comply avoid higher flood insurance premiums and reduce their property's risk of future floods damage.
- New Neighborhood Special Districts: In 2017, New York City established Special Coastal Risk Districts in Queens and Staten Island. The special districts place limits on the density and uses allowed within these areas, because these areas face exceptional flood risks.

Many local laws and policies have been created by New York City to mitigate hazards associated with coastal storms. These are discussed in detail in this report's Coastal Erosion and Flooding risk-management sections.

## NATURAL/OPEN SPACE PROTECTION

Since Sandy, New York City is exploring how it can use nature-based strategies to protect its coastline from the damaging effects of pounding waves, storm surge, and high winds from coastal storms:

- Living Shorelines: This bank stabilization technique uses plants, sand and/or soil, and minimal hard infrastructure to protect the shoreline — an engineered buffer that relies on nature.
- Wetlands: Large wetlands use friction to slow the rate of storm surge, and in some cases reduce flood heights. Wetlands provide wildlife with a place to thrive right near urban metropolis. Their plants and soils retain and filter water — another benefit. New York City has built acres of wetlands, combining protective infrastructure and ecological enhancements.
- Beaches, Dunes, and Beach Nourishment: These natural and nature-based features serve as sandy buffers, which protect shorelines from the destructive impact of strong waves and floods.

One of the most visible consequences of a severe coastal storm or nor'easter is fallen trees in many City parks, along green parkways, and on quiet residential streets. To mitigate the risk that falling trees could disrupt service and power by hitting utility infrastructure, New York City and utility suppliers have implemented several programs, are detailed in this publication's High Winds risk-management section.

## BUILDING PROTECTION

New York City's high rises and homes can suffer significant damage from coastal storms. As noted above, the City has enacted many policies and regulations that pertain to property insurance and resilient design practices.

A significant amount of new construction is happening across New York City. All new construction conforms to the latest standards that strengthen both the interiors and exteriors of buildings against high winds.

For older buildings, New York City is encouraging building owners to retrofit and strengthen existing structures to withstand high winds and floods. The Department of City Planning's *Retrofitting Buildings for Flood Risk* publication helps owners to identify their risk and define how they can retrofit single and two-family, multi-family, and mixed-use buildings.

## INFRASTRUCTURE PROTECTION

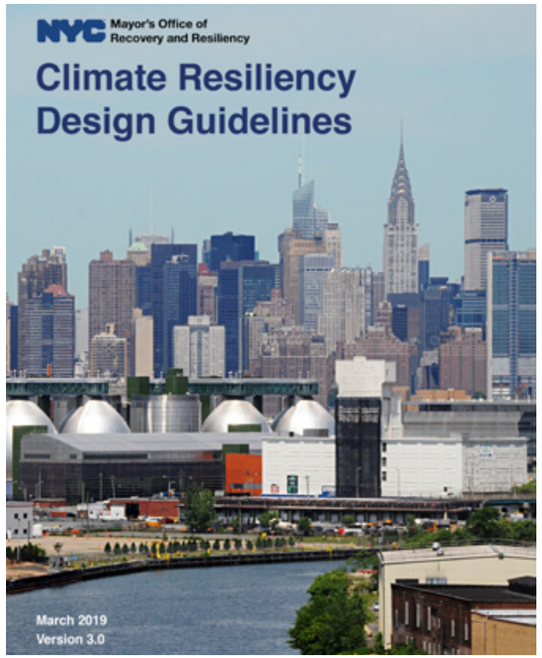
Because so much of New York City's infrastructure is situated in low-lying areas and crosses various bodies of water, transportation and utility operators are aggressively pursuing risk mitigation strategies to ensure that high winds, storm surge, and floods do not shut down essential services. Examples include:

- Subway Protection: The MTA is elevating air vent gratings to prevent floodwaters from entering the system and raising or dry flood-proofing track switches and electrical equipment.
- Tunnel Protection: The MTA is improving its capacity to pump out flood water in its subway system, along its commuter rail lines, and in passenger car tunnels.
- Power Plant Protection: Con Edison, National Grid, and Public Service Enterprise Group are improving redundancy in their power supply networks by increasing the number of power supply feeders, installing additional distribution transformers, and building new substations outside of flood-prone locations.
- Hospital Protection: Hospitals are elevating electrical equipment and ensuring emergency backup power in hospitals.

## COASTAL STORM PROTECTION: RETROFIT OLDER BUILDINGS

- Strengthen connections among structural components of wood buildings — anchor the building to its foundations and its roof frame to load-bearing walls.
- Replace unreinforced brick masonry parapets with reinforced masonry parapets and securely anchor them to the building.
- Replace the roof covering with larger pavers in compliance with Building Code standards to keep roof materials from blowing off.
- Install windows that are rated by the American Architectural Manufacturers Association (AAMA).
- Install functional window shutters.
- Reinforce and secure rooftop heating, ventilation, and air conditioning units.

SOURCE: MAYOR'S OFFICE OF RESILIENCY




## PUBLIC AWARENESS

New York City has developed several communications initiatives to alert residents and property owners to take precautions for threatening coastal storms:

- Public Weather Alerts: When dangerous weather conditions threaten, New York City monitors and disseminates the information it receives from the National Weather Service (NWS) and other sources. This includes NWS Watches and Warnings like a Storm Surge Watch, which indicates a possibility of life-threatening inundation from rising water moving inland from the shoreline, generally within 48 hours. Alerts like these provide New Yorkers time to take the necessary precautions needed against coastal storms.
- Construction Site and Property Alerts: New York City sends weather advisory notifications to property owners, contractors, and developers to encourage them to take specific preventive actions when coastal storms threaten, such as removing or securing loose construction materials and items from sites that could become airborne in high winds.

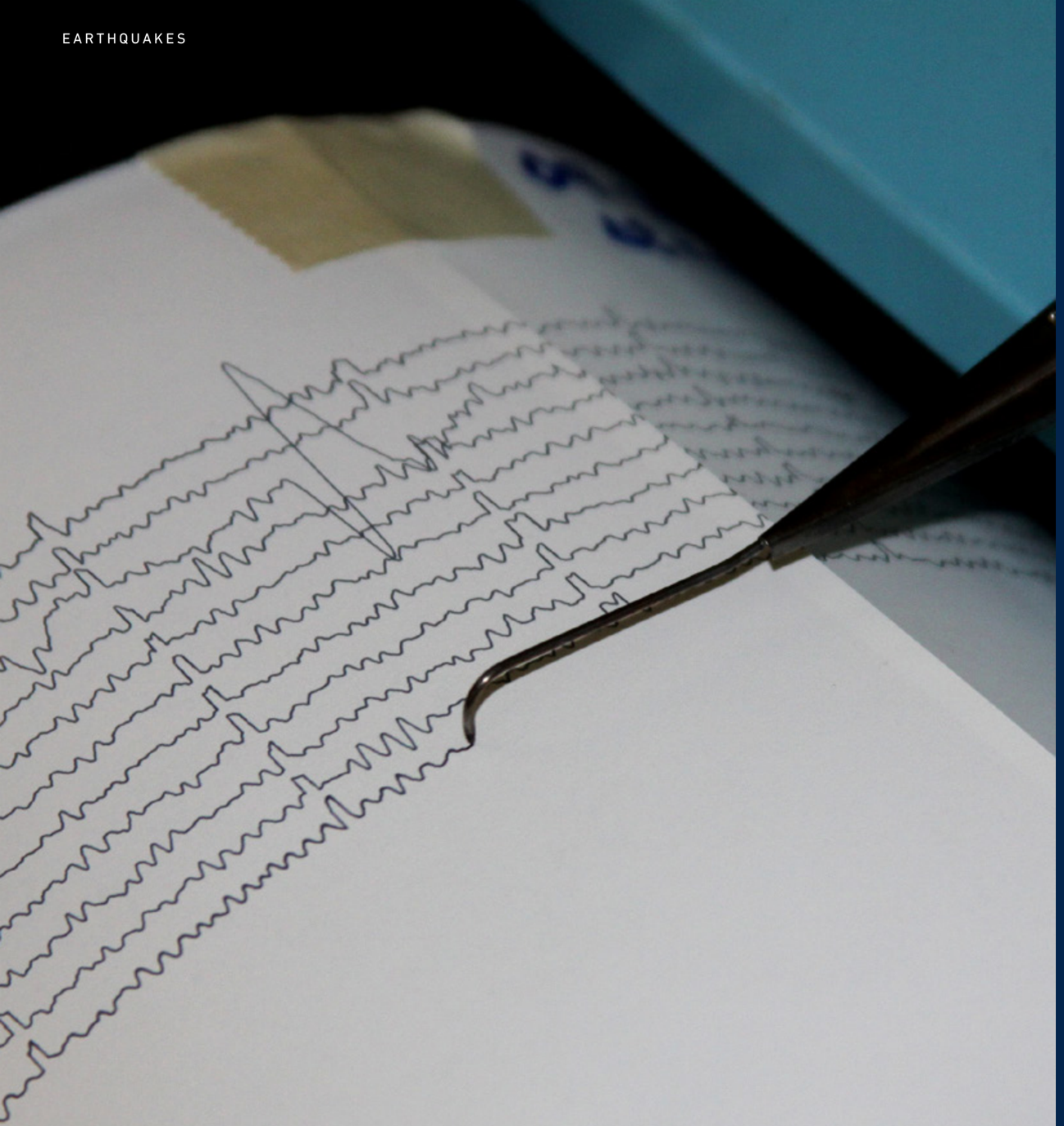
To help New Yorkers prepare for and respond to threats from coastal storms, two NYCEM initiatives are:

- Know Your Zone Campaign: NYCEM provides a variety of toolkits, planners, and digital aids so that residents can find their hurricane evacuation zone and understand how to prepare.
- Ready New York: NYCEM has a branded emergency-preparedness initiative that includes a multilingual hurricane and coastal storm publication as part of its series.

## RESEARCH AND STUDIES

New York City is looking ahead and building upon the results of its extensive climate-change study and its projections of coastal inundation from different categories of hurricanes.

The Mayor's Office Resiliency, in consultation with the Department of Buildings (DOB), is completing a report that investigates New York City's localized wind patterns in depth. The report analyzes how high winds impact at-risk buildings, raised buildings, and buildings under construction. Projections will include the frequency, intensity, and path of future storm events and whether climate change and other factors affect wind speeds that New York City's buildings and infrastructure must withstand.







**LEARN ABOUT EARTHQUAKES**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 03
# EARTHQUAKES

Although New York City does not sit on a major fault system, like the San Andreas in California, earthquakes may still occur in the City.

The likelihood that a strong earthquake will occur is moderate, but if one did occur, the risk is heightened due to New York City's population density, the scale of its built environment, the extent to which buildings sit atop landfill, the interdependency of its critical infrastructure, and the high proportion of buildings constructed before 1995 when seismic design provisions were incorporated into City building codes.

# WHAT IS THE HAZARD?

An earthquake is a sudden, rapid shaking of the earth as plates shift, rock cracks beneath its surface, and large plates either collide or try to push past one other. As rocks and the earth's plates are strained by these tremendous geological processes, energy builds up under the earth's surface and eventually releases abruptly in seismic waves that shake the earth's surface.

The high-frequency motions of the older, harder bedrock in the Northeast can travel long distances before they subside. Aftershocks that follow are typically less intense but may occur for weeks, months, or years after the initial earthquake. Under certain conditions, earthquakes can trigger landslides and soil liquefaction, when the ground vibration causes unconsolidated, water-saturated soils to soften and behave like liquid.

## SEVERITY

Strong earthquakes in New York City have not been registered, but moderate-magnitude earthquakes are possible.

The Moment Magnitude scale measures the size of an earthquake at its source in regard to the size of the fault and the degree to which the fault is displaced. It replaced the Richter scale in the 1970s as a more accurate measure of the strength of earthquakes. The scale is logarithmic, which means that each one-point increase in the scale represents about 32 times the energy released. In theory, the magnitude scales does not have an upper limit, but no earthquake event has yet reached a magnitude of 9.5.

One of the strongest earthquakes to occur near New York City (thought to have originated somewhere between Brooklyn and Sandy Hook, New Jersey) happened on August 10, 1884. Based on contemporary reports of its damage, it was estimated that earthquake had a magnitude of 5.2. Although it only ranks as moderate on today's magnitude scales, the earthquake was felt from Virginia to Maine and shook hard enough to damage chimneys and brick buildings in New Jersey and New York City.

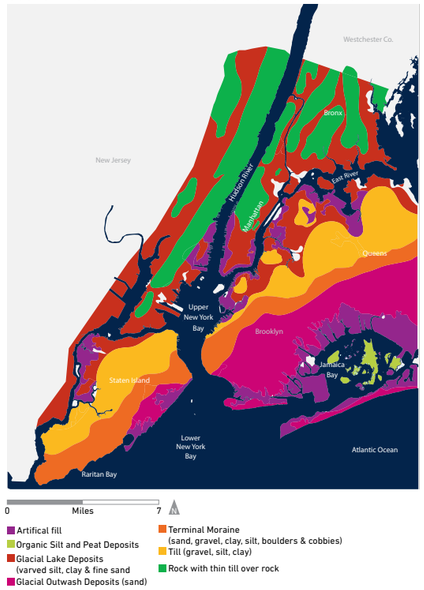
The intensity of ground shaking depends upon the amount of released energy, the earthquake's depth under the earth's surface, its distance from the fault, and the type of underlying soil or bedrock.

Subsurface conditions in New York City, which vary widely across the five boroughs, can affect the amplification of an earthquake's ground motion. The map shows that geologic conditions range from solid bedrock at ground surface to artificial fill.

## FAR AWAY BUT FELT RIGHT HERE

**AN EARTHQUAKE'S EPICENTER IS THE POINT ON THE EARTH'S SURFACE THAT IS DIRECTLY ABOVE THE SOURCE DEEP INSIDE THE EARTH.** Even if an earthquake's epicenter is far away, the geologic nature of the Northeast United States can cause New Yorkers to feel the ground shake. Many people in the eastern United States felt tremors from the 2011 earthquake in east-central Virginia and the 2013 earthquake along Canada's Ottawa River. The 2011 Virginia earthquake, which had Moment Magnitude of 5.8, was felt more than 500 miles from its epicenter, making it the most-felt earthquake in modern U.S. history.

**NEW YORK AND EASTERN NEW JERSEY GEOLOGICAL MAP**
SOURCE: MUESER RUTLEDGE CONSULTING ENGINEERS, 2014








These unique characteristics could result in significant shaking if an earthquake were to happen in New York City today. For centuries, soft sediments and marshes have been filled in to expand space for building development. Manhattan's Chinatown was built on land that filled in New York's historic water supply, the Collect Pond; the 1964 World's Fair site in Flushing, Queens was built on an ash dump; and JFK Airport was built atop a hydraulic sand fill on Brooklyn's south shore.

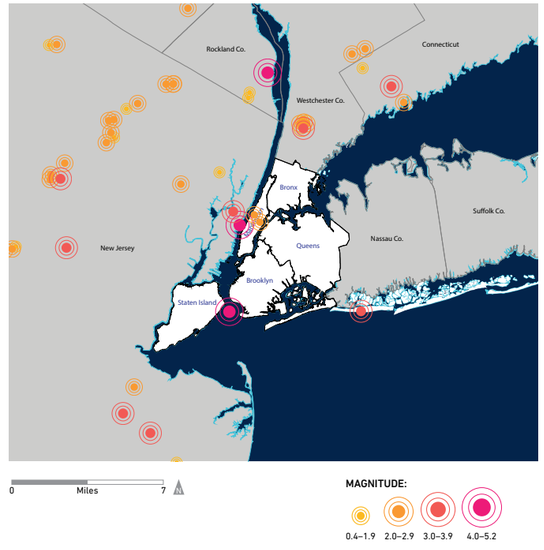
Soil amplification would occur due to the sharp contrast between these softer soils and very hard bedrock, and to short, high-frequency shaking of the bedrock itself.

## PROBABILITY

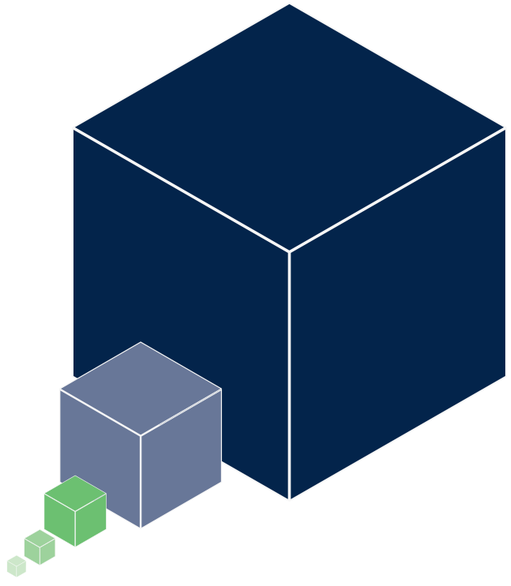
The U.S. Geological Survey (USGS) studies seismic conditions and periodically produces maps to indicate the location, frequency, and severity of future earthquakes. The latest USGS maps, released in July 2014, show that larger, more damaging East Coast earthquakes are more likely to occur in the New York City area than previously considered. The USGS map indicates that New York City has a moderate seismic hazard.

The historic earthquake map below shows the location of earthquake epicenters throughout the tristate area from 1737 — 2018. Historically, larger earthquakes have a longer "return period" in New York City. That is, they happen much less frequently than smaller earthquakes.

**HISTORICAL EARTHQUAKE EPICENTERS IN THE NEW YORK CITY METROPOLITAN AREA (1737 — 2018)**
SOURCE: USGS, NYS DHSES

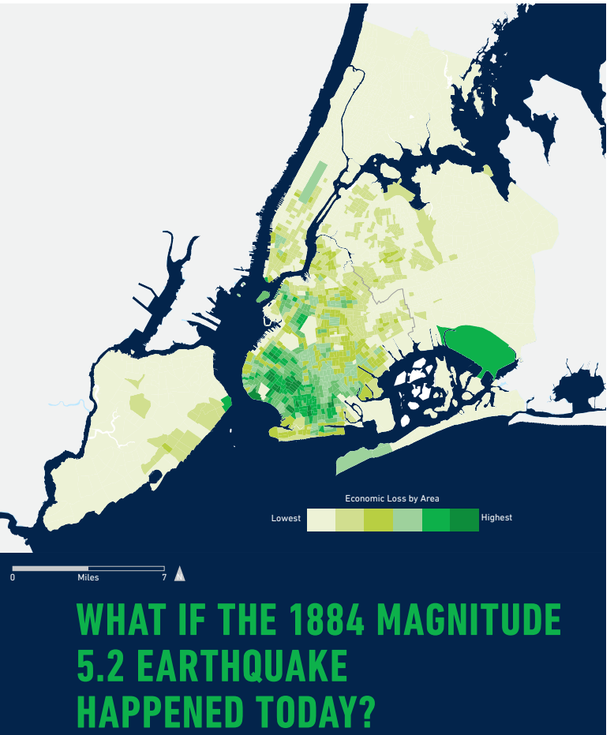



**COMPARING THE MAGNITUDE SCALE (TBD)**
SOURCE: USGS; GEOPHYSICAL INSTITUTE, UNIVERSITY OF ALASKA FAIRBANKS



**A SINGLE STEP IN THE MAGNITUDE SCALE REPRESENTS AN INCREASE OF ABOUT 32 TIMES THE AMOUNT OF ENERGY RELEASED**

MAGNITUDE 5
MAGNITUDE 6
MAGNITUDE 7
MAGNITUDE 8
MAGNITUDE 9




## WHAT IF THE 1884 MAGNITUDE 5.2 EARTHQUAKE HAPPENED TODAY?

Considering the amount of building and development in New York City since 1884, if the same magnitude earthquake occurred today, the amount of damage to people and property would be far worse. New York City Emergency Management (NYCEM) GIS team used HAZUS-MH software, FEMA's loss-estimation tool, to model the 1884 M 5.2 earthquake to understand the potential impacts if it occurred today. NYCEM assumed the epicenter to be in the same location as the 1884 earthquake, and used data on current New York City buildings and building values provided by the NYC Department of Finance (DOF).

The result is that an earthquake of this magnitude could potentially cause $4.7 billion in damage to buildings, transportation, and utilities. The map above shows the areas that would have the greatest economic loss from building damage -- south Brooklyn and Breezy Point in the Rockaways. Approximately 100 buildings would be completely damaged, and nearly 2,000 people would have to seek shelter.

**TOP:**

**DIRECT ECONOMIC LOSS TO BUILDINGS — MODELED ON 1884 M 5.2 EARHQUAKE**
SOURCE: HAZUS AND DEPARTMENT OF FINANCE

# WHAT IS THE RISK?

An earthquake has the potential to destroy buildings, damage infrastructure, and take lives. An earthquake can put New York City's economy at risk, displacing and disrupting businesses and utilities, impairing people's ability to work, creating homelessness, and requiring property owners to make expensive repairs.

## PEOPLE AT RISK

Unlike other natural hazards, earthquakes occur without warning, putting the population at immediate risk. In New York City, the dense urban environment itself puts people at risk:

- **Collapsing buildings:** In a study of 1,100 fatal earthquakes around the globe, 75 percent of fatalities were caused by collapsing buildings.
- **Injuries inside buildings (homes, offices, public spaces):** Non-structural components that create risk include cladding, plaster ceilings, electrical components, bookcases and filing cabinets that may slide, swing, or overturn during an earthquake if they are not tightly affixed to the building's structure. According to FEMA, non-structural failures (not part of a building's structural system) account for the vast majority of earthquake damage. Buildings become nonfunctional and exit routes are blocked.
- **Falling building elements:** Earthquakes can topple rooftop water towers and tanks, potentially injuring people below and disrupting residents' water service.

**UNLIKE OTHER NATURAL HAZARDS, EARTHQUAKES OCCUR WITHOUT WARNING, PUTTING THE POPULATION AT IMMEDIATE RISK.**





Since New Yorkers experience earthquakes less frequently than other natural hazards, the population could be considered to be at higher risk, because people may think they do not have to prepare for one. In California and in other seismically active regions, many homeowners understand earthquake risk and take precautions — securing shelves to walls, anchoring valuable items, securing water heaters, and other mitigation efforts. Residents on the East Coast rarely do this, because they may assume that the earthquake risk is low.

The consequences of an earthquake for New Yorkers are:

- **Immediate personal risk:** A moderate (magnitude 5.5 to 6) earthquake in New York City could cause significant injuries and casualties. Mortality and injury typically peak within the first 72 hours following an earthquake.
- **Disruptions to medical and emergency services:** A large-magnitude earthquake could disrupt emergency and medical services.
- **Displacement:** Damage to buildings after a moderate earthquake could force thousands of New Yorkers into interim housing or require permanent relocation. It may be a challenge to find a locations for interim housing if the surrounding region is also affected.
- **Long-term health risk:** Long-term health risks associated with earthquakes include post-traumatic stress disorder and a range of mental health problems, such as depression and anxiety.

People with disabilities or access and functional needs face greater risk from earthquakes than the rest of the population as, among other reasons, they may not be able to get to safety on their own during an earthquake or they may not be able to escape from the consequences of an earthquake on their own. Earthquakes can also have indirect consequences on people with disabilities or access and functional needs as they may damage necessary equipment or critical infrastructure to support a person's functionality or livelihood.

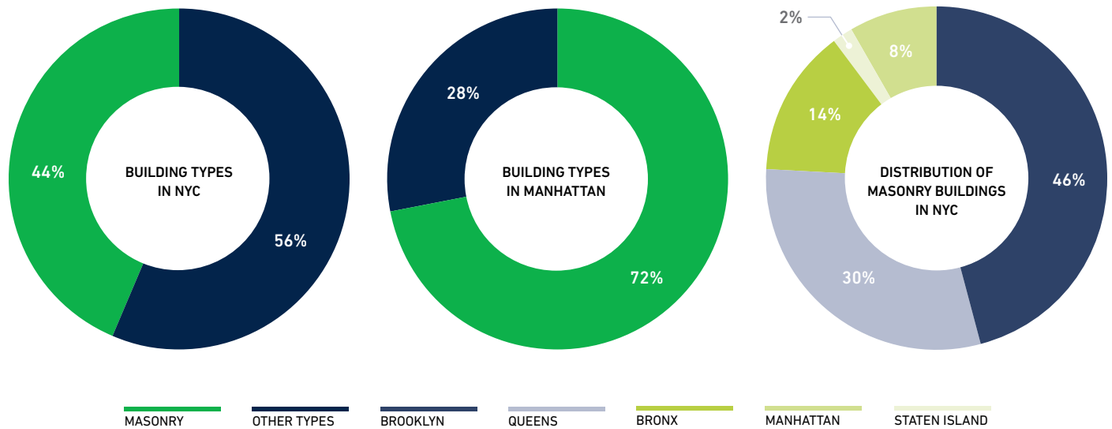
## BUILDINGS AT RISK

With nearly one million buildings, New York City has a unique concentration of commercial and residential skyscrapers and low-rise buildings. Damage to a building during an earthquake depends upon how intensely it responds to shaking. A building's age, construction, material, height, location, and foundation are all factors.

### Older buildings at risk

The Building Code did not address seismic provisions in New York City until 1995; however, most buildings in New York City were built before 1995. In fact, New York City has over 200,000 multi-family, unreinforced brick buildings, built largely between the mid-1800s and 1930s, that are particularly vulnerable to seismic events.

**MASONRY AND OTHER TYPES OF BUILDINGS IN NEW YORK CITY**
NYC DEPARTMENT OF FINANCE, 2018



### Unreinforced Masonry Buildings at Risk

Unreinforced masonry buildings are unable to absorb tensile forces (strength of the force require to pull something apart) during an earthquake. Instead of bending or flexing, walls, facades, and interior structures break or crumble. During a strong earthquake, the structural support system of an unreinforced masonry building has an increased risk of collapse.

Brooklyn has the largest number of masonry buildings (165,661), followed by Queens (108,694), the Bronx (49,734), Manhattan (29.766), and Staten Island (7,041). Masonry loft buildings are vulnerable because they lack interior walls and have higher-than-average ceilings. New York City neighborhoods with rows of attached, unreinforced masonry buildings are also vulnerable. The buildings rely on one another for stability, so any building that sits at the end of a block or next to a vacant lot is particularly vulnerable during an earthquake.

### Foundations on Shallow Soil or Fill at Risk

High-frequency earthquake shaking, which is common in the Eastern United States, is likely to affect short, two- to five-story masonry buildings. A shallow layer of soft soil (less than 100 feet in depth) sitting atop hard bedrock can amplify the shaking for a short time period during an earthquake. A high-rise building atop deeper soil, by contrast, will shake longer and more slowly.

Even if a building did not have visible above-ground damage after an earthquake, damage to its foundation could render a building uninhabitable, particularly if it sits atop filled-in wetlands or wasteland because this soil type is vulnerable to liquefaction. New York City's recent guidelines recommend that owners elevate coastal buildings so floodwaters can pass through a soft story base; however, during an earthquake, if this soft story base sits on land having poor subsurface conditions, the building's load could shift to its foundation and concentrate damage in the bottom story.

**WITH NEARLY ONE MILLION BUILDINGS, NEW YORK CITY HAS A UNIQUE CONCENTRATION OF COMMERCIAL AND RESIDENTIAL SKYSCRAPERS AND LOW-RISE BUILDINGS.**

## INFRASTRUCTURE AT RISK

Earthquake damage to critical infrastructure — bridges, tunnels, utility systems, dams, and highways — often has a cascading set of impacts. Damage to roads and transportation infrastructure hinders delivery of critical emergency and medical services. Damage to upstate dams, reservoirs, and aqueducts could affect the water supply to New Yorkers and could impede first responders' ability to suppress fires following an earthquake.

Some of New York City's critical infrastructure is vulnerable due to its age and maintenance issues. Portions are undergoing change, upgrade, and renewal; however, the seismic vulnerability of complex, interlinked infrastructure remains poorly understood and is of high concern to risk-mitigation teams.

During an earthquake, other risks affecting infrastructure include:

- **Ground failure:** During an earthquake, soil liquefaction could damage pavements, compromise building foundations, and disrupt underground utilities. Areas built atop artificial fill are vulnerable to liquefaction, and a seismic event could cause structures to sink and settle.
- **Underground soil instability:** Damage to underground infrastructure usually occurs when pipes and utility transmission lines are unable to withstand soil movements. Damage to these could trigger secondary impacts with even greater public risk — water contamination and fires.

## HOW TO MANAGE THE RISK

Even though earthquakes occur without warning and cannot be prevented, many strategies can be used to reduce the risks associated with them. The body of knowledge that informs these strategies continues to grow as seismologists, geologists, engineers, architects, emergency responders, and other experts continue to pursue research to advance their fields.

The primary strategies involve more robust seismic requirements in New York City's building code, encouraging retrofits for existing buildings, and additional inspection, retrofits, and maintenance of critical infrastructure.

### REGULATION AND POLICY

New York City's current building code is as stringent as any in the United States. The likelihood that a modern, code-compliant structure will fail or collapse in New York City is the same as in California, which is known for its' highly effective requirements.





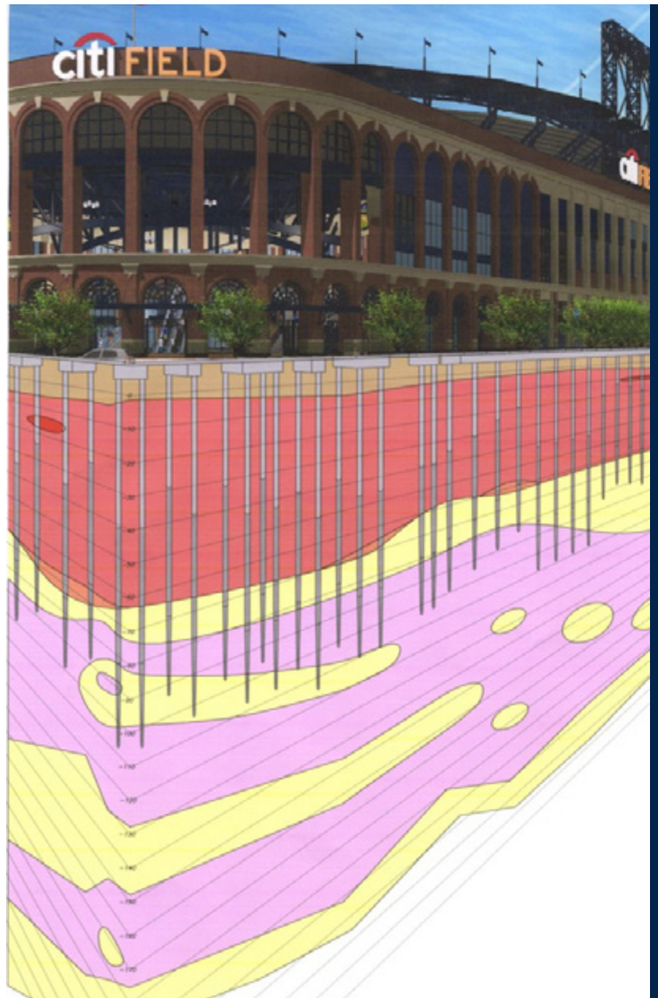
The first seismic provisions in New York City's Building Code were signed into law in 1995 and took effect in February 1996. Since then, New York City has continued to increase the stringency of its seismic requirements.

In 2008, the Department of Buildings (DOB) adopted the International Code Council's family of codes as the New York City Construction Codes to make buildings stronger, more flexible, and more ductile — able to absorb energy without breaking in a brittle manner. The Codes have sections on soil types and building foundations, and require seismic detailing to sustain a building's joints, structural connections, and piping during an earthquake. Critical facilities, such as firehouses and hospitals, are now designed not only to survive an earthquake but keep functioning afterward.

In 2014, the DOB revised the Construction Codes and moved toward a risk-based approach, following the model of the American Society of Civil Engineers Standard 7-2010 for designing and constructing seismic-resistant structures. These enhanced codes reduce the risk that new buildings will collapse or sustain significant damage during an earthquake.

The revised code also strengthens the design requirements for soil liquefaction and takes the city's unique geologic conditions into account. Special detailing for electrical and mechanical systems, building contents, and architectural components are also specified.

Code committee work is now in progress for the next revision of the construction codes. DOB is also working on an existing building code and analyzing potential provisions that could improve safety or mitigate hazards in existing buildings constructed before the seismic requirements were enacted.




## SEISMIC PROVISIONS FOR THE CONSTRUCTION OF CITI FIELD STADIUM

The site of the Citi Field baseball stadium in Queens, New York, home to the New York Mets, has some of the worst soil conditions that could be used for building new structures. The site's soft subsurface soil was created dumping incineration residue there for years — a practice that continued until this site was developed for the 1939 and 1964-65 World's Fair.

During an earthquake, soft soils, like the fill dumped at the Citi Field site, can lead to soil liquefaction and cause buildings to sink or settle. To understand and mitigate this risk, engineers performed site-specific seismic analysis, including cross-hole testing to 200 feet, dynamic resonant laboratory testing, and seismic amplification and soil-structure interaction studies.

The construction team installed 3,000 Monotube piles to hold the stadium's foundation slab. The piles were installed at varying depths based on soil conditions, as shown in the diagram. The team used concrete shear walls around the stair towers for additional support and structural expansion joints to accommodate potential seismic movements within the structure.

**LEFT:**

**CITI FIELD DIAGRAM**
SOURCE: MUESER RUTLEDGE CONSULTING ENGINEERS, 2010.

## BUILDING PROTECTION

Architects and engineers design new buildings and retrofit older ones to meet seismic standards by increasing their structural flexibility, reducing the building's mass, and strengthening foundations placed in poor soil. Additional protective measures include:

- **Strengthening connections among building elements:** Anchoring walls to the roof and walls to the foundation strengthens connections among structural elements of unreinforced masonry buildings, which increases the ability of these existing structures to transfer loads during an earthquake. Adding steel frames to unreinforced brick walls also increases a building's resistance to out-of-plane forces.
- **Anchoring building elements:** Parapets are often the most damaged element of unreinforced masonry buildings. Parapets can be anchored with bolt diagonal steel struts and have their mortar repaired. Unreinforced masonry parapets can also be replaced by masonry parapets anchored to the building. Anchoring water tanks on buildings that are six or more stories prevents the tower from toppling over and potentially injuring pedestrians, and ensures that a building's occupants continue to have water following an earthquake.
- **Securing interior elements:** Anchoring or bolting furniture to a wall reduces the risk that a building's contents are damaged if an earthquake shakes it.
- **Bracing elevated buildings:** Guidelines written to protect coastal buildings from flooding and coastal storms also incorporate seismic safety, particularly the vulnerabilities of elevated buildings. If a building has a soft story base, the extra load can be lessened by adding bracing or shear walls, or to enlarge or strengthen the columns and piles.
- **Routine maintenance:** Routine maintenance minimizes the risks associated with earthquakes — keeping roofs secure and in good condition, securing cornices and aluminum panels, repointing mortar regularly (especially on parapets and chimneys), and fixing all cracks.

## INFRASTRUCTURE PROTECTION

Earthquakes can cause major damage to infrastructure that was not originally designed to withstand shaking, including older bridges, tunnels, sewers, water supply systems, and wastewater treatment plants. New York City is acting to require that new infrastructure is designed to meet more robust seismic loading requirements, and that older infrastructure is retrofitted to meet these standards. Federal, state, and local government agencies all play roles.

### Protecting Bridges

After the 1989 Loma Prieta earthquake, which caused extensive damage to several bridges in Northern California, many central and northeastern states began to adopt new seismic provisions for highway bridges, and bridge owners in New York hired seismologists to perform risk assessments.

Under a 1991 inspection and rehabilitation program mandated by Congress, the Federal Highway Administration administers seismic retrofits of bridges through local authorities. Seismic assessment requires each bridge to be evaluated for performance standards based upon whether the bridge is determined to be critical, essential, or other.

In 1998, the New York City Department of Transportation (NYC DOT) developed Seismic Criteria Guidelines, which are updated as new science and solutions emerge, and began seismic retrofitting of New York City's critical and essential bridges.

NYC DOT is in the process of implementing seismic retrofits of these bridges. In addition, NYC DOT is retrofitting the Brooklyn Bridge so that it conforms to current seismic performance requirements — replacing the original timber piles with stronger structural piles and reinforcing the masonry elements of the bridge. Other bridges were replaced when seismic performance was deemed poor.





## PUBLIC AWARENESS

Many New Yorkers are unaware that their community is at risk to seismic danger from earthquakes. Because earthquakes occur unexpectedly, New Yorkers will not have advanced warning that one will strike, so promoting awareness and preparedness among local communities is essential. Initiatives include:

- **Emergency awareness campaigns:** New York City Emergency Management's (NYCEM) Ready New York campaign encourages New Yorkers to be prepared for all types of emergencies, to develop a personal disaster plan, and to stay informed about the entire range of hazards that may affect the city.
- **Preparation guides:** NYCEM's Ready New York *Earthquake Safety* guide explains what to do when an earthquake strikes and the steps to take immediately after.
- **Homeowner advice:** NYCEM's Ready New York *Reduce Your Risk* guide includes long-term strategies for homeowners and residents to reduce the potential damage that an earthquake can cause.
- **Drills:** FEMA and the Northeast States Emergency Consortium organize annual Great Northeast Shakeout drills to encourage organizations, households, and agencies to practice safety during an earthquake. Drills encourage participants to update preparedness plans, restock supplies, and secure items in homes and workplaces to prevent damage and injuries.

The Earthquake Engineering Research Institute has also established a New York–Northeast chapter to promote awareness of earthquake risk and to offer educational resources on how to reduce this risk at all levels. The organization relies on interdisciplinary expertise from the fields of engineering, geoscience, architecture, planning, and the social sciences.

## RESEARCH AND STUDIES

Collaboration among seismologists, geologists, engineers, architects, politicians, and emergency managers is required to manage New York City's earthquake risks and to expand knowledge about this hazard. Research and study initiatives include:

- **USGS maps and forecasts:** In July 2018, USGS produced a one-year probabilistic seismic hazard forecast for the central and eastern United States from induced and natural earthquakes. The new seismic hazard maps will inform future research.
- **New earthquake models:** The Next Generation of Ground-Motion Attenuation Models is a multi-disciplinary research project coordinated by the Pacific Earthquake Engineering Research Center, which includes researchers from academia, industry, and government. These experts are working to develop a consensus for new ground-motion prediction equations, hazard assessments, and site responses for the Central and Eastern North American region.
- **Building studies:** The Multidisciplinary Center for Earthquake Engineering (MCEER), in collaboration with the Structural Engineering Association of New York, has initiated studies on the vulnerabilities of unreinforced masonry buildings in New York City. Working with the State University of New York at Buffalo, MCEER has shake-table tested prototypes of unreinforced masonry structure as a precursor to a much larger program that will develop engineered solutions for New York City's archaic building stock.

Future research may include further earthquake-impact modeling to estimate potential physical and economic losses, incorporating New York City's large stock of older buildings, soil conditions, and unique geological characteristics.

**BECAUSE EARTHQUAKES OCCUR UNEXPECTEDLY, NEW YORKERS WILL NOT HAVE ADVANCED WARNING THAT ONE WILL STRIKE, SO PROMOTING AWARENESS AND PREPAREDNESS AMONG LOCAL COMMUNITIES IS ESSENTIAL.**





**LEARN ABOUT EARTHQUAKES**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 04 EXTREME HEAT

Annually, more heat-related deaths occur in New York City than from all other extreme weather events combined. New York City is particularly susceptible to this hazard due to its dense urban environment, which absorbs and traps heat. Air conditioning on New York's hottest days provides relief, but can also trigger a power outage if the demand for electricity surges.

Climate change is likely to bring hotter temperatures and more hot days, leading to far longer and more frequent heat waves.

# WHAT IS THE HAZARD?

During the summer, New York City usually experiences one or more periods of extreme heat between June and August, but heat waves can occur any time between May and September. Between 1981 and 2010, temperatures in Central Park reached 90°F or higher on average 18 days each year. Hazards from extreme heat are made worse when accompanied by either of the following:

- **High humidity:** Hazardous conditions are worse if the amount of moisture in the air and the temperature are both high. A combination of temperature and humidity — what the temperature "feels like" — is known as the heat index.
- **Poor air quality:** During the summer, stagnant atmospheric conditions can trap humid air and pollutants, such as ozone, near the ground. Ozone, a major component of smog, is created when pollutants emitted by cars, power plants, industrial boilers, and other sources chemically react in the presence of sunlight, making it hard to breathe.

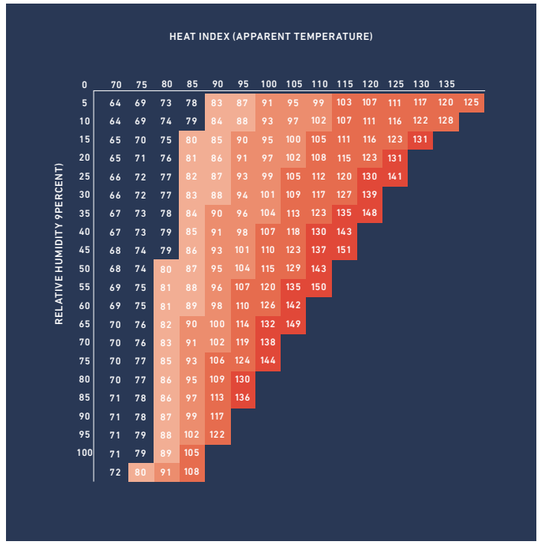
New York City's densely built environment contributes to the phenomenon known as the "urban heat island effect" — where natural terrain is covered with asphalt and buildings that absorb and retain heat. This slows the natural cooling process, meaning that temperatures stay higher than those in surrounding rural areas, particularly in the evening.

On summer nights, New York City temperatures are on average seven degrees warmer than the suburbs, and can be as much as 10 to 20 degrees warmer under certain conditions.

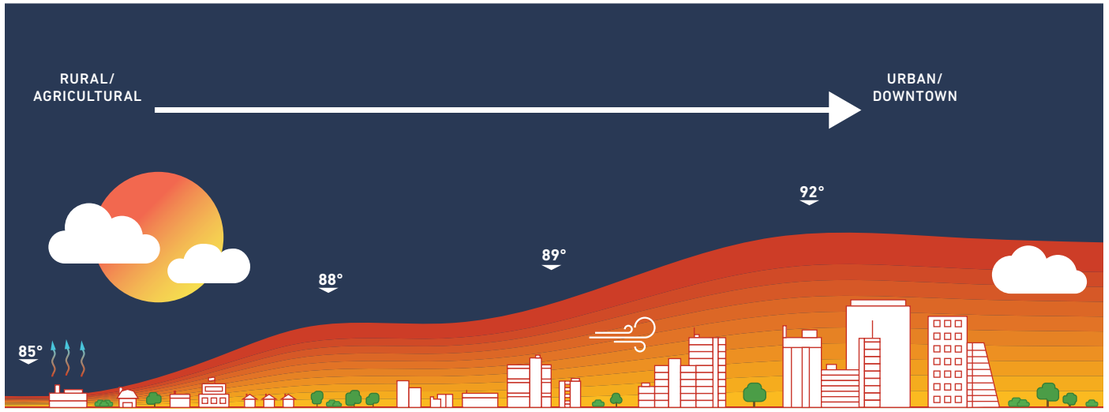
## SEVERITY

The severity of an extreme heat event is typically measured by how temperature and humidity combine to affect people's health, as shown in the heat index chart developed by the National Weather Service (NWS).

**THE HEAT INDEX**
SOURCE: NWS, 2019




**URBAN HEAT ISLAND EFFECT**
SOURCE: NYCEM, 2014





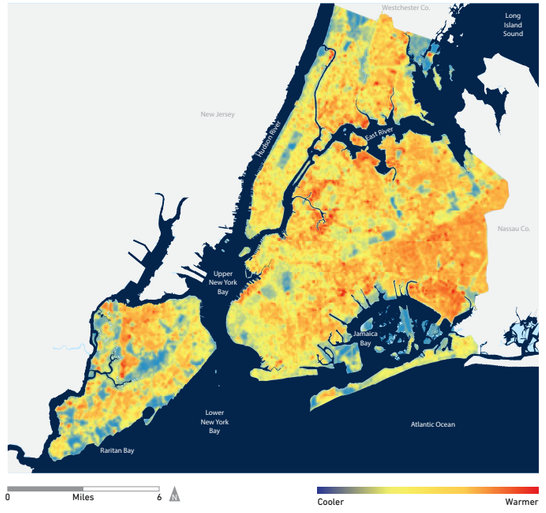



The NWS issues heat advisories, watches, and warnings for New York City, based on analyses of the relationship between weather conditions and mortality that are conducted by the New York City Department of Health and Mental Hygiene (DOHMH).

Areas of New York City with the highest building density and the least vegetation tend to retain higher temperatures. Thermal maps of New York City show warmer neighborhoods in orange and red, and cooler neighborhoods in blue and yellow.

| PRODUCT | CRITERIA |
|---|---|
| **Heat Advisory (NYC)** | Issued within 24 hours prior to the onset of any of the following conditions:<br>· Heat index of 100°F-104°F for any period<br>· Heat index of 95°F-99°F or greater for two consecutive days |
| **Excessive Heat Watch** | · Issued 24-48 hours prior to the onset of the following condition:<br>· Heat index of at least 105°F for at least two consecutive hours |
| **Excessive Heat Warning** | · Issued within 24 hours of the onset of the following condition:<br>· Heat index of at least 105°F for at least two consecutive hours |

**NEW YORK CITY THERMAL IMAGERY TAKEN JULY 17, 2018**
SOURCE: USGS




The Air Quality Index (AQI), created by the U.S. Environmental Protection Agency, is another scale referenced during periods of extreme heat. As New York City's AQI value rises, the risk to its population's health rises. When levels of ozone and/or fine particles are anticipated to exceed an AQI value of 100, New York State Department of Environmental Conservation and the State Department of Health issue an Air Quality Health Advisory and recommend that people limit vigorous outdoor physical activity during the afternoon and early evening hours.

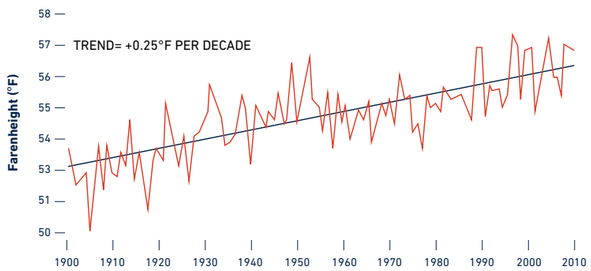
## PROBABILITY

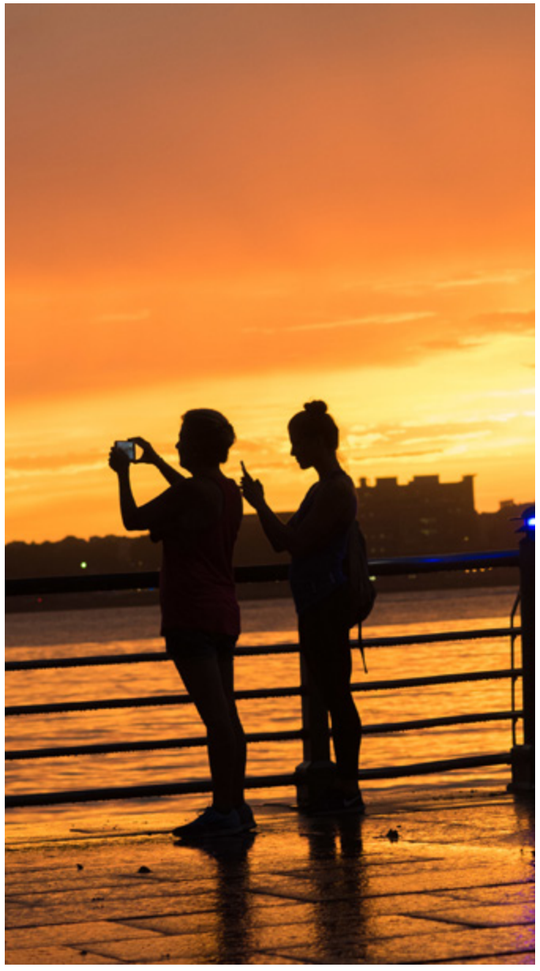
The 2015 New York City Panel on Climate Change (NPCC) report estimated that from 1971 to 2000, New York City had an average of 18 days per year where maximum temperatures reached 90°F or more and had heat waves lasting an average of four days. [Note that the NPCC calculation uses a different time period (1971 - 2000) than the one used by meteorologists (1981 - 2010)].

Based on historical NWS data recorded near Belvedere Castle in Central Park, the annual number of days with high temperatures of 90°F and above has been increasing since the late 19th century.

In the future, the number, duration, and intensity of heat waves at or above 90°F are expected to continue to increase as a result of climate change.

OBSERVED ANNUAL TEMPERATURE IN CENTRAL PARK (1900 — 2011)
SOURCE: NPCC, 2013



# WHAT IS THE RISK?

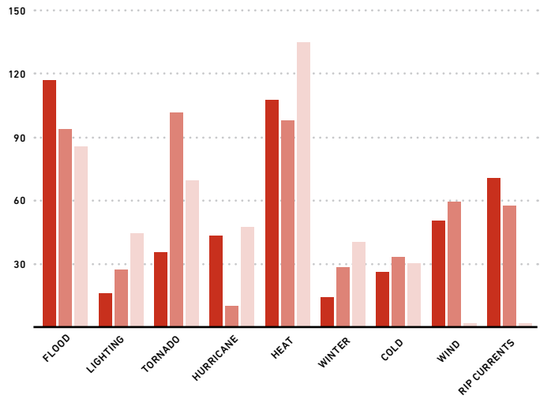
More heat-related deaths occur in New York City and the United States annually than casualties resulting from any other type of extreme weather event. In addition to the physical danger, periods of extreme heat stress New York City's infrastructure. Heat waves cause people to increase their usage of air conditioning, which can strain the power grid and trigger power outages; power outages in turn, can lead to adverse health impacts.

## PEOPLE AT RISK

In New York City, where people live, the activities they undertake, and their overall health can either heighten or lessen their personal risk during periods of extreme heat, high humidity, and poor air quality.

Each year, more people in New York City die from causes associated with extreme heat than from hazards associated with any other type of extreme weather event.

ANNUAL WEATHER FATALITIES IN THE UNITED STATES
NOAA, 2017




**EACH YEAR, MORE PEOPLE IN NYC DIE FROM CAUSES ASSOCIATED WITH EXTREME HEAT THAN FROM HAZARDS ASSOCIATED WITH ANY OTHER TYPE OF EXTREME WEATHER EVENT.**

## EXCESS DEATHS

In addition to causing heat stroke deaths, heat can cause an excess of natural cause deaths (or "excess mortality"). This occurs when chronic conditions are exacerbated by heat and result in death, but heat is not documented as a contributing cause on the death certificate.

Excess mortality is estimated using statistical models to determine whether more people died during a heat wave than was expected with normal summer conditions.

Between 1997 and 2013, New York City averaged 115 annual excess deaths due to natural causes that were exacerbated by extreme heat.

### Personal Health Risks

Anyone with prolonged exposure to very high temperatures can experience serious health problems, including dehydration, heat exhaustion, heat stroke and, in severe cases, death. Each New York City summer averages 13 heat-stroke deaths, 150 hospital admissions, and 450 emergency-room visits for heat-related illness.

Poor air quality can occur during heat waves when stagnant atmospheric conditions trap pollutants, such as ozone, in urban areas. Increased ozone levels can cause or worsen respiratory problems.

Approximately 80 percent of heat-related deaths among New Yorkers are due to extended exposure to heat in the home, which suggests that air conditioning could prevent most heat-related deaths and illness. According to estimates, one in four New Yorkers (25 percent of the adult population) either do not have or do not regularly use air conditioning during hot weather.

The high expense of purchasing and running a home air conditioner is an economic barrier that places many lower-income New Yorkers at risk. In 2014, about 17 percent of households in higher poverty neighborhoods lacked air conditioning compared to just 6 percent of households in lower poverty neighborhoods.

### Risks from Power Outages

Power outages can have severe, pervasive impacts on people who depend upon life-sustaining medical equipment, oxygen concentrators, rechargeable motorized wheel chairs, and refrigerated medications. Anyone needing air conditioning to stay cool during a heat wave is at increased risk if there is a power outage.

A citywide power outage that occurred in August 2003 during normal weather led to approximately 90 excess deaths — a figure that could likely have been higher if this occurred during a heat wave.

## EXTREME HEAT: KEY FACTS

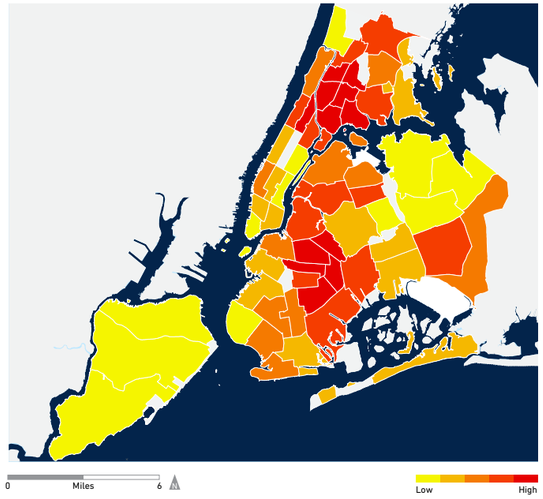
Prolonged exposure to extreme high temperatures can impact anyone's health, but people may have higher risk if they are in one or more of these categories:

- Do not have or use air conditioning
- Are 65 years or older
- Have chronic health condition(s), including:
  - » Cardiovascular, respiratory, or renal disease
  - » Obesity [having a Body Mass Index (BMI) of more than 30]
  - » Diabetes
  - » Psychiatric illness (e.g. schizophrenia or bipolar disorder )
  - » Cognitive or developmental disorder that impairs judgment or self-care
- Take certain medications, which can disrupt the regulation of body temperature, including:
  - » Diuretics
  - » Anticholinergics
  - » Neuroleptics
- Are socially isolated
- Have a disability or others with access and functional needs
- Misuse alcohol or drugs (e.g. amphetamines, cocaine and ecstasy)
- Are outdoors vigorously working or exercising in extreme heat

## Heat Vulnerability Index (HVI)

People living in certain areas and communities in New York City may be at higher risk during periods of extreme heat than others. The Heat Vulnerability Index (HVI) analyzes heat-related mortality in New York City and compares the level of vulnerability in different neighborhoods to each other in terms of how at risk they are during extreme heat events. The HVI enables New York City to direct resources more effectively to communities that are at higher risk of health impacts during extreme heat. It is important to note that residents are still at risk for heat illness and death in all neighborhoods - even if they reside in neighborhoods with low HVI scores.

**HEAT VULNERBILITY INDEX (HVI) FOR NEW YORK CITY COMMUNITY DISTRICTS**
SOURCE: NYCEM, 2014




New York City communities with highest vulnerability to death or illness during periods of extreme heat have the following characteristics: higher surface temperatures, less green space, and poor communities of color whose populations have experienced historical racism and segregation.

## BUILDINGS AT RISK

Power outages can shut down a building's critical equipment — air conditioners, elevators, and pumps that supply water to the upper floors of high-rises.

People can be placed at higher risk of heat-related illness if their building's architecture traps heat, limits ventilation, or if cooling systems are absent or broken. Glass transmits heat far more readily than brick, masonry, and wood, so windows can create an internal greenhouse effect.

Mechanical systems that pump out heat or hot vapor into sidewalks can increase the heat that people outside at street level feel on sweltering days. Asphalt roofs and parking lots also amplify heat.

## INFRASTRUCTURE AT RISK

Extreme heat and any resulting power outages put New York City's infrastructure at risk:

- **Transportation and telecommunications infrastructure:** Railroad tracks, wires, and pavement on roads and bridges may crack, buckle, or sag in hot weather, risking service disruptions, hazardous travel conditions, or expensive repairs.
- **Water system:** People illegally opening fire hydrants to cool off can cause water pressure levels to drop, limiting the ability of first responders to put out fires fast.
- **Power grid:** Extreme heat increases the demand for power to run air conditioners. Periods of extreme heat can stress the power grid, causing outages that can create a cascade of negative impacts throughout the City, including physical damage to the infrastructure.

If there is no backup power, outages can shut down all types of equipment that are plugged into the grid — building systems, computers, and life-sustaining medical equipment.





## FUTURE ENVIRONMENT

Based on historical NWS data recorded at Central Park, the annual number of days with high temperatures of 90°F and above has been increasing since the late 19th century.

Scientists predict that in the future, extreme heat events in New York City will increase in frequency, intensity, and duration. This table, adapted from the 2015 New York City Panel on Climate Change (NPCC), illustrates this projected change through the middle of the 21st century.

In the future, the NPCC projects that New York City will experience between three to four heat waves per year, each lasting an average of five days. By the 2050s, New York City could experience as many ninety-degree days annually as Birmingham, Alabama does today — more than triple the 18 extremely hot days that New Yorkers currently experience in an average year.

**BASED ON HISTORICAL NWS DATA RECORDED AT CENTRAL PARK, THE ANNUAL NUMBER OF DAYS WITH HIGH TEMPERATURES OF 90°F AND ABOVE HAS BEEN INCREASING SINCE THE LATE 19TH CENTURY.**

## LESSONS LEARNED: MAJOR HEAT WAVES

Two of the most significant heat waves in recent memory occurred in Chicago in 1995 and across much of Europe in 2003.

- 1995 Chicago heat wave: This historic heat wave in July 1995 lasted for two weeks. The heat index peaked at nearly 120°F, claiming over 700 lives.
- 2003 European heat wave: This heat wave was very dramatic, widespread, and lasted most of the summer. Air conditioning is much less common in European homes and businesses than in the United States, which likely contributed to the severe impact of the heat wave. Heat-related death estimates ranged from 50,000 to 70,000, with nearly 15,000 in France alone.

New York City's ten-day heat wave in 2006 was one of the worst heat waves of the last 20 years, prompting New York City to expand its Heat Emergency Plan to increase outreach to residents who are at greater risk from heat-related illness and the various organizations and providers that serve them to emphasize how using air conditioning can prevent heat illnesses. New York City also carried out heat-health analysis that led to lower thresholds for the NWS heat advisories here.

**QUANTITATIVE CHANGES IN EXTREME TEMPERATURE EVENTS**
SOURCE: NEW YORK PANEL ON CLIMATE CHANGE (NPCC) 2015

| | | 2020s | | 2050s | | 2080s | |
|---|---|---|---|---|---|---|---|
| **Heat Waves** | Baseline (1971-2000) | Middle Range (25th-75th percentage) | High End (90th percentile) | Middle Range (25th-75th percentage) | High End (90th percentage) | Middle Range (25th-75th percentage) | High End (90th percentile) |
| **Number of days per year at or above 90°F** | 18 | 26 to 31 | 33 | 39 to 52 | 57 | 44 to 76 | 87 |
| **Number of heat waves per year** | 2 | 3 to 4 | 4 | 5 to 7 | 7 | 6 to 9 | 9 |
| **Average duration (days)** | 4 | 5 | 5 | 5 to 6 | 6 | 5 to 7 | 8 |

# HOW TO MANAGE THE RISK

New York City has initiated a suite of programs to keep its communities safe in extreme heat, including public education efforts, neighborhood initiatives to promote social cohesion, tree planting to cool down hot City streets, simple solutions to keep buildings cool, and programs to minimize the risk of power outages on hot days.

## REGULATION AND POLICY

New York City is committed improving air quality, reducing energy consumption, mitigating power outages, and promoting sustainable design:

- **Greenhouse gas reductions:** The Mayor's Office released One City: Built to Last, a plan to reduce greenhouse gas emissions 80 percent by 2050.
- **Energy consumption:** This policy report was followed by New York City's Roadmap to 80 X 50, which proposes reducing building energy use by improving the efficiency of building systems, equipment, and operations, and by dramatically expanding on-site renewable energy generation.
- **Construction code:** New York City modified its Construction Code to encourage sustainable design.

In June 2017, the Mayor's Office launched a cornerstone initiative, Cool Neighborhoods NYC, a $106 million mitigation effort that monitors neighborhood temperatures to determine which are highest risk, deploys tree-planting and cool roof initiatives, partners with community-based organizations to reach out to people most at risk, and trains home and community health workers about heat risks and safety.

## NATURAL/OPEN SPACE PROTECTION

New York City's Green Infrastructure Program, led by the NYC Department of Environmental Protection (DEP), places additional vegetation in certain neighborhoods to reduce local air temperatures, similar to the previous MillionsTreesNYC campaign.

As part of the Vision Zero Great Streets project, DOT has turned approximately 30,000 square feet of paved medians into planted medians. The target is to plant nearly 400,000 square feet as part of major reconstruction projects along the Grand Concourse, Atlantic Avenue, Queens Boulevard, and other major thoroughfares.

## BUILDING PROTECTION

New York City encourages sustainable design to help reduce the impacts of heat events. Some examples include:

- **Green roofs:** Building owners are now allowed to construct green roofs, instead of having to request special permission.
- **Heat reflection:** Building owners are now required to use heat-reflective coverings on any roof having a less-than-25-percent slope.

New York City Greenhouse is a program developed by the New York City Department of Housing Preservation and Development (HPD) to help owners retrofit their buildings with higher-performance materials to reduce the amounts of energy and water that they use. The program provides tax credits, rebates, and incentives to promote energy efficiency and offers tips on lowering energy bills.

New York City's CoolRoofs program is a partnership among the New York City Department of Small Business Services (SBS), the Mayor's Office of Sustainability, the Mayor's Office of Resiliency, and Sustainable South Bronx, a division of The HOPE Program. This program has re-coated over nine million square feet of roofs with lighter-colored materials. Since light-colored surfaces reflect more light and heat than dark surfaces, this program has reduced both internal building temperatures and the local urban heat island effect.

PHOTO: DOB — SAMANTHA MODELL, 2014

## INFRASTRUCTURE PROTECTION

Infrastructure initiatives to mitigate the impact of extreme heat are to shore up the resiliency of the power grid, reduce peak demand, mitigate the impact of heat upon the transportation infrastructure, and use materials that reduce the heat emanating from City streets.

Utilities employ two complimentary approaches to keeping the power grid operational during periods of high energy demand:

- **Supply-side strategies:** To reduce strain on the system, utilities reinforce the system itself, improve its reliability, increase its operational readiness, and pre-positioning back-up generators.
- **Demand-side strategies:** During extreme heat events, utilities manage load on the system to sustain operations, including using smart meters to tell the utility about customer outages and using voluntary utility-demand response programs that involve their customers.

Several initiatives will build on this work in the future:

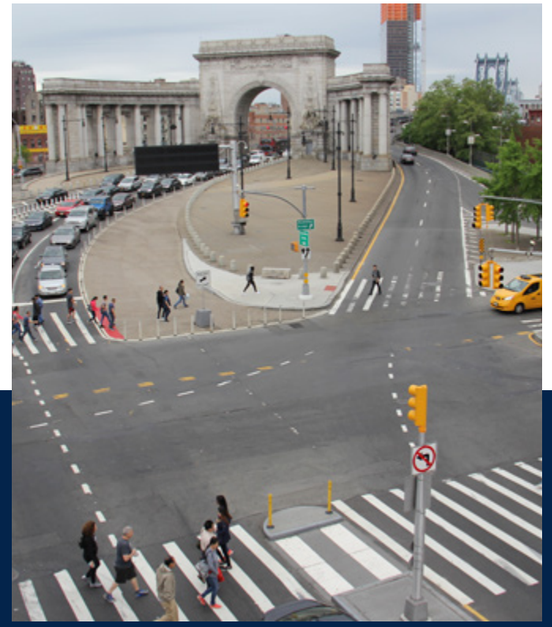
- DOT is updating its Street Design Manual to encourage private entities to use permeable pavements, as appropriate.
- The Public Design Commission (PDC) approved permeable pavers for use in portions of the sidewalk.
- As part of the Cool Neighborhoods program, New York City will assess the feasibility of increasing the use of cool and permeable surfaces in heat-vulnerable neighborhoods and determine applications that make the most sense for certain typologies, such as plazas, playgrounds, parking lots, and low-traffic roads.

## NYC AND DEMAND RESPONSE PROGRAMS

New York City is a leader in reducing its energy consumption, increasing the reliability of the power grid, and being a good steward of City resources. In 2013, the Department of Citywide Administrative Services (DCAS) launched a voluntary Demand Response program to reduce energy demand when New York City's temperatures are high to sustain the utility's infrastructure. Voluntary programs offered by utilities and New York State's grid manager provide financial incentives to large users who reduce their demand at critical times.

New York City participates in four electric and two gas Demand Response programs, offered by Con Edison and National Grid. These programs provide financial incentives to energy end-users to reduce consumption during peak demand periods, helping ensure the reliability of energy infrastructure. New York City enrolls City buildings into the programs, allowing City agencies to not only support the electricity grid and gas supply reliability, but also to receive revenue from utility providers in exchange for their reduced energy use. This revenue is then reinvested in building improvements and energy efficiency upgrades.

During Fiscal Year 2018, 410 facilities across 23 agencies took part in the City's Demand Response program, reducing approximately 75 MW of load from the grid during peak demand periods — a reduction equivalent to removing approximately 300 mid-size schools from the grid. New York City government accounts for less than 10 percent of the energy consumed here; however, it accounts for 20 percent of peak load reduction.



# COOL PAVEMENTS

## TRANSPORTATION SYSTEMS ARE PROTECTED FROM EXTREME HEAT HAZARDS BY:

- Upgrading rail system equipment, which involves replacing or retrofitting tracks, wires, signals, and switches.
- Retrofitting roads and bridges with heat-resistant materials to prevent cracking and buckling from thermal expansion.

Dark-colored asphalt pavements reradiate absorbed heat and contribute to the urban heat island effect. Light-colored, "cool" pavements reflect the sun's radiation. When used alongside cool roofs and shade-tree planting, reflective pavements are estimated to lower ambient air temperatures, on average, between 4°F and 9°F.

Increasing the reflectivity and porosity of paved surfaces helps to mitigate the urban heat island effect:

- **Reflective pavement:** Fortunately, over 90 percent of the City's sidewalks are already light-colored. The NYC Department of Transportation (DOT) converted 2.2 million sq. ft. of dark asphalt to lighter tan or gray-colored surfaces to date.
- **Porous pavement**: Some New York City sidewalks and streets include permeable and porous pavement, which reduces heat through evaporative cooling, and DOT is encouraging further deployment.

**LEFT TO RIGHT:**

**LIGHT COLORED PAVEMENT AT THE MANHATTAN BRIDGE**
SOURCE: DOT, 2018

**LIGHT PAVEMENT AT GRAND CONCOURSE, IN THE BRONX WITH PLANTED MEDIANS**
SOURCE: DOT, 2018





# PUBLIC AWARENESS

New York City has several initiatives to mitigate the risks to residents, especially vulnerable populations, before heat waves occur:

- **Prevention:** As part of the Cool Neighborhoods NYC initiative, coordinated by the Mayor's Office of Resiliency, New York City Department of Health and Mental Hygiene (DOHMH) works with different partners to promote heat resiliency. An example is the *Be A Buddy* campaign, a community-led pilot project to develop and implement strategies to promote social cohesion and increase community resilience for extreme heat, power outages, and other types of extreme weather.
- **Outreach:** The City conducts outreach to the general public through press releases, social media posts, in-person training and workshops, and direct electronic communications to partners. New York City Emergency Management (NYCEM) supplies important safety tips and information through its *Ready New York* brochures and *Beat the Heat* website.
- **Cooling centers:** During heat emergencies, cooling centers are opened at designated locations, such as community centers, senior centers, and public libraries, to provide access to air-conditioned spaces to anyone who needs to escape the heat. During summer 2018, New York City had over 500 air-conditioned spaces available.
- **Financial assistance:** The New York City Department of Social Services (DSS) assists New York City residents to apply for the federally funded Home Energy Assistance Program (HEAP) to purchase and install an air conditioner, if residents meet the program's criteria.





**LEARN MORE ABOUT NYC**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 05
# FLOODING

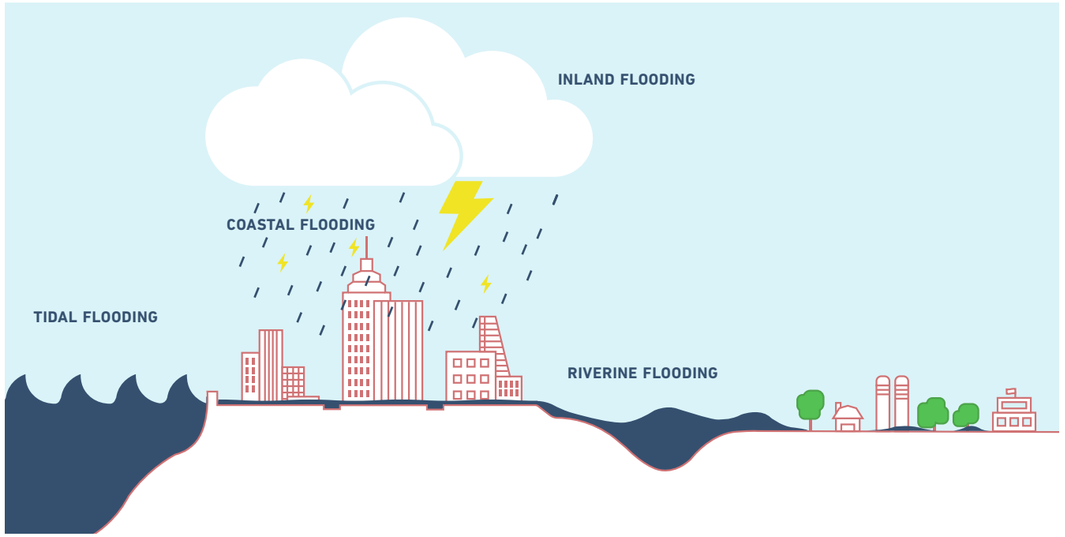
Flooding is one of the most common natural disasters, occuring more freqeuently in the United States than any other natural disaster. Severe flooding can destroy property, natural resources, and lives.

New York City's 520 miles of shoreline, concentration of impervious surfaces, and high population density are some of the factors that make it vulnerable to many different types of flooding. Over time, climate change is likely to increase these flood risks.

# WHAT IS THE HAZARD?

New York City is subject to four types of flooding, each caused by different interactions among the forces of nature, the physical terrain, infrastructure, and whether land has buildings or open space.

**FOUR MAJOR TYPES OF FLOODING IN NYC**
SOURCE: NYCEM




## TYPES OF FLOODING

### Coastal Flooding

Coastal flooding is primarily caused by the storm surge that accompanies a strong coastal storm. Storm surge occurs when water washes onto shore through the force of the wind blowing across the ocean surface, and the low pressure of the storm causing the water to bulge upward.

Storm surge can cause floods with waves or create "stillwater" flooding — rising water levels without significant waves. In both cases, the hazards include coastline erosion, structural damage to buildings and infrastructure, and brackish or saltwater inundation that can harm machines, electrical equipment, and vegetation.

The elevation and slope of a shoreline influences how storm surge behaves. For example, low-lying areas both on the coast and inland are at risk of flooding. Additionally, New York City's geography magnifies the effect of storm surge and the likelihood of coastal floods when severe coastal storms funnel ocean water into New York Harbor.

### Tidal Flooding

Tidal flooding is caused by the gravitational pull by the moon and/or sun on earth's ocean. Lunar or seasonal high tides make some low-lying neighborhoods throughout New York City vulnerable to flooding and can occur even when there is no storm — a phenomenon also known as "nuisance," "blue-sky," or "sunny day" flooding.

Each day, New York City experiences two high tides and two low tides due to the the alignments of the moon and sun, which affect the gravitational pull on the earth's ocean. Twice a month, when the sun and the moon are both aligned with Earth in their orbits, the gravitational tug they exert on the oceans is strongest. This results in "spring tides"— named because these tides can "spring the banks".

### Inland Flooding

Heavy rain, infrastructure, and the high percentage of developed land in New York City intensify the risk of inland floods.





Commonly called "flash floods," "cloudbursts," or "urban flooding," inland floods can be caused by short, intense rainfall often associated with sudden, small-scale thunderstorms or downpours from very large storm systems. An inland flood can also be caused by a weak storm if it stalls or drifts slowly over an area and rain falls continuously for several days.

In addition to rain, other factors contribute to the risk of inland flooding in New York City:

- **Sewer and Drainage Capacity:** Excessive rainfall in low-lying areas can overwhelm the capacity of sewers or the stormwater management infrastructure. Improper street grading and blocked outfalls can also contribute to inland flooding.
- **Impervious Surfaces:** The ground's capacity to absorb rainfall is reduced if buildings, streets, sidewalks, and parking lots cover it. The rain falling on impervious surfaces increases the volume of surface runoff flowing into sewers, which could cause flooding if the volume exceeds the capacity of the surface.

### Riverine Flooding

Riverine flooding occurs when the volume of freshwater flowing in a river or a stream exceeds its holding capacity and water overruns the banks. Over time, the erosion of river and stream banks will likely increase our risk of riverine flooding.

## SEVERITY

The National Weather Service (NWS) categorizes the severity of flooding into three categories.

**NATIONAL WEATHER SERVICE FLOOD CATEGORIES**
SOURCE: NWS

| CATEGORY | DESCRIPTION |
|---|---|
| **Minor** | · Minimal or no property damage<br>· Possibly some inconvenience |
| **Moderate** | · Inundation of secondary roads<br>· Transfer to higher elevation necessary to save property<br>· Some evacuation may be required |
| **Major** | · Extensive inundation and property damage<br>· Often involves the evacuation of people and the closure of primary and secondary roads |

Flood severity across New York City varies significantly according to the type of flood and its cause, duration, and other factors, such as the capacity of sewers and other pathways that allow water to exit.

## THE "100-YEAR" AND "500-YEAR" FLOOD CONCEPTS

**USING THE TERMS "100-YEAR" AND "500-YEAR" WHEN DISCUSSING THE HAZARDS ASSOCIATED WITH COASTAL AND RIVERINE FLOODING CAN BE MISLEADING AND MAY CONVEY A FALSE SENSE OF SECURITY ABOUT FLOODING HAZARDS.**

100-year flood (also known as the 1 percent annual chance flood) represent a 1 percent chance of flooding in any given year. If a homeowner experiences a 100-year flood, it does not decrease the chance of a second 100-year flood occurring that same year or in any following year.

Even the 1 percent concept can be misleading because of the way probability is calculated. The 1 percent chance flood refers to the probability of a flood in any given year. But if you look at the probability of one flood occurring in a longer timeframe, the probability is compounded. That means that, as you increase the number of years considered, the probability of a flood occurring is much higher. So while a building located in the 1 percent annual chance floodplain has a 1 percent chance of experiencing a flood in any given year, it has a 26 percent chance of experiencing a flood during the lifespan of a 30-year mortgage.

Similarly a 500-year flood is not a flood that happens once every 500 years. Rather it has a 0.2 percent (1 in 500) chance of occurring in any given year.

## PROBABILITY

The probability that a New York City neighborhood will experience one or more floods depends upon the area's terrain, shoreline proximity, elevation, watershed characteristics, stormwater infrastructure capacity, and the water table.

- **Coastal Flooding** can occur anywhere along New York City's 520-mile shoreline, but the severity of flooding likely in different neighborhoods varies widely. New York City uses the FEMA Flood Insurance Rate Maps (FIRMS) to determine the location and probability of coastal and riverine flooding (see FIRM and Flood Zones section).
- **Riverine Flooding** affects only a very small portion of flood-prone areas in New York City. Staten Island and the Bronx are the most vulnerable boroughs, since the Bronx and Hutchinson Rivers can create floods in the Bronx, and streams and rivers along the south shore and the middle of Staten Island can overflow.
- **Tidal Flooding** is most likely to occur in the lowest-lying areas in New York City — Broad Channel, Hamilton Beach, portions of the bay side of the Rockaway Peninsula, and in low-lying sections of Staten Island and Red Hook.
- **Inland Flooding** has affected certain New York City neighborhoods for many years, according to an analysis of flooding complaints received by New York City's 311 line between 2004 and 2017. The areas that had the most flooding complaints are either built upon filled-in wetlands, or have limited stormwater infrastructure.

### Flood Insurance Rate Maps (FIRMS) and Flood Zones

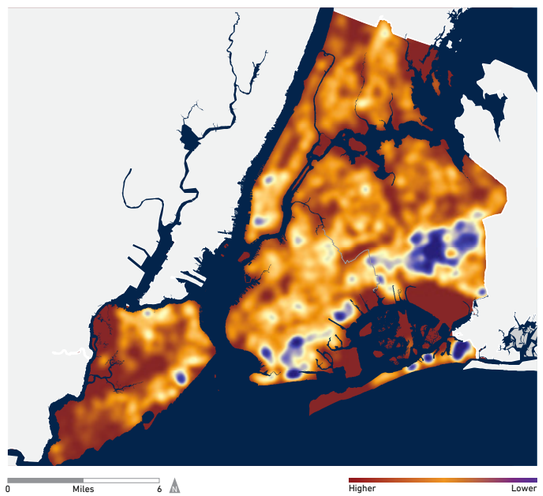
New York City consults the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) to determine the flood risk probability for coastal and riverine flooding. The FIRMs, which are used to determine flood insurance rates, graphically represent the federal government's official assessment of flood risk in specific areas of the city.

The flood zones shown on the FIRMs are geographic areas classified according to levels of flood risk, with each aonze reflecint the severeity and/or type of flooding.

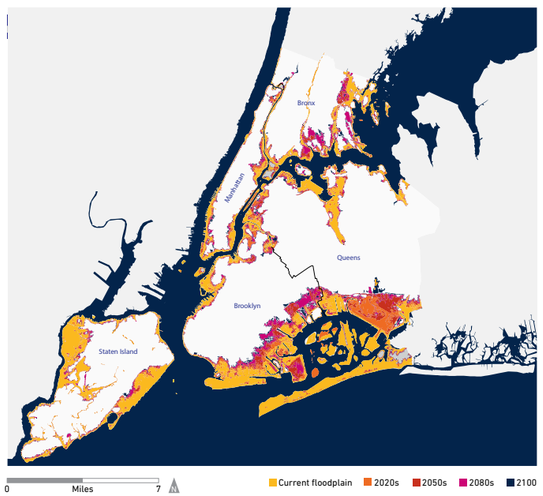
FEMA's FIRMs were initially created for New York City in 1983. The FIRMs had a minor update in 2007, but remained largely unchanged until 2015 when FEMA released significantly different Preliminary Flood Insurance Rate Maps (PFIRMs). In reviewing the maps, New York City discovered that FEMA made a modeling error that overestimated the size of its 1 percent annual chance floodplain. As a result, FEMA is currently revising the PFIRMs which are scheduled to be released in 2022.

The map below shows the areas included in New York City's **1 percent annual chance floodplain** based on the 2015 PFIRMS. Additionally, the map shows how the floodplain could increase over the next several decades due to climate change. These areas have a one-percent-or-greater chance of experiencing coastal or riverine flooding in any given year.

**311 FLOODING COMPLAINTS FROM 2004–2017**
SOURCE: NYC 311, 2004 - 2007




**CURRENT AND PROJECTED 1 PERCENT ANNUAL CHANCE FLOODPLAIN**
SOURCE: FEMA, CUNY INSTITUTE FOR SUSTAINABLE CITIES

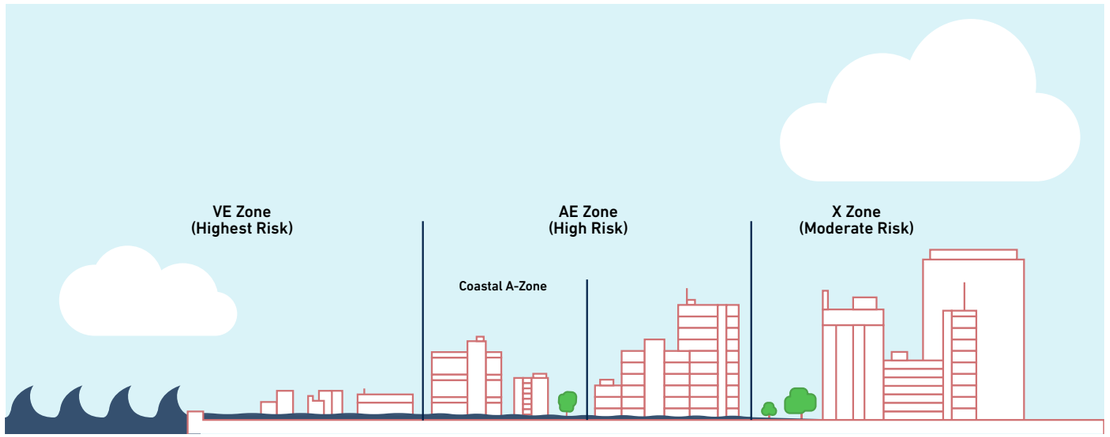



*Data Reflects NPCC's High End (90th Percentile) Projections





**UNDERSTANDING FEMA'S FLOOD ZONES**
SOURCE: FEMA




| FLOOD ZONE CATEGORY | DESCRIPTION |
|---|---|
| **VE*** | · Coastal areas subject to inundation by a 1 percent annual chance flood<br>· Additional hazards associated with storm-induced waves more than 3 feet high |
| **Coastal A** | · A sub-area of the A/AE flood zone that has additional hazards associated with storm-induced waves that range between 1.5 and 3 feet high |
| **AE*** | · Areas subject to inundation by a 1 percent annual chance flood |
| **X (shaded)** | · Areas subject to inundation by a 0.2 percent annual chance flood<br>· Also called the "500-year flood zone" |

*E indicates that the FIRMS show base flood elevation

### National Flood Insurance Program (NFIP) and Flood Risk Locations

FEMA uses the FIRMs to determine flood insurance rates. FEMA sets insurance premiums, and designates minimum building standards for structures situated in the 1 percent annual chance floodplain. Owners of property located within the 1 percent annual chance floodplain must purchase flood insurance if they have a federally-backed mortgage.

FEMA administers the National Flood Insurance Program (NFIP) and has a vast database documenting which NFIP-insured structures were vulnerable to floods in the past, including:

- **Repetitive Loss structures:** structures for which a policyholder received two or more claim payments of $1,000 or more after flood events within a 10-year period.
- **Severe Repetitive Loss structures:** Any insured structure that has incurred flood damage for which:
  - » At least two separate claim payments have been made under a Standard Flood Insurance Policy, where the cumulative amount of such claim payments exceeds the fair market value of the insured buildings on the day before each loss;
  - » At least four or more claim payments worth over $5,000 each, or with a cumulative amount exceeding $20,000.

# WHAT IS THE RISK?

Vulnerability to flooding varies across New York City. Different neighborhoods face different risks. Risks of harm vary, depending on the flood type, the number of people and types of property or infrastructure that are most exposed to flooding, the degree of exposure to floods, and how well the people and the built environment can withstand damage.

**POPULATION AND HOUSEHOLDS IN 1 PERCENT ANNUAL CHANCE FLOODPLAIN**
SOURCE: U.S. CENSUS 2010

| | NEW YORK CITY | | BRONX | | BROOKLYN | | MANHATTAN | | QUEENS | | STATEN ISLAND | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | % | Count | % | Count | % | Count | % | Count | % | Count | % |
| **Population** | 407,254 | 4.9 % | 26,165 | 1.9 % | 164,841 | 6.6 % | 86,480 | 5.5 % | 98,156 | 4.4 % | 31,612 | 6.7 % |
| **Residential Units** | 175,036 | 5.2 % | 6,338 | 1.2 % | 71,165 | 7.1 % | 9 | 5.1 % | 42,560 | 5.1 % | 12,006 | 6.8 % |

## PEOPLE AT RISK

Of New York City's more than 8.2 million residents, approximately 400,000 people live within the 1 percent annual chance floodplain and are therefore at greater risk of coastal flooding hazards.

The disruption following a flood could cause a large number of people to be displaced, creating safety, health, and economic challenges:

- **Seniors:** Approximately 6 percent of New Yorkers (67,188) living in the 1 percent annual chance floodplain are seniors. For this population, risks include difficulties of making a timely evacuation or moving to higher ground, and post-flood exposure to mold in flood-damaged buildings.
- **People with Chronic Health Conditions or Disabilities:** Risks include difficulty accessing health services, assistance, evacuating from flood, getting to safety during a flood, medication during and following a major coastal flood, and post-flood exposure to mold in flood-damaged buildings, which could harm people with respiratory infections, asthma, allergies, or other health issues.
- **Low-Income Residents:** Approximately 19 percent of residents in the 1 percent annual chance floodplain (79,000) live below the federal poverty level. These people may lack the resources to prepare for or recover from a flood, and would face higher health and safety risks from a coastal flood.
- **Rent or Housing Cost-Burdened Households:** About 36 percent of owner-occupied homes with mortgages in the floodplain are housing cost-burdened and about 41 percent of renter-occupied floodplain households are housing cost-burdened, meaning households pay more than 30 percent of their pre-tax income for housing and are not assisted by either public housing or other housing vouchers.





Due to the high cost of housing in New York City, finding alternative housing options—even temporarily during an evacuation or immediately following a flood—can be a challenge.

After a flood, some individuals and families, particularly people already spending a high percentage of their income on rent, might choose to simply stay in their damaged homes to avoid paying higher rent or to avoid being homeless. This is a risk, because it increases residents' exposure to mold and other hazardous materials, which could lead to health problems, lost wages, loss of employment, or further financial stress.

## BUILDINGS AT RISK

In New York City, the 1 percent annual chance floodplain includes 67,600 buildings, including approximately 175,000 residential units that house over 400,000 New Yorkers. The most vulnerable buildings are:

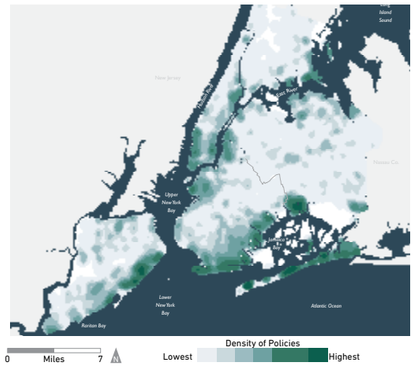
- **Older Buildings:** A building's age is the best indicator of its structural vulnerability. Approximately 81 percent of the buildings in New York City's 1 percent annual floodplain were built before 1983. They are more likely to sustain significant flood damage than newer buildings, which are subject to more recent stringent building and zoning standards.
- **Low-Rise Buildings:** Low-rise buildings are often constructed with lighter, wood-stud frames, which are more prone to structural damage from flooding than other building types. Approximately 69 percent of the buildings in New York City's 1 percent annual floodplain are one to two stories.
- **Building of Wooden Construction:** Wood homes are at higher risk from fires generated by electrical shorts caused by flooding, than other building types. Although wood buildings are less expensive to repair, reconstruct, and elevate than masonry buildings, new wood-frame housing are not permitted in most areas of New York City.

The number of vulnerable buildings in New York City's 1 percent annual floodplain is significant. As of November 2018, there were 35,709 active policies with premiums adding up to $57 million. From November 2017 to October 2018 there were 125 claims filed with a building damage total of $594,000 and content damage total of $35,000. The volume of claims and payouts indicate the magnitude of risk from future coastal flood damage:

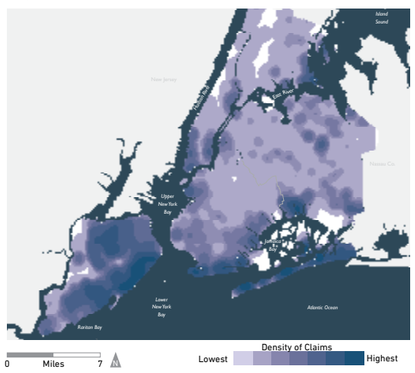
- **NFIP Claims:** Since 1976, New York City has had almost 42,000 claims. Between Sandy in 2012 and January 2019, 16,900 claims were filed in New York City, totaling $1.4 billion in payouts.
- **NFIP Repetitive Losses:** As of September 2018, New York City had 4,188 Repetitive Loss claims amounting to $238 million in payouts. Approximately 57 percent of these structures were located within the 1 percent annual chance floodplain. These claims were concentrated in Howard Beach, Breezy Point, Arverne, Broad Channel, and the Midland Beach areas.
- **NFIP Severe Repetitive Losses:** As of May 2018, there were 38 Severe Repetitive Loss structures that represented $5.3 million in payouts. These structures are a high priority for flood mitigation.

Visualizing this data pinpoints where New York City structures are most at risk. High-risk areas are concentrated on Staten Island's East Shore, in portions of Brooklyn and Queens that face the Atlantic Ocean and Jamaica Bay, and in the low-lying southeast section of the Bronx.

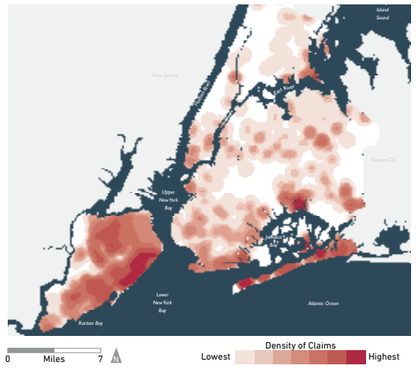
**NFIP POLICIES, 2018**
SOURCE: FEMA, NFIP




**NFIP CLAIMS 1976–2018**
SOURCE: FEMA, NFIP



NFIP REPETITIVE LOSSES, 2018
SOURCE: FEMA, NFIP




REPETITIVE LOSS CLAIMS BY HOUSING TYPES, 2012 - 2018
SOURCE: FEMA/NFIP

| HOUSING TYPES | PERCENTAGE OF REPETITIVE LOSS CLAIMS (4,188 TOTAL) |
|---|---|
| **Single-family** | 69% |
| **2- to 4-family** | 23% |
| **Assumed Condo** | 1% |
| **Other residential** | 2% |
| **Non-residential** | 5% |
| **Unknown** | Less than 1% |

## INFRASTRUCTURE AT RISK

New York City has a vast number of critical utility and transportation assets located within the 1 percent annual chance floodplain. If this infrastructure is damaged by a coastal flood, delivery of vital services is at risk.

- **Electrical Infrastructure:** Approximately 53 percent of in-city electric generation capacity, 37 percent of transmission substation capacity, and 12 percent of large distribution substation capacity are within the 1 percent annual chance floodplain.
- **Steam System Infrastructure:** Approximately 88 percent of the city's steam generation capacity lies within the 1 percent annual chance floodplain.
- **Telecommunications Infrastructure:** These facilities are generally situated farther from the floodplain than other types of infrastructure, yet almost 10 percent of New York City's critical telecommunication facilities lie in the 1 percent annual chance floodplain. These networks' high dependency on the power infrastructure significantly increases the risk of service interruption during a flood.
- **Transportation Infrastructure:** Approximately 19 percent of rail stations, all airports, nearly all ferry landings, and 19 percent of bus depots are in the 1 percent annual chance floodplain.
- **Highways:** Approximately 18 percent of the city's roads are located in the 1 percent annual chance floodplain, including all major tunnels except the Lincoln Tunnel. The West Side Highway, FDR Drive, and other roadways, which are at low elevation along the shoreline, are particularly vulnerable to flooding. Heavy downpours pose only a moderate risk to roads and bridges, because although they may experience more frequent temporary floods, they do not sustain lasting damage.
- **Wastewater Systems and Hazardous Materials:** Much of this infrastructure is located in the 1 percent annual chance floodplain. All 14 wastewater treatment plants are located at low elevations along New York's waterfront. Flooding could lead to combined sewer overflows and waterway contamination. Flooding at facilities having improperly stored hazardous materials and solid waste risks dispersing contaminants, which would harm employees, nearby communities, and natural areas.

## NATURAL ENVIRONMENT AT RISK

Approximately 20 percent of all City-owned parkland is within New York City's 1 percent annual chance floodplain, and is subject to several risks:

- **Coastal Flooding** can submerge wetlands for prolonged periods of time and cause barrier islands to narrow or split.
- **Waves and Storm Surge** can flood inland vegetation with salt water, erode the shoreline edge, and damage non-salt tolerant trees and shrubs that act as buffers for inland parks and neighborhoods.
- **Heavy Rainfall** can severely damage planted park areas that lack adequate drainage, causing loss of vegetation or porous soils that absorb water runoff and, thereby reducing and the adverse impact on adjacent areas.

Returning these features to their natural functions after flooding can be difficult and expensive.

## FUTURE ENVIRONMENT

The New York City Panel on Climate Change (NPCC) projects that climate change will exacerbate flooding hazards in the future due to increased rainfall, rising sea levels, and increasingly intense coastal storms:

- **Increased Rainfall:** According to the NPCC, the annual precipitation in New York City is projected to increase by 4 to 11 percent by the 2050s and 5 to 13 percent by the 2080s.
- **Rising Sea Level:** The NPCC projects that the mean sea level of waters is projected to increase between 11 and 21 inches by mid-century and between 18 and 39 inches by the 2080s. This magnitude of sea level rise would threaten low-lying communities in New York City with regular and highly disruptive tidal flooding.
- **Increased Storm Surge:** The rise in sea level could cause higher storm surges that could flood larger areas.
- **Increased Tidal Flooding:** Low-lying areas of the city that currently experience coastal flooding at astronomical high tides will be increasingly vulnerable to ongoing, regular flooding from daily and monthly high tides.
- **More Intense Storms:** Changes in the nature of storm activity may lead to the more intense coastal storms and an increase in rainfall events.
- **More Frequent Flooding:** The frequency of current 1 percent annual chance floods is also projected to increase.

## NFIP PROPERTIES WITHIN FUTURE FLOODPLAIN

As previously mentioned, FEMA's National Flood Insurance Program (NFIP), offers flood insurance for property owners within in the 1 percent annual chance floodplain. In New York City, 22,655 properties within the current floodplain are presently insured by NFIP. As climate change worsens, and the flood plain grows, more NFIP property owners will be placed in the floodplain. For example, the number of NFIP properties in New York City would grow to 24,184 by 2020 as shown in the future floodplain map. By 2100, it would grow to 25,722. Flood insurance and flood resilient building construction will be crucial to mitigate the economic impacts of floods in the future, as sea levels rise with time and storm surge becomes more severe.

| HOUSING TYPES | NFIP CLAIMS INSIDE FLOODPLAIN | NFIP CLAIMS OUTSIDE FLOODPLAIN |
|---|---|---|
| Current | 22,655 | 14,971 |
| 2020s | 24,184 | 13,442 |
| 2050s | 24,899 | 12,727 |
| 2080s | 25,474 | 12,152 |
| 2100s | 25,722 | 11,904 |

SOURCE: FEMA/NFIP AND NYCEM

# HOW TO MANAGE THE RISK

An integrated approach to managing flood risk begins with the recognition that flooding is a natural process that cannot altogether be prevented. These strategies — regulatory controls, land use management policies, surface and subsurface measures, protections for buildings and infrastructure, and environmental restoration — add up to a broad multidimensional approach to achieving flood-risk resiliency in New York City.

## REGULATION AND POLICY

Agencies at all levels of government play roles in managing risk from flood hazards. Most guidance is issued at the federal level, with a number of state and local agencies coordinating to implement it at the local level.

FEMA's NFIP protection of property in the 1 percent annual chance floodplain and the mandate that all property owners with federally-backed mortgagespurchase flood insurance.

A significant component of local regulation and policy is the New York City Building Code's Appendix G, which contains flood-resistant construction standards. New and substantially improved residential structures located in the FIRMs A-zones within the 1 percent annual chance flood plain must comply with the following restrictions:

- **Occupied Floors:** The lowest occupied floor must be constructred above the design flood elevation (DFE).
- **Lower Floors:** If an enclosed space exists below the DFE, it can only be used for parking, storage, and building access.
- **Utility Protection:** Utilities must be elevated above the DFE or be designed so that water is prevented from entering and accumulating.

Zoning rules implemented by the City, also detailed in the Coastal Storms section of this report, are key mechanisms to minimize flood risk. The City has established Special Coastal Risk Districts in Queens and Staten Island and actively works with all communities to encourage resiliency.

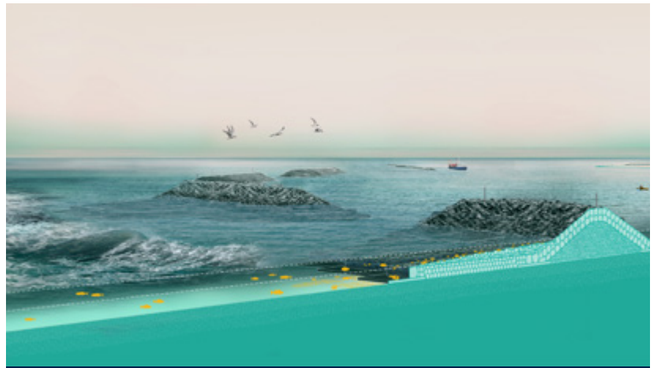
Local laws and development of policy manuals are other vehicles used by New York City to mitigate hazards associated with flooding, for example:

- **Flood Resiliency Zoning Text Amendment:** This encourages new and existing buildings to comply with the new, higher flood elevations specified by FEMA and the New York City Construction Code.
- **NYC Local Law 48 of 2015:** This law mandates that catch basins—storm drains or sewer grates that collect storm water— be cleaned and maintained annually instead of the previously mandated three-year cycle. If a non-functioning catch basin is found, it must be cleared within nine days.

## NATURAL/OPEN SPACE PROTECTION

Since Sandy, New York City is exploring how natural and nature-based structures and systems can be integrated into coastal defense strategies alongside the hard-structure approach.

The Coastal Storms section of this report describes three approaches — living shorelines, wetland preservation, and the use of beaches, dunes, and beach nourishment to absorb energy from storm surge and waves to protect structures behind them.



### CASE STUDY: TOTTENVILLE LIVING BREAKWATERS

Tottenville is an innovative coastal infrastructure project designed to reduce or reverse erosion and damage from storm waves, improve the ecosystem health of Raritan Bay, and encourage stewardship of nearshore waters. The New York State Governor's Office of Storm Recovery (GOSR) is planning a breakwater project in Tottenville on the South Shore of Staten Island.





## COASTAL PROTECTION

Prior to Sandy, New York City implemented structural solutions to protect flood-prone properties in coastal areas. Post-Sandy, these initiatives expanded to include integrated flood protection systems, increased coastal edge elevation, and protection of infrastructure and critical services.

Studies, funded by federal and state recovery funds, have evaluated coastal protection measures that are best suited to the unique vulnerabilities of specific New York City sites and neighborhoods:

- **Bulkheads, or Seawalls,** are usually made of stone, concrete, or steel, to protect infrastructures from coastal flooding. They are located along the New York City's waterfront, protecting industrial areas, commercial and residential areas, and parkland. Approximately 25 percent of New York City's shoreline is protected by bulkheads.
- **Levees,** also called dikes, are earthen embankments built at the shoreline to protect land from flooding. Levees are commonly used throughout the country along riverbanks.
- **Floodwalls** are permanent or deployable vertical structures anchored in the ground either at the shoreline or upland to prevent flooding from rivers or storm surge.
- **In-Water Surge Barriers** made out of steel and concrete, would provide a high level of protection from storm surge. In the aftermath of Sandy, their feasibility was studied for areas such as Gowanus, Newtown Creek, and Coney Island.

## INFRASTRUCTURE PROTECTION

Strategies to protect infrastructure from damaging floods range from floodproofing or elevating individual facilities and equipment, to implementing larger operational or design changes in transportation and energy networks.

Projects to protect New York City's critical infrastructure systems were detailed in the Coastal Storms section of this report. Agencies such as the NYC DEP, DOT, NYC Health and + Hospitals , the MTA, and the Port Authority of New York and New Jersey (PANYNJ) are making improvements to subways, tunnels, power plants, hospitals, and wastewater infrastructure to safeguard public health and the environment. Since Sandy, the number of joint-initiative projects undertaken by utility providers, such as Con Edison, National Grid, and PSEG/LIPA, has increased significantly.

### NY-NJ HARBOR AND TRIBUTARIES COASTAL STORM RISK MANAGEMENT FEASIBILITY STUDY

The U.S. Army Corps of Engineers is conducting its NY-NJ Harbor and Tributaries Coastal Storm Risk Management Feasibility Study to contribute to the resilience of communities, critical infrastructure, and the environment and manage the risk of coastal storm damage in this area. The study is evaluating coastal defenses such as levees, flood walls, bulkheads, and storm surge barriers.

### FLOOD PROTECTION IN LOWER MANHATTAN

Since Sandy, New York City initiated plans for an integrated flood protection system on the east side of Manhattan from East 25th Street to Montgomery Street. This project aims to protect the East Side against flooding and sea level rise. It will provide access to public spaces, and protect thousands of people living in public housing in that area. The project includes a system of walls, deployables, and berms (raised land to protect or separate low-lying areas from adjacent water bodies) along the FDR Drive, East River Park, and Stuyvesant Cove Park. Currently, the city plans to extend the line of protection to the Two Bridges neighborhood, the finanicial district and South Street Seaport, the Battery, and Battery Park City. Part of the flood protection strategies includes expanding the shoreline into the water.

## Managing Surface and Groundwater

Excess rainwater and flash flooding can be managed effectively by cleaning and maintaining drainage infrastructure, building out the sewer infrastructure, managing surface water run-off, employing green infrastructure, and providing floodwater storage.

In New York City, the NYC DEP works with the DOT, DSNY, and NYC Parks) to implement risk management strategies to manage surface and groundwater, including:

- **Stormwater Management Investment:** Expansion of sewer and drainage infrastructure capacity — adding high-level storm sewers, improving stormwater and sewage pumps, installing backflow valves, and increasing effectiveness of catch basin and storm drain maintenance.
- **Preserving/Restoring Natural Drainage Corridors:** Natural drainage corridors help convey, store, and filter stormwater. For example, the Staten Island Bluebelt uses a network of streams, ponds, and other wetland areas to provide ecologically sound and cost-effective stormwater management for approximately one-third of the borough.
- **Investments in Green Infrastructure:** Absorbing or diverting water with porous surfaces, rain gardens, and roadside drainages to reduce the amount of water retained on the surface and to minimize the risk of flooding.

## BUILDING PROTECTION

New York City is encouraging building owners to retrofit and strengthen older buildings to withstand floods. The Department of City Planning's *Retrofitting Buildings for Flood Risk* publication helps owners to identify their risk and guides them to retrofit their homes through several flood-mitigating strategies, which include:

- **Dry Floodproofing:** Using watertight construction methods to keep water out of a building. This can include installation of temporary shields or barriers, such as deployable or permanent floodwalls, to surround the building's perimeter.
- **Wet Floodproofing:** Constructing or retrofitting buildings with materials that resist flood damage yet allow water to freely flow in and out without causing significant damage.
- **Building Elevation:** Raising a building so that the lowest floor is above the Design Flood Elevation (DFE).
- **Equipment Elevation:** Elevating mechanical equipment above the DFE by either moving it to a higher floor or placing it on a raised platform. For example, high-rise buildings can employ a system to prevent elevators from descending into floodwaters.
- **Land and Street Elevation:** Elevating the land and street on the development site of a building complex. This strategy works best on large development sites or at a neighborhood scale, where lots and streets can be raised in a coordinated manner.

## RESEARCH AND STUDIES

New York City recognizes that higher sea levels could increase flooding in the future and is conducting research on flood-resistant structure solutions to protect people and property on its coast:

- **Floating Structures:** Designed to move vertically with tidal fluctuations and storm surge. Utility connections are flexible, allowing the structure to move naturally with the water, although the structure cannot move through water on its own.
- **Amphibious Structures:** Structures built on dry land atop buoyant foundations and pile supports, so they are able to float if a site is flooded. A few amphibious homes have been constructed in Louisiana and the Netherlands.

### CLOUDBURST RESILIENCY PLANNING STUDY

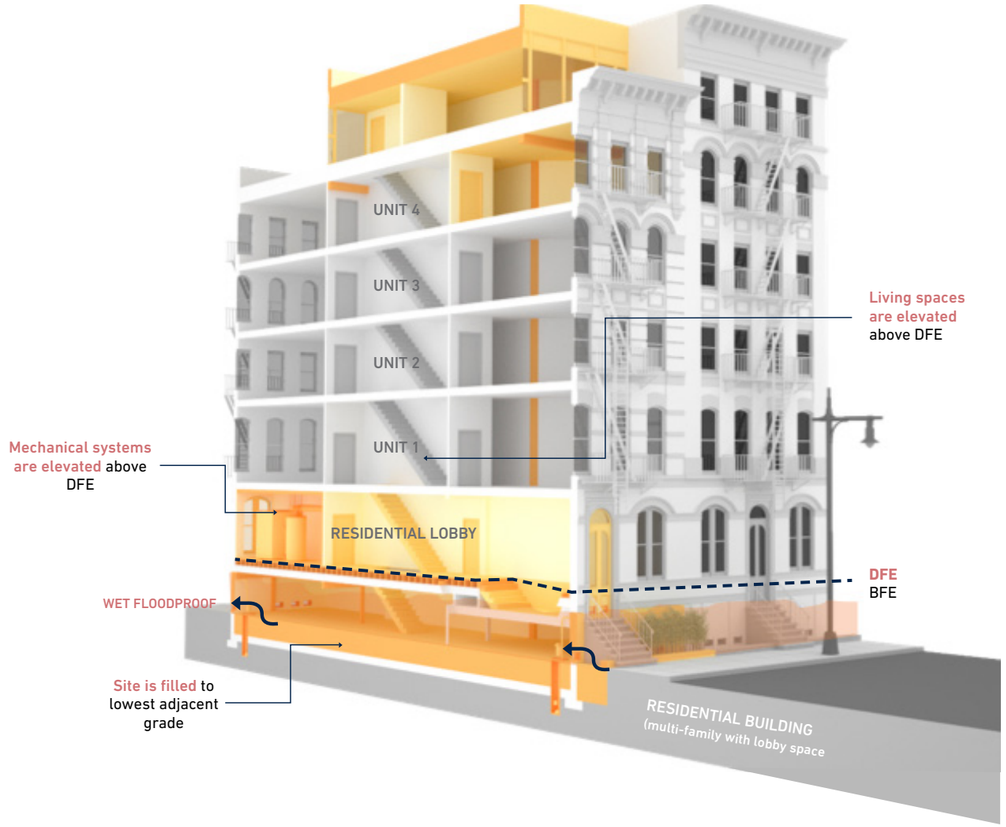
**IN 2016, NYC DEP KICKED OFF ITS CLOUDBURST RESILIENCY PLANNING STUDY TO ASSESS RISKS, PRIORITIZE RESPONSE, DEVELOP NEIGHBORHOOD-BASED SOLUTIONS, AND ASSIGN COSTS AND BENEFITS TO MANAGE EXTREME RAIN EVENTS, OR "CLOUDBURSTS," USING SOUTHEAST QUEENS AS A FOCUS AREA.** The study adapted an approach developed in Copenhagen to manage large volumes of stormwater using streets and open space. By modeling the flow of floodwater over the local topography, the study is able to identify opportunities to slow and safely convey water so as to minimize damage and maximize co-benefits to the community.

Working in coordination with the NYC Department of Transportation (DOT), the Department of Design and Construction (DDC), and New York City Housing Authority (NYCHA), DEP initiated two pilots in St. Albans and South Jamaica Houses in Queens. The initiatives will incorporate green infrastructure to reduce the impact of flash flooding by capturing 2 to 3 inches of rainfall per hour.





**EXAMPLES OF RETROFITTING BUILDINGS FOR FLOOD RISK**
SOURCE: NYC DCP




**FLOOD RESILIENT CONSTRUCTION STANDARDS REQUIRE CERTAIN BUILDINGS TO ELEVATE THE LOWEST FLOOR, AS WELL AS MECHANICAL EQUIPMENT, ABOVE THE DESIGN FLOOD ELEVATION (DFE).**





**LEARN MORE ABOUT NYC**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 06 HIGH WINDS

High-wind events can occur with little warning, damaging property and infrastructure, disrupting transportation, knocking down trees and power lines, and causing serious personal injuries. New York City's dense high-rise environment, numerous older buildings, and many open construction sites heighten its vulnerability to dangerous winds.

## WHAT IS THE HAZARD?

High wind events are winds that exceeds 50 to 60 miles, which aligns with NOAA's definition of damaging winds. The Coastal Storm section of this report explains more about high-winds associated with hurricanes and nor'easters, but the following weather conditions are associated with high-wind hazards:

- **Tornadoes:** Violently rotating columns of air with wind speeds between 65 and 300 miles per hour; generally associated with severe thunderstorms; able to uproot trees, demolish buildings, and turn debris into dangerous projectiles; the path of destruction can be 1 mile wide and 50 miles long.
- **Severe thunderstorms:** Associated with wind speeds over 58 miles per hour, heavy rain, and hailstones of at least 1 inch in diameter; can develop into a tornado.
- **Straight-line winds:** Winds blowing in a single direction; wind speeds exceeding 50 to 60; associated with intense low atmospheric pressure.
- **Microbursts or macrobursts:** Powerful downdrafts causing severe, localized damage; associated with thunderstorms.

### TORNADOES IN NEW YORK CITY:

A common misconception is that tornadoes do not occur in dense urban areas like New York City. However, over the past 40 years, twelve tornadoes appeared in the city. Since 1950, at least one tornado has occurred in each of the five boroughs.

## WHAT IS THE RISK?

High-wind events can increase risks to public safety, particularly since New York City is home to ever-taller skyscrapers, a growing number of construction sites, and a high concentration of older, more vulnerable buildings. Construction workers, other people who work outdoors, homeless people, individuals with disabilities or access and functional needs, or anyone caught outdoors during a high-wind event is vulnerable to injury and death. Certain populations, such as individuals with disabilities or other access and functional needs, are at greater risk of injury because of physical conditions or reliance on others for assistance to get them to safety and away from high-wind events. If high-winds damage property or cause injury, members of vulnerable populations and those with constrained finances are particularly at risk as these populations may not be able to rebound as quickly as other segments of the population. In addition to potentially injuring people and property, downed trees can also disrupt utility wires, which can lead to power outages, putting people and property at further risk. Utility outages can also disrupt the day-to-day operations of New York City.

The built environment is also vulnerable to high-winds. Although the 1938 New York City Building Code addressed high-wind loads for buildings taller than 100 feet, these older requirements are not as stringent as today's building codes. The 1968 Building Code incorporated new requirements to make buildings better able to withstand high-winds. Thus, some buildings that pre-date the 1968 Building Code are particularly vulnerable because engineers were not required to consider wind loads as a factor in designing buildings under 100 feet high, and wind load calculations were less precise.

Although buildings constructed after the 1968 code must be designed to withstand windstorms, there is no clear engineering method to design for tornadoes. Also vulnerable are façade elements of historic buildings; wood-frame structures — as opposed to steel and concrete structures; and exposed construction sites.

**SINCE 1950, AT LEAST ONE TORNADO HAS OCCURRED IN EACH OF THE FIVE BOROUGHS.**

### HISTORICAL TORNADOES 1950–2018

**WIND EVENTS:**

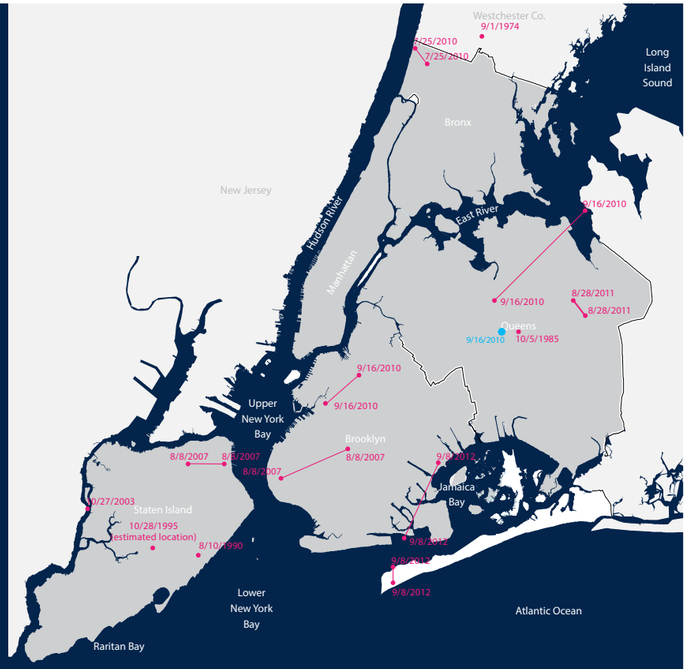
- Tornadoes
- Thunderstorm Wind (Macrobursts)
- Tornado Track

*8/31/1995 New York County (Manhattan) is not displayed on the map. No accurate coordinates are available for this event.

**RIGHT:**

**HISTORICAL TORNADOES**

SOURCE: NOAA NATIONAL CLIMATIC DATA CENTER




## HOW TO MANAGE THE RISK

Since 2008, New York City Construction Codes have included provisions requiring that new buildings be able to withstand high-winds in a dense, high-rise environment. Older buildings can be retrofitted to withstand high wind loads. Building inspections are also recommended so that structural weaknesses can be identified and repaired. New York City's Department of Buildings (DOB) Façade Safety Inspection Program works to accomplish this by requiring owners of buildings taller than six stories to have exterior walls and appurtenances inspected once every five years and to file a technical report with the DOB.

Another mitigation measure is Local Law 81 (2013), which requires the Mayor's Office of Resiliency (MOR), in consultation with DOB, to complete a report to analyze the impact of high-winds on certain at-risk buildings and to forecast whether climate change and other factors might influence wind speeds affecting New York City in the future. The analysis will also assess the benefits of further studies regarding the city's localized wind patterns.

Pruning trees and appropriate tree maintenance strategies can also mitigate the risk of tree limbs or entire trees falling. Two applicable programs are Department of Parks' block pruning and commitment-pruning programs, and Con Edison's Vegetation Maintenance program.

Because damaging winds can arrive suddenly, New York City uses various techniques, including text messaging, email, local radio, TV stations, social media, and Notify NYC to issue emergency alerts regarding forecasted severe thunderstorms or other high-wind events. DOB may also issue Inclement Weather Advisories to property owners, builders, and contractors, which include advice on precautions to take to prepare for high-winds at their properties.





**LEARN MORE ABOUT NYC**

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# 07
# WINTER WEATHER

During winter months in New York City, residents may experience prolonged periods of extremely cold temperatures, as well as large amounts of snow, ice, sleet, freezing rain, and high winds.

Periods of heavy snow and ice can disrupt the city's infrastructure and services; strand commuters and other travelers; interrupt the flow of and access to food, medicine, and other essential supplies; and constrain emergency response and delivery of medical services.

Extended periods of extreme cold and hazardous winter weather can take a toll on people's health and safety, homes, roadways, and infrastructure, inducing dangers like traffic accidents, road closures, power outages, airport shutdowns, and other transportation disruptions.

# WHAT IS THE HAZARD?

Extratropical cyclones, the most frequent type of storm in the Northeast, commonly cause rain, snow, and wind that combine to create severe winter weather storms. In addition to these storms, periods of extremely cold temperatures present a risk to New York City.

## WINTER STORMS

Extratropical cyclones are storms produced by the convergence of warm and cold air masses. The boundary at which these masses converge are called frontal boundaries, commonly known as fronts. At these fronts, cold air sinks and warm air is lifted. When warm air is lifted high enough in the atmosphere, it condenses into clouds contributing to the formation of extratropical cyclones.

The intensity of these winter storms ranges from light snow to blizzards and nor'easters, as described in the Coastal Storms section of this report. The types of winter storms and their hazards include:

- **Snow:** Ice crystals forming as water vapor freezes in the air.
- **Sleet:** Fully or partially frozen raindrops, or refrozen, partially melted snowflakes.
- **Snow Showers:** Brief periods of snow falling at different intensities with accumulation of one inch or less.
- **Blizzard:** A combination of certain storm conditions for three or more hours — blowing snow, reduction of visibility to one-quarter mile, and sustained winds or frequent gusts of over 35 miles per hour.
- **Snow Squalls:** Intense, brief periods of moderate-to-heavy snowfall, accompanied by strong, gusty winds and possibly lightning, with significant snow accumulation possible.
- **Thundersnow:** A snowstorm accompanied by thunder and lightning.
- **Ice Storms:** Freezing rain with potential accumulations of one-quarter of an inch or more.
- **Bomb Cyclones:** Low-pressure systems that intensify very rapidly with a fall in pressure of 24 millibars or more in 24 hours.

The impacts from winter storms on New York City can be significant:

- Snow Accumulations can block roadways, public transit infrastructure, and sidewalks and damage overhead power and telecommunications lines.
- Wintry Precipitation — a mix of snow, sleet, and freezing rain that makes hazardous travel conditions worse. Freezing rain creates severe travel hazards, since it falls as rain, freezes on contact with a surface, and forms a glaze of ice.
- Ice Storms develop quickly, and can produce ice accumulations that weigh down or damage overhead lines, and cause power and communications service outages. It can also endanger drivers and pedestrians, render roads impassable, and affect commuter train rail beds and switches in the mass transit system.
- Weight of Snow and Ice can cause trees and limbs to fall, damage roofs, harm vehicles and other property.
- Falling Ice and Snow, such as icicles and heavy snow falling from buildings, can injure pedestrians, damage vehicles, and disrupt traffic.

**ICE STORMS DEVELOP QUICKLY, AND CAN PRODUCE ICE ACCUMULATIONS THAT WEIGH DOWN OR DAMAGE OVERHEAD LINES, AND CAUSE POWER AND COMMUNICATIONS SERVICE OUTAGES.**





## EXTREME COLD

An extreme cold event is defined as an a 12 hour period with temperatures at or below 32°F, which commonly occurs in New York City between December and March. Extremely cold temperatures can occur with or without storms.

One of the greatest hazards affecting people and animals is the wind-chill effect. As the temperature drops and wind speed increases, heat drains rapidly from people's bodies and leaves them feeling colder than the actual temperature. Frostbite risk increases the longer people are exposed to freezing temperatures and bitter wind.

### FLASHBACK FEATURE: THE 2014 POLAR VORTEX

In 2014, New York City experienced a rush of artic air, commonly known as the "polar vortex." This swirl of cold air surrounding each of the Earth's poles is a low-pressure system circulating in a counter-clockwise motion to keep cold air near the poles. However, on January 6-7, 2014, cold air spilled outside of the region of the North Poles and dipped south. New York City temperatures dropped 50 degrees in a matter of hours. Central Park recorded a low of 4°F , breaking the previous 1896 record of 6°F. LaGuardia and JFK airports also recorded record low temperatures. Although the term "Polar Vortex" has recently been popularized, this weather feature is not new. In fact, before 2014, New York City experienced cold outbreaks in 1859, 1899, 1917, and 1985, to name a few. Since 2014, the City has experienced cold outbreaks in 2015 and 2017.

## SEVERITY

### Winter Storms

Winter storms are classified by meteorological measurements and their societal impacts. The Northeast Snowfall Impact Scale (NESIS) is a post-event classification that characterizes and ranks high-impact Northeast snowstorms, which drop 10 or more inches of snow over large areas. NESIS scores are derived from the size of the area affected, the amount of snow accumulation, and the population in the storm's path.

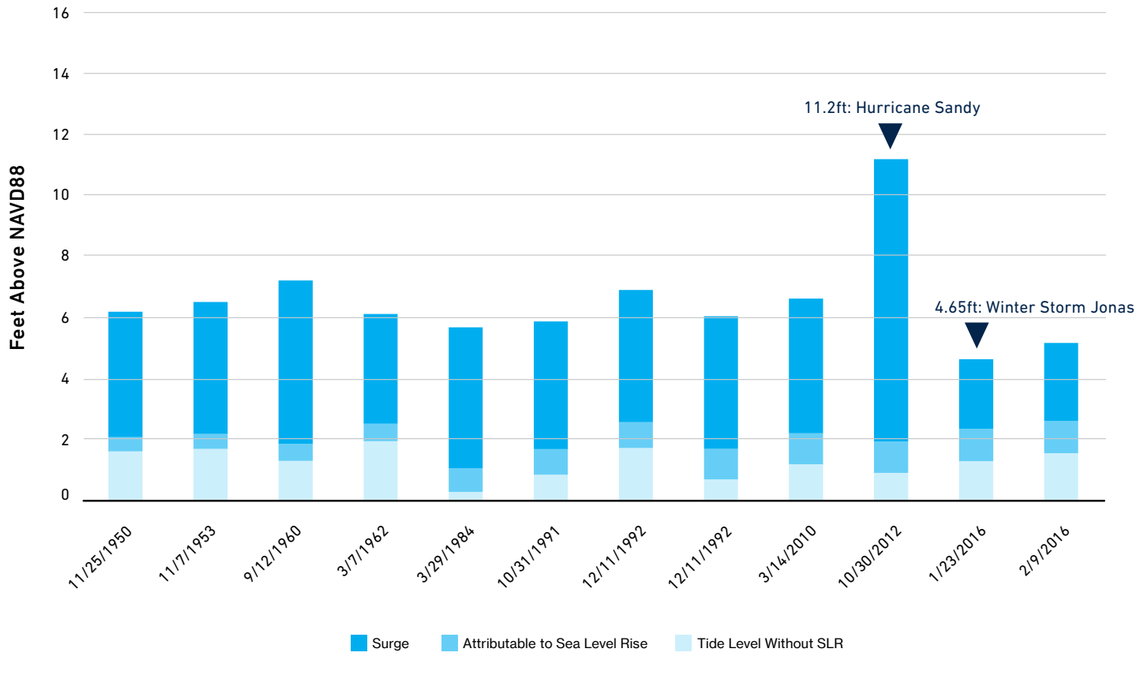
**THE NORTHEAST SNOWFALL IMPACT SCALE**
SOURCE: NOAA/NATIONAL CLIMATE DATA CENTER


Since 1869, New York City has experienced 28 snowstorms with 12" or more of snow. Out of all these storms, only one would be classified as "extreme" or a category five by using the NESIS scoring. This event was known as the Blizzard of 1996 and it dropped a total of 20.5 inches.

In the last 25 years, three winter snowstorms and blizzards were sufficiently damaging to earn presidential disaster declarations for New York City and the surrounding region—the Blizzard of 2010 (December 2010), the President's Day Snowstorm II (February 2003), and Blizzard of 1996 (January 1996).

Of the top five snowstorms to impact New York City, Winter Storm Jonas broke the record with 27.5 inches of snowfall accumulation.

| DATE | INCHES OF SNOW | NESIS RATING |
|---|---|---|
| January 22 to 24, 2016 | 27.5 inches | 4 |
| February 11 to 12, 2006 | 26.9 inches | 3 |
| December 26 to 27, 1947 | 25.9 inches | 4 |
| March 12 to 14, 1888 | 21.0 inches | 4 |
| January 6 to 8, 1996 | 20.5 inches | 5 |




# FLASHBACK FEATURE: WINTER STORM JONAS

Winter Storm Jonas, which developed in the Pacific Northwest and traversed the continental United States, is one of the strongest winter storm to hit New York City, producing 27.5 inches of snow in January 2016. Unofficial records logged snowfall as high as 34 inches in Queens. Jonas reached New York City on January 22 and disrupted the city for three days. Transportation systems came to a complete shutdown, and 4,800 flights were canceled in all three NYC-area airports. Intense winds, snow, and coastal flooding led to $50 million in damage. The storm also occurred during spring tide bringing moderate storm surge to low-lying areas of New York City — a reminder that winter storms can bring other hazards beyond snow, such as coastal flooding.

The table below compares the height of the water during Coastal Storm Sandy to other historic coastal storms. As shown, Winter Storm Jonas pushed the water level to nearly 4.7 feet, flooding coastal areas while its snow buried the city.

An example in New York City is Rockaway Beach, where the USACE placed 3.5 million cubic yards of sand following Hurricane Sandy at a cost of $36.5 million. This renourishment increased the resiliency of the beach and the berm system, and protected the built area adjacent to the coastline.

Other related examples include “beneficial reuse” projects, in which New York City uses sand that the USACE has dredged to clear navigation channels to replenish local beaches instead of transporting the sediment away from the region. Such work is scheduled during spring 2019 at Rockaway Beach.

**TOP**

**HISTORIC HIGH WATER EVENTS AT NYC’S BATTERY VS. WINTER STORM JONAS**
SOURCE: NOAA; UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH (UCAR); COURTESY OF MAYOR’S OF RESILIENCY (MOR)





## Extreme Cold

New York City currently experiences an average of 72 days per year with temperatures at or below 32°F. The National Weather Service (NWS) classifies extreme cold according to a wind-chill chart, which shows the temperature that a person feels on their exposed skin as air temperatures fall and wind speed increases. The NWS issues a wind-chill advisory for New York when wind-chill values are expected to fall between -15°F and -24°F, and a wind-chill warning when values are expected to fall to -25°F or colder.

## PROBABILITY

Winter storms occur frequently in New York City. Based on historic averages, New York City is likely to experience a winter storm that drops 6 or more inches of snow about 13 times every decade.

According to the New York City Panel on Climate Change, New York City currently averages 72 days per year in which temperatures are at or below 32°F — a pattern likely to decrease over the next several decades.

**WIND CHILL CHART**
SOURCE: NOAA

**Temperature (°F)**

| Wind (mph) | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | -5 | -10 | -15 | -20 | -25 | -30 | -35 | -40 | -45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calm | | | | | | | | | | | | | | | | | | |
| 5 | 36 | 31 | 25 | 19 | 13 | 7 | 1 | -5 | -11 | -16 | -22 | -28 | -34 | -40 | -46 | -52 | -57 | -63 |
| 10 | 34 | 27 | 21 | 15 | 9 | 3 | -4 | -10 | -16 | -22 | -28 | -35 | -41 | -47 | -53 | -59 | -66 | -72 |
| 15 | 32 | 25 | 19 | 13 | 6 | 0 | -7 | -13 | -19 | -26 | -32 | -39 | -45 | -51 | -58 | -64 | -71 | -77 |
| 20 | 30 | 24 | 17 | 11 | 4 | -2 | -9 | -15 | -22 | -29 | -35 | -42 | -48 | -55 | -61 | -68 | -74 | -81 |
| 25 | 29 | 23 | 16 | 9 | 3 | -4 | -11 | -17 | -24 | -31 | -37 | -44 | -51 | -58 | -64 | -71 | -78 | -84 |
| 30 | 28 | 22 | 15 | 8 | 1 | -5 | -12 | -19 | -26 | -33 | -39 | -46 | -53 | -60 | -67 | -73 | -80 | -87 |
| 35 | 28 | 21 | 14 | 7 | 0 | -7 | -14 | -21 | -27 | -34 | -41 | -48 | -55 | -62 | -69 | -76 | -82 | -89 |
| 40 | 27 | 20 | 13 | 6 | -1 | -8 | -15 | -22 | -29 | -36 | -43 | -50 | -57 | -64 | -71 | -78 | -84 | -91 |
| 45 | 26 | 19 | 12 | 5 | -2 | -9 | -16 | -23 | -30 | -37 | -44 | -51 | -58 | -65 | -72 | -79 | -86 | -93 |
| 50 | 26 | 19 | 12 | 4 | -3 | -10 | -17 | -24 | -31 | -38 | -45 | -52 | -60 | -67 | -74 | -81 | -88 | -95 |
| 55 | 25 | 18 | 11 | 4 | -3 | -11 | -18 | -25 | -32 | -39 | -46 | -54 | -61 | -68 | -75 | -82 | -89 | -97 |
| 60 | 25 | 17 | 10 | 3 | -4 | -11 | -19 | -26 | -33 | -40 | -48 | -55 | -62 | -69 | -76 | -84 | -91 | -98 |

**Frostbite Times**

30 minutes | 10 minutes | 5 minutes

Where, T= Air Temperature (ºF) V= Wind Speed (mph)
Wind Chill (ºF) = 35.74 + 0.6215T - 35.75(V0.16) + 0.4275T(V0.16

# WHAT IS THE RISK?

During the winter, snow and ice accumulations and extremely cold temperatures can pose risks to public health, public safety, utility and telecommunication infrastructure, and roadways. During and after major winter storms, businesses may see a drop in revenue and productivity in the short term.

## PEOPLE AT RISK

Extreme cold, wintry conditions, and ice all pose health risks to even to the most intrepid New Yorkers due to:

- **Treacherous Travel Conditions:** Every type of wintry precipitation — and particularly freezing rain — can cause accidents that injure motorists, bicyclists, and pedestrians; and potentially result in fatalities.
- **Power Outages:** Power outages caused by winter storms also put people at risk — for example, endangering the health of anyone relying upon powered medical equipment or risking home fires as people use candles and stoves, or other temporary ways to light and heat their homes.
- **Downed Power Lines:** Accidental contact with a downed power line can cause electrocution.
- **Exposure to Extreme Cold and Wintry Conditions:** Being outside in extreme cold, especially during snow or ice storms, is hazardous for outdoor workers, homeless people living outside of a shelter, and other at-risk people on the street. These wintry conditions can also trigger a range of injuries — falling on icy sidewalks or stairs, and back injuries and heart attacks from shoveling snow.

**NEW YORK CITY RECORDS AN AVERAGE OF 180 TREAT-AND-RELEASE HOSPITAL EMERGENCY DEPARTMENT VISITS AND 240 HOSPITAL ADMISSIONS ASSOCIATED WITH COLD-RELATED ILLNESS.**

Although carbon monoxide poisoning can occur at any time of the year, the danger is greater during winter. People without heat in their homes during extreme cold are at high risk, particularly seniors, infants, people with chronic medical conditions, and anyone with a disability. To stay warm, people sometimes use home appliances, notably gas kitchen ranges, space heaters, and boilers, can emit carbon monoxide if they are not propertly maintained and ventilated. Using a space heater improperly or using one that is poorly made is also a fire risk. Running vehicles inside garages can cause carbon monoxide to accumulate to fatal levels inside a person's car, garage, or even a home with an attached garage.

Hypothermia occurs after a person is exposed to cold temperatures for an extended period of time and their body loses heat faster than heat can be generated, causing a drop in their body's temperature. Frostbite happens when the body's outer tissue freezes, affecting a person's nose, ears, cheeks, chin, fingers, or toes. New York City records an average of 180 treat-and-release hospital emergency department visits and 240 hospital admissions associated with cold-related illness (i.e. hypothermia, frostbite, and extremity injuries), and 15 cold-related deaths (with outdoor and indoor exposures) during the cold season (October through April).

## BUILDINGS AT RISK

If a building's roof is not properly maintained, snow accumulation can cause damage, leaks, and collapse; however, New York City rarely experiences building collapses or structural damage due to snow and ice. Poorly maintained vacant wooden buildings, which are most at risk from the impact of winter storms, constitute only a small portion of New York City's total building stock.

New York City has a significant number of older masonry buildings, which are at risk if not properly maintained. Standing water in masonry cracks that turns to ice can hasten damage to the building's façade and cause wood or brick masonry to decay.

Prolonged periods of extremely cold weather primarily pose risks to homes and smaller masonry buildings. — frozen or burst pipes, triggering water shutdowns, and operational strain put on boilers to maintain interior heat.





## INFRASTRUCTURE AT RISK

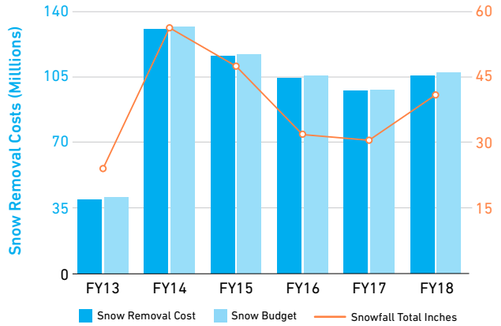
The types of infrastructure at greatest risk from winter storms are power and telecommunications networks, fuel supply chains, transporation systems, and local roadways:

- Utility and Telecommunications Network Risk: Power lines are built to withstand one-quarter of an inch of ice accumulation; however, winter storms can cause trees to topple onto overhead lines or create so much ice that lines are weighed down, disrupting utility or telecommunications service.
- Fuel Supply Chain Risk: If a winter storm interrupts the supply of fuel oil, natural gas, steam, or electricity to heat buildings, the health of residents is at risk from lack of indoor heat.
- Airport Disruption: Since New York City is a travel hub, winter storms that trigger flight delays and cancellations can disrupt travel on a global and national scale, with economic consequences for the flow of international and domestic businesses, conferences, meetings, and events.
- Rail and Transit Risk: Ice accumulation affects rail beds and mass transit rail switch systems, creating dangerous conditions for commuters. If transit railways are subject to sustained extreme cold temperatures, they can break or crack under stress.
- Roadway Risk: Bridges and overpasses are especially dangerous, because elevated roadways freeze before other road surfaces. Freezing temperatures and repeated freeze-thaw cycles often cause potholes and increase the extent of pre-existing road damage.

New York City's Department of Sanitation spreads rock salt on roadways to melt snow and ice. The thaw phase of freeze-thaw cycles can dissolve rock salt, creating salty water. This salty water can seep into manholes, corroding and short-circuiting underground electrical cables. This can create a risk of service disruptions, manhole fires, or, in rare cases, explosions.

New York City's Departments of Sanitation, Transportation, and Parks and Recreation sometimes bearadditional expense for snow and ice removal and for pothole repair if there are unanticipated winter weather events. Since 2014, the City has budgeted close to or exceeded $100 million due to increased snow events.

**HOW MUCH SNOW REMOVAL COST THE CITY IN RECENT YEARS**
SOURCE: NYC INDEPENDENT BUDGET OFFICE




## NATURAL ENVIRONMENT AT RISK

The two greatest risks posed by winter weather to New York City's natural environment are:

- Heavy Ice Accumulation, which adds weight to the tree limbs and risks injuring the tree by causing them to sever from the trunk. Severe ice accumulation can bring down entire trees.
- Volume of Snowmelt and Ice Runoff, which flows into New York City's sewer system. If the volume of runoff plus the volume of sanitary waste is greater than the handling capacity of the City's wastewater treatment plants, untreated wastewater is discharged into local waterways, creating risk to human health and marine life.

## FUTURE ENVIRONMENT

According to the New York City Panel on Climate Change, projections over the foreseeable future indicate that snowfalls will become less frequent, length of snow seasons will decrease, and winters will be warmer.

The number of days each year with minimum temperatures at or below 32°F is expected to decrease by 25% by the 2020s, and 33% by the 2050s.

With these reductions, snow accumulation is expected to last for shorter periods of time. However, since these are 10-year averages, individual winters could still have as much snow and snow cover as our current climate, though they are expected to occur less frequently. Given climate change, it is uncertain whether New York City will have the same level of risk from extreme ice storms in the future.

# HOW TO MANAGE THE RISK

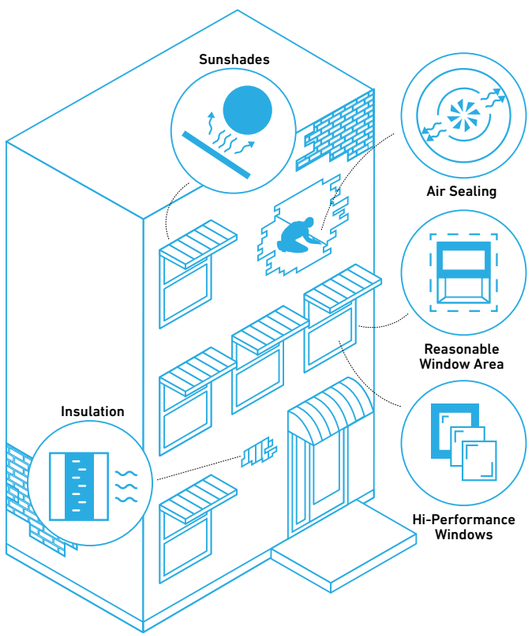
Strategies for managing winter-weather risks include strengthening construction standards, encouraging building maintenance and retrofits to retain heat, protecting infrastructure, and continuing efforts to help New Yorkers prepare for and respond to severe winter weather.

## REGULATION AND POLICY

Increasingly robust engineering requirements in New York City's Construction Codes contain provisions regarding:

- **Snow Load on Roofs:** standards to ensure that roofs are able to withstand the weight of deep, wet snow to mitigate the risk of roof collapse.
- **Thermal Protection:** standards to ensure that buildings are insulated against extreme cold and that windows provide thermal protection.

**HIGH-PERFORMING BUILDING PRACTICES AND MATERIALS**
SOURCE: URBAN GREEN COUNCIL




## NATURAL/OPEN SPACE PROTECTION

New York City and utility companies prune and maintain trees to lower the risk that snow and ice will weigh down power lines and branches, and trigger outages during winter storms:

- **Pruning Programs:** New York City Department of Parks and Recreation's Central Forestry Division oversees block pruning and commitment-pruning programs, in which it requires all street trees on a block to be pruned.
- **Vegetation Maintenance Program:** Con Edison's program trims branches near power lines along right of ways. This initiative also removes damaged or unhealthy trees and vegetation to create safe, minimum cleared distances between power lines and the surrounding trees.

## BUILDING PROTECTION

To help buildings withstand winter weather, the New York City Department Of Buildings encourages building owners to conduct periodic inspections and repair vulnerable masonry and wood buildings. Recommended activities include:

- Clearing snow and ice off of roofs and overhangs, and cleaning gutters and roof drains before and after snow or ice storms.
- Regularly inspecting building elements including parapets, cornices, window lintels, exterior walls, and roofs.
- Regularly inspecting roof structures for wood rot and making necessary repairs, particularly when rot is close to outside walls.
- Repairing sagging ceilings so they can better withstand heavy snow load and replacing all damaged roof joists

To help buildings retain more heat and withstand severe winter weather, building owners are encouraged to make the following improvements:

- Caulk and air-seal doors, windows, and air ventilation systems.
- Install insulation and high-performance windows, such as multi-paned windows with reflective coatings.
- Recognize that insulated walls retain building heat better than glass, and add either inside insulation or a new exterior layer.
- Fit exposed pipes with insulation sleeves or other wrapping to slow heat transfer.
- Seal cracks and holes in outside walls and foundations near water pipes with caulking.





## INFRASTRUCTURE PROTECTION

To mitigate risk from severe winter storms, protect city streets, and handle excessive runoff from melting snow and ice, several initiatives are undertaken by New York City and MTA:

- **Protecting Train Equipment:** The MTA stores trains underground when forecasts predict that temperatures will dip to -10°F, and if ice storms, icy conditions, or more than five inches of snow are expected.
- **Investing in Green Infrastructure:** The New York City Department of Environmental Protection's Green Infrastructure Plan will explore ways that green infrastructure can capture ice and snowmelt so that runoff does not reach and overwhelm wastewater treatment plants.

## PUBLIC AWARENESS

So as to ensure everyone is prepared, New York City undertakes several types of communications initiatives to warn the public and property owners when winter storms are threatening:

- **Public Warnings and Alerts:** Public warnings and alerts of impending winter storms are sent out through various government channels such as Wireless Emergency Alerts by the National Weather Service and Notify NYC messages by New York City Emergency Management.
- **Construction Site and Property Alerts:** Weather advisories are sent to property owners, contractors, and developers on specific preventive actions they can take quickly, such as clearing snow and ice from roofs and gutters.
- **Public Education:** Long-term education initiatives help New Yorkers understand, prepare for, and respond to extreme cold and other winter weather hazards, which include New York City Emergency Management's *Ready New York: Preparing for Emergencies in New York City,* and the New York City Department of Health and Mental Hygiene's website and brochure on precautions to take for extremely cold weather and safety measures to prevent carbon monoxide poisoning.

## ALTERNATIVE PAVEMENT FOR SNOW MELTING

Many cities around the world are experimenting with and deploying technology to melt snow in public areas more effectively. Reykjavik, Iceland pumps hot water through tubes under many sidewalks, like an outdoor version of an in-floor heating system. Oslo, Norway has embedded electric heating cables into sidewalks to melt snow. Montreal, Canada has experimented with heated sidewalks, but has had to replace its technology with a better solution.

In the United States, researchers are analyzing the potential of snow-melting concrete, which uses a mix of paraffin wax and concrete to melt snow all on its own. Paraffin wax becomes solid in colder temperatures, but, in doing so, the wax releases enough heat to warm the surrounding concrete and melt the snow.

These alternatives have advantages over melting snow with sprinkled salt, because salt can erode street surfaces, creating potholes. Manhole fires can also happen when melted salted water drains into underground electric networks. Heated sidewalks can reduce such impacts, while making conditions less hazardous.

**TOP RIGHT TO BOTTOM:**
SOURCE: ICELAND NATIONAL ENERGY AUTHORITY
SOURCE: REYKJAVIK ENERGY





**LEARN MORE ABOUT NYC**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 08 CYBER THREATS

The Internet's largely open and unregulated nature means that New York City is vulnerable to cybersecurity threats and incidents. New York City's vulnerability to cyber-attacks may change significantly in the future as technology evolves and online services and functions increase.

Looking ahead, New York City government, utilities, and other internet users are employing increasingly innovative security measures to protect their systems and citizens.

## WHAT IS THE HAZARD?

A cyber-attack involves either the theft or modification of information on City agency computer systems, or a system compromise that has the potential to disrupt essential services.

A system compromise can impact one or more City agencies, a private utility, or specific Critical Infrastructure/Key Resources (CIKR) such as the power grid, public transportation systems, and wireless networks.

A cyber-attack can affect a system's:

- Confidentiality, which protects user's private information.
- Integrity, which ensures that data is protected and is not altered by unauthorized parties.
- Availability, which keeps services running and ensures that administrators retain access to key networks and controls.

Cyber-attacks differ by motive, attack type and vector, and perpetrator profile. Motives can range from the pursuit of financial gain to political or social aims. A variety of perpetrators including external, internal, and partners to the organization, agency, institution, or business may carry out cyber-attacks.

Unlike many other hazards that affect New York City, the causes of cyber-attacks are not always related to geographic location. For instance, most cybercrime is mobile, with over 60 percent of online fraud carried out through mobile platforms.

## WHAT IS THE RISK?

Every facet of life in the City — from the delivery of water and electricity, to transportation, life safety, and emergency response — has become deeply reliant on technology. A cyber-attack can have wide-ranging effects on public and private infrastructure if industries related to utilities, health care, transportation, social services, and telecommunications are targeted and attacked.

Cyber-attacks can affect New York City in a number of ways. Stolen personal information may destroy the financial standing of an individual. Additionally, cyber-attacks can damage public trust in institutions that are otherwise considered stable and secure. Cyber-attacks may also create fear and erode the public trust needed for private and public services to run successfully.

## HOW TO MANAGE THE RISK

In 2017, the City created the New York City Cyber Command (NYC3) to enhance its efforts to protect New Yorkers. NYC3 educates New Yorkers about cyber threats, helps them to prevent and detect threats, and takes other measures to increase network and system security.

NYC3 created the Citywide Cybersecurity Awareness Program to mitigate the risk of cyber-attacks. This education program provides City employees with a range of training and awareness initiatives including classroom sessions, computer-based training, anti-phishing simulation testing and training, various media initiatives, and role-based training for employees with privileged access to networks and systems.

In 2018, New York City launched NYC Secure, a free app which alerts New Yorkers about unsafe activity on their mobile devices and provides guidance on how to remediate issues.

The NYCx program out of the Mayor's Office of the Chief Technology Officer and NYC3 have collaborated to launch the Cybersecurity Moonshot Challenge, which is encouraging industry experts to arm small businesses with the information and tools they need to protect their information from cyber threats.

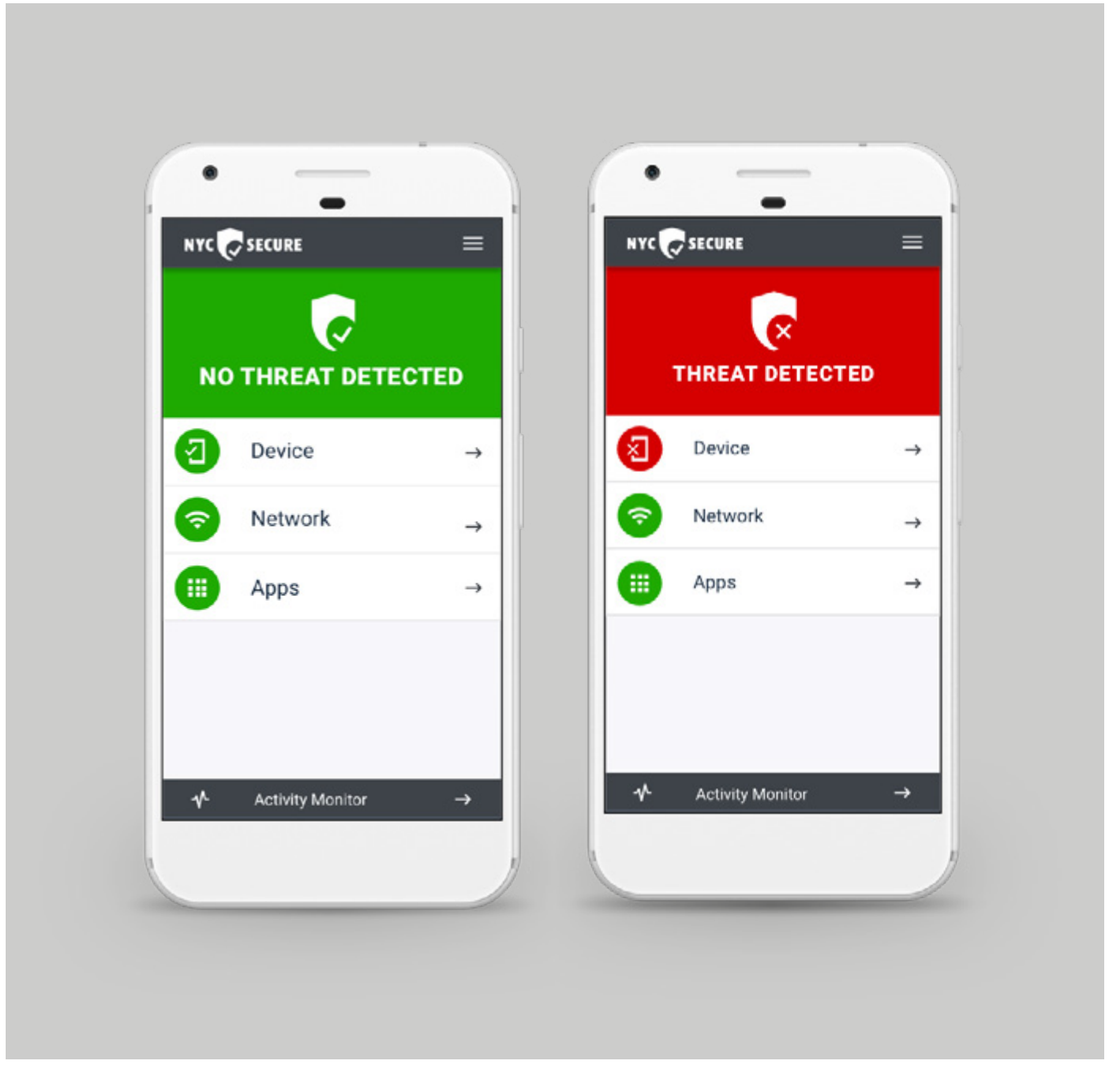
To strengthen the protection of Wi-Fi in the City's public spaces, NYC3 is working to deploy a Domain Name System (DNS) protection across all City-owned systems in order to ensure that devices are not infected by malicious websites. NYC3 is encouraging other providers of free Wi-Fi in New York City to follow suit.





**OUR STREETS ARE ALREADY THE SAFEST OF ANY BIG CITY IN THE COUNTRY — NOW WE'RE BRINGING THAT SAME COMMITMENT TO PROTECTING NEW YORKERS INTO CYBERSPACE.**

**NEW YORK CITY MAYOR, BILL DE BLASIO**







**LEARN MORE ABOUT NYC**

What is the Hazard?
What is the Risk?
How does NYC Manage this Risk?

# 09 HAZARDOUS MATERIALS: CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND NUCLEAR (CBRN) RELEASES

A hazardous materials incident is a situation in which harmful substances are released into the environment. These types of releases are often classified as chemical, biological, radiological, or nuclear (CBRN) and result from one of two conditions:

- **Accidental releases** that result from human error, tainted food products, technological failure, or natural disaster. These include spills, leaks, airborne releases, or seepage into uncontained areas.
- **Intentional releases** of hazardous materials that are criminal acts. These include purposeful dumping by businesses to avoid regulatory requirements, or terrorist acts that target a specific location, possibly involving a dispersal device or an explosive.

New York City's density and congestion leave it highly vulnerable to CBRN releases. The City's position as a cultural and economic center make it a likely target for intentional CBRN releases. As a result, law enforcement must be prepared to deter and respond to CBRN threats.

# WHAT IS THE HAZARD?

CBRN hazards affect people and the environment in different ways, and under worst-case scenarios, each could be lethal.

## Chemical

A chemical is considered hazardous if it is toxic, reactive, corrosive, or flammable. The chemical properties of hazardous substances can react with and cause damage to living cells and tissue. Exposure can be caused by inhalation, skin contact, ingestion, and injection. In New York City, the hazards include:

- **Household chemicals:** An unintended release of everyday household chemicals (such as cleaning solutions) or materials (such as heating oil) can pose a hazard, depending on the type of chemical and the amount of a person's direct exposure.
- **Accidental releases:** Accidents can occur when chemicals are in transit or at fixed sites, such as industrial facilities, open industrial areas, construction sites, commercial businesses, and residential buildings that use heating oil. Hazardous chemicals (known as Toxic Industrial Chemicals, or TICs) that may be released unintentionally include petroleum substances (such as oil, gasoline, and liquid natural gas) and industrial chemicals (such as chlorine and pesticides). Fires and explosions can disperse chemicals even more widely.
- **Chemical weapons:** Dangerous chemicals are classified according to their effect on the body and the primary organ system affected.

## Biological

Biological hazards come in the form of biological agents, bacteria, and viruses. They can impact people in several ways:

- **Airborne exposure**, or inhaling, as with airborne B. anthracis spores that cause anthrax.
- **Ingesting contaminated food or water**, as with E. coli, which causes gastrointestinal infection.
- **Direct contact** with infected individuals or touching contaminated surfaces, as with viruses that cause influenza.

Ricin, a chemical toxin of biological origin, has been used in small-scale attacks on individuals, typically through injection or inhalation. High-profile examples include the 1978 assassination of Georgi Markov, where the attacker used an umbrella rigged with a special tip to inject a ricin pellet under Markov's skin, and letters contaminated with ricin sent in 2013 to NYC Mayor Bloomberg and the gun control group he founded.

**CHEMICAL WEAPONS (TITLE TBD)**
SOURCE: ORGANIZATION FOR PROHIBITION OF CHEMICAL WEAPONS (OPCW), 2019

| TYPES OF CHEMICAL WEAPONS | EXAMPLES | EXPOSURE |
|---|---|---|
| **Nerve Agents** | Novichok, VX, and VR | Enters the body through the skin or lungs and affects the nervous system |
| **Blood Gases or Systemic Agents** | Hydrogen cyanide | Enters the body through inhalation and is distributed through the bloodstream. Blood agents inhibit the ability of blood cells to use and transfer oxygen, effectively causing the body to suffocate |
| **Choking Agents** | Chlorine, phosgene | Is inhaled and can cause severe irritation or swelling of the respiratory tract (lining of the nose, throat, and lungs) |
| **Blister Agents** | Mustard gas, lewisite | Acts through inhalation or skin contact, damaging the skin, eyes, and airways. If absorbed into the body, can also affect other parts of the body |





## Radiological

Radiation exposure can be either natural or intentional. For example, people can inhale radon gas decay products that are produced in radium-bearing soils, or be exposed to gamma-rays emanating from uranium decay products found in soils and rocks.

On the other hand, intentional exposure could come from radiological dispersal devices (RDDs), such as dirty bombs — an explosive device designed to disperse radioactive material. Malevolent actors could also use cesium-137, a key component used in medical equipment for research and blood irradiation, to create dirty bombs. If deployed in a bomb, the impacts could be significant (To learn more about what the city is doing to reduce this risk, please refer to the section on How to Manage the Risk). Radiological exposure devices (REDs) are hidden, non-explosive devices that emit gamma rays and expose people without their knowledge.

People can be exposed to harmful doses of radiation externally (such as exposure to radioactive dust, powder, or liquid that touches their skin, hair, or clothing) or internally (such as swallowing or inhaling radioactive materials).

## Nuclear

Nuclear incidents involve the release of large amounts of energy in the form of intense light, heat, pressure, and ionizing radiation. With a nuclear incident, radiation exposure occurs on a much larger scale than in a radiological incident. Such incidents have the potential to cause catastrophic loss of life and do direct damage to city infrastructure. An incident of this magnitude could significantly disrupt or terminate civil services. Although the nuclear devices that terrorist organizations may fabricate under special circumstances tend to be relatively small, their use can still cause mass casualties.

Another form of nuclear-related incident is the release of radioactivity from a nuclear power plant via a plant malfunction, terrorist action, or other unexpected event.

# SEVERITY

A chemical, biological, radiological, or nuclear release becomes a citywide emergency when it poses a threat to human safety or the environment. The severity of any hazard depends upon the type and amount of material released, how near the release is to the population, and the nature of people's exposure.

## Chemical

The severity of a chemical release depends on the chemical's toxicity, latency, transmissibility, and persistency.

When responders are uncertain about a chemical's persistency, they act with extreme caution. For example, the 2018 Novichok chemical-weapon attack in Salisbury, England required a lengthy environmental remediation effort, because the persistency of Novichok, which collects in low-lying areas, is unknown. The location of a chemical release and the proximity to residential and commercial areas is a key factor in determining the extent of likely exposure.

### HOW CHEMICAL RELEASES ARE ANALYZED

**TOXICITY**

Degree to which the chemical impairs human health.

**LATENCY**

Time interval between exposure and the development of clinical symptoms.

**TRANSMISSIBILITY**

Potential passage of the chemical between exposed persons and others, particularly rescue workers, such as hospital staff.

**PERSISTENCY**

Time it takes for the chemical to disperse.

## Biological

The severity of a biological hazard depends on the type, location, and amount of the release, as well as the size, density, and characteristics of the population affected.

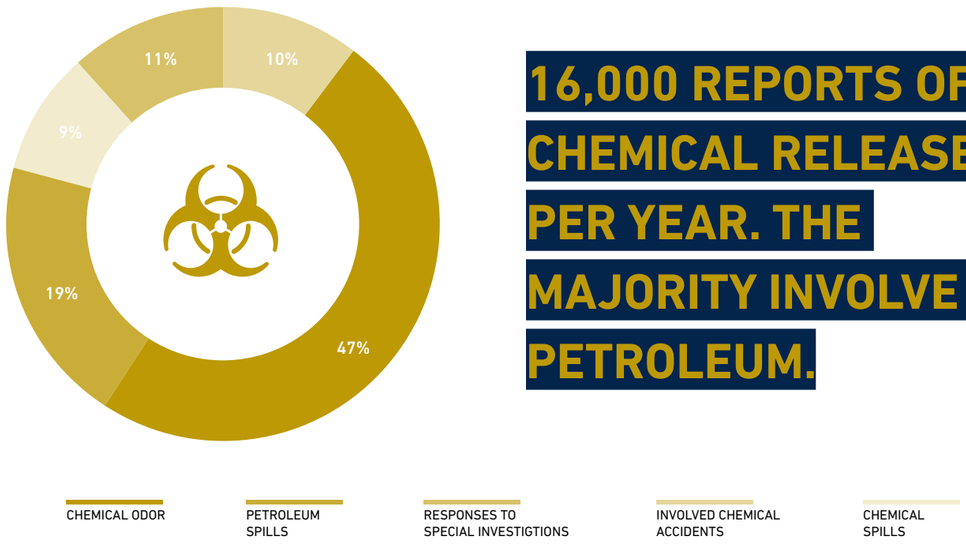
## Radiological

Severity of radiological hazards is discussed in terms of "dose", or the amount of energy absorbed by tissue per unit mass. The severity of a radiological hazard depends on a number of factors — whether the dose was a whole or partial body dose, the exposure rate and duration, the effectiveness of the radiation to harm human tissue, and if internalized, the organs affected. Exposure to a single, short-duration, high dose of radiation can cause health impacts, such as acute radiation syndrome. Relatively low doses that occur over extended periods can have a cumulative effect that results in chronic health effects later.

## Nuclear

In a nuclear incident, radiation exposure occurs on a much larger scale than in a radiological incident and has the potential to cause catastrophic loss of life and direct damage to city infrastructure.

**NY STATE CHEMICAL RELEASES**
SOURCE: TBD




**16,000 REPORTS OF CHEMICAL RELEASES PER YEAR. THE MAJORITY INVOLVE PETROLEUM.**

# PROBABILITY

CBRN releases are generally not predictable because calculating the probability or recurrence intervals for specific events is difficult. However, they can be estimated (see NYCDOHMH Public Health Jurisdictional Risk Assessment 2018). The probability of an event will be higher near facilities that are not routinely maintained or inspected, at potential targets for an intentional attack, and at ports or other facilities such as refineries where high volumes of hazardous materials are frequently moved.

When comparing the probability among chemical, biological, radiological and nuclear releases, chemical releases are more likely and occur more frequently, because hazardous chemicals are widely transported and used by a wide range of businesses in day-to-day operations. Nuclear releases are less probable, though the impact could be much greater than a chemical, biological, or radiological release due to atmospheric dispersion and the long-term issues of decontamination and epidemiologic surveillance.





# LOCATION

## Chemical

Hazardous materials are subject to significant federal, state, and local controls, which makes it less likely that major unintentional chemical releases will occur in New York City. Small incidents, however, do occur and pose a risk to public health if they contaminate groundwater, surface water, the air, and soil.

The NYC Department of Environmental Protection's (DEP) Division of Emergency Response and Technical Assessment (DERTA) responded to nearly 3,600 chemical-release incidents between July 1, 2017 and June 30, 2018. The New York State the Department of Environmental Conservation (NYSDEC) receives an average of about 16,000 reports of confirmed and suspected chemical releases each year. The majority concern small quantities of petroleum products, which are contained and cleaned up quickly.

Although heavy industry, including petroleum production and storage facilities, have mostly moved out of New York City, many remaining small businesses and large facilities (airports, electrical production and delivery systems, fueling facilities, sewage treatment plants) still use and store chemicals and petroleum products in bulk.

A significant number of chemical spills and leaks are due to accidents that happen during transit to and from storage or manufacturing facilities; therefore, most accidental chemical releases in New York City are near chemical plants, industrial facilities/storage sites, warehouses, and fuel stations.

Many industrial facilities are located along the waterfront, such as Hunts Point in the Bronx; Newtown Creek in Queens and Brooklyn; the Brooklyn Navy Yard, Gowanus Canal, and Sunset Park in Brooklyn; and Kill Van Kull in Staten Island. Flooding and coastal storm events heighten the risk of an unintentional hazardous materials release from facilities in these locations. Residential areas, especially low-income neighborhoods, may be near industrial facilities and present special concerns regarding recovery.

For intentional chemical releases, the locations most likely to be targeted are crowded, densely populated places (such as tourist attractions, the subway system, and entertainment venues), financial centers, government offices, and critical infrastructure facilities (water supply reservoirs and distribution systems, power plants, ports, and hospitals). On a much smaller scale, an unintended release of everyday household chemicals (such as cleaning solutions) or materials (such as heating oil) can pose a hazard to human health and life depending on the chemical and amount of direct exposure to humans.

## Biological

Biological incidents can occur anywhere in the city, but New York City's high-density neighborhoods enable biological agents to spread quickly, increasing the probability of an outbreak. Outbreaks could start from, for example, restaurants or markets selling tainted food or a combined sewer overflow outfall that exposes people to raw sewage.

## Radiological

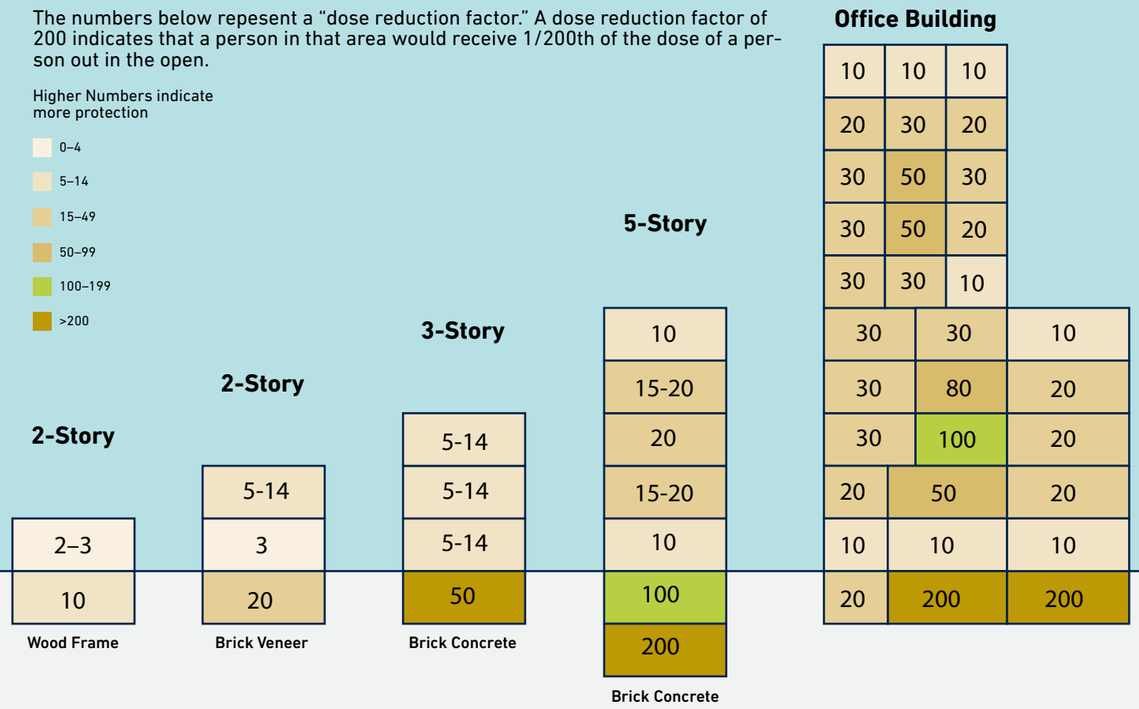
Accidental radiological incidents are most likely to occur near facilities storing radioactive materials or waste. Buildings that store radioactive materials include hospitals, medical facilities, research and development facilities, colleges, and universities. Hospitals, medical facilities, research and development facilities, colleges, and universities may suffer small spills on occasion.

New York City has about 375 licensed sites that possess radioactive material for medical, academic, and research purposes. Some hospitals perform research using short half-lived Positron Emission Tomography (PET) isotopes. These activities generate radioactive waste — beakers, stirrers, sample tubes, gloves, and occasionally other lab equipment. Medical isotope transport, particularly short-lived iodine-131, is a daily occurrence. Accidental radiological incidents are most likely to occur near facilities storing radioactive materials or waste, such as hospitals, medical facilities, research and development facilities, colleges, and universities.

The most likely targets for an intentional radiological attack are often public spaces where contamination can be spread.

## Nuclear

The nuclear power facility closest to New York City is the Indian Point Nuclear Power Plant in Buchanan, New York. A nuclear release from this plant (whether accidental or intentional) is not expected to expose New York City residents to harmful radiation unless the release is extremely large and combines with a very unique set of meteorological conditions.




# FLASHBACK: FALLOUT SHELTERS

During the 1960s, the United States was concerned over the Cold War nuclear threat. Air raid drills were common, and prior to the 1962 Cuban missile crisis, President Kennedy created a national nuclear shelter program. New York's Governor Nelson A. Rockefeller encouraged the creation of hundreds of thousands of fallout shelters. In 1963, the Army Corps of Engineers identified 17,448 rooms in New York that could safely secure 11.7 million people. Governor Rockefeller released $15 million of state funds to stock each shelter with aspirin, toilet paper, and appetite-suppressing hard candies. As the nuclear threat diminished in the 1970s, the stored supplies were removed and distributed, and the shelters faded from public memory. In 2006, NYC Department of Transportation employees discovered one of these relics inside the Brooklyn Bridge.

Following a nuclear explosion, any building can be used as a shelter; although, some buildings will provide better protection than others. The amount of protection a building provides depends on the construction materials and the location in the building where a person takes shelter. Per Lawrence Livermore National Laboratory, even the basement of a single-story, wood-framed house could reduce an individual's exposure by 90%, which is enough to save lives.

In New York City, many buildings are medium or large, multi-storied structures with basements that will provide effective shelter. Since radioactive fallout presents an immediate concern following a nuclear explosion, the best action a person can take is to immediately enter the most protective nearby building, rather than travel a distance outside to one of the buildings once designated as "fallout shelters" by the Army Corps of Engineers.

**TOP:**

**EXAMPLE OF PROTECTION FACTORS (PFS) FOR A WIDE VARIETY OF BUILDING TYPES AND LOCATIONS**
KEY RESPONSE PLANNING FACTORS FOR THE AFTERMATH OF NUCLEAR TERRORISM (PDF - 4.52 MB) (LAWRENCE LIVERMORE NATIONAL LABORATORY, AUGUST 2009, PAGE 12, FIGURE 9)

**LEFT TO RIGHT (NEXT PAGE):**

MINORITY POPULATIONS IN INDUSTRIAL FLOOD ZONE
SOURCE: U.S. CENSUS, NYC DCP, NYCEM, NYC-EJA'S WATERFRONT JUSTICE PROJECT
POVERTY LEVEL IN INDUSTRIAL FLOOD ZONE
SOURCE: U.S. CENSUS, NYC DCP, NYCEM, NYC-EJA'S WATERFRONT JUSTICE PROJECT





# WHAT IS THE RISK?

## PEOPLE AT RISK

CBRN releases could potentially compromise the safety and health of anyone who resides in, works in, or visits New York City. Specific impacts will vary according to people's proximity to the accidental or intentional release, whether the hazard is communicable to others, if vulnerable segments of the population are particularly susceptible and may have trouble seeking safety or health resources without assistance, and whether the hazard is dispersed over a wide area.

### Chemical

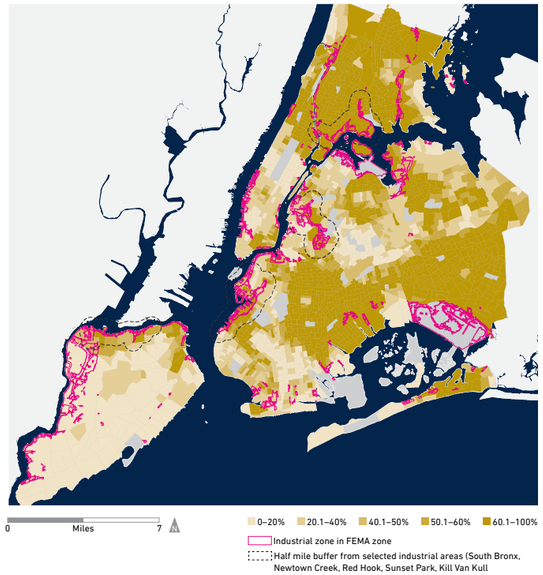
Because New York City's population density is higher than most other cities in the United States, the risk to the general population is high if a large-scale chemical release occurs. Release of toxic chemicals results in:

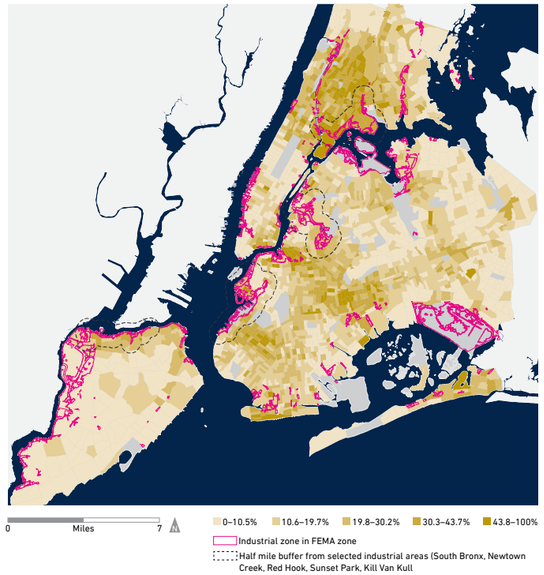
- **Direct physical impact:** Release of toxic chemicals containing carcinogens, corrosives, or other agents may affect a person's lungs or blood. Toxic chemicals pose other physical hazards when they are flammable, combustible, explosive, or reactive.
- **Contamination risk:** If water, air, soil, or ground water is contaminated by toxic chemicals, potential consequences include injuries, long-term illnesses, other health hazards, and death.

Anyone living or working in close proximity to sites storing hazardous materials is at higher risk from chemical hazards, as are:

- **First responders:** Emergency responders, who could be exposed to hazardous chemicals in the line of duty.
- **Waterfront residents:** The large number of New Yorkers who live near waterfront industrial areas — such as the South Bronx, Red Hook, Sunset Park, Newtown Creek, and the North Shore of Staten Island.
- **Low income Individuals:** People living near industrial areas are often low-income communities with high concentrations of minorities. Communities such as these in which equity issues are coupled with localized health, environmental, and commercial concerns are known as Environmental Justice Communities.

Industrial flood zone maps show where flooding and coastal storm events heighten the risk of an unintentional hazardous materials (HAZMAT) release.



### Biological

Factors creating higher risk from biological hazards are:

- **Urban density:** Densely populated residential areas, crowded business districts, and tourist attractions are at increased risk from biological hazards due to the potential for increased rates of transmission where people are crowded together.
- **Social and medical vulnerability:** People who are at higher risk than the general population are senior citizens, young children, people with disabilities, persons with mobility impairments, and individuals with pre-existing medical conditions or weakened immune systems.

### Radiological

The dose and intensity of radiation exposure affect its impact upon a person's health — a single, short, high dose can cause acute radiation syndrome, while low doses over time may have a cumulative effect in chronic health issues that manifest later.

Factors creating higher risk from radiological hazards are:

- **Age:** Children are generally more sensitive to internalized radioactivity because their organs are smaller, so they can experience higher concentrations of radiation deposition per unit mass (the definition of radiation dose) than adults.
- **Sex:** In general, women exposed to significant radiation doses are at slightly greater risk of developing cancer than men exposed to the same dose.
- **Pregnancy:** The fetus is also sensitive to radiation dose, mostly between the 2nd and 5th week from conception.

Radiological incidents, should they occur, can be devastating to human health:

- **High Radiation Dosage Inhalation Risk:** Anyone in close proximity to a dirty-bomb incident is likely to have high contamination levels as well as trauma.
- **Inhalation risk:** Aerosolization of radioactive material contributes to the risk that airborne material is inhaled and a person's organs are affected.

### Nuclear

A nuclear release from the Indian Point Power Plant, the nuclear facility closest to New York City, is not expected to expose New York City residents to harmful radiation unless a very unique and rare set of meteorological conditions (wind direction and atmospheric stability) happens simultaneously with an extremely large nuclear release.

An intentional nuclear incident, such as the detonation of a nuclear device, has the potential to cause catastrophic loss of life due to massive radiation exposure.

## BUILDINGS AND INFRASTRUCTURE AT RISK

Biological hazards do not pose as much of a threat to New York City's built environment as other hazardous releases do. Smaller chemical releases, however, can threaten infrastructure, industrial, and residential buildings:

- **Corrosive chemicals** have the potential to damage building materials and infrastructure.
- **Chemical vapors** from spilled materials can collect in houses and businesses, creating health impacts, fires, and explosions.

Chemical and radiological incidents can also cause widespread disruption:

- **Chemical incidents:** An incident could shut down or destroy the public and private transportation infrastructure, causing massive transportation delays, and potentially impact New York City's supply chain for food and other goods.
- **Dirty bomb:** The most significant impacts from the explosion of a radiological dispersal device (RDD), or dirty bomb, would be the direct damage of the explosion and the potential for widespread contamination of property and people.

A nuclear incident — considered to be the most catastrophic of all the CBRN hazards — has the potential to cause widespread damage to city infrastructure and significantly disrupt or terminate civil services.





## NATURAL ENVIRONMENT AT RISK

CBRN releases each have the potential to cause a long list of risks to New York City's natural environment — water and soil contamination, creating a toxic environment that destroys plants and marine life, and disrupting and/or poisoning the human food supply. The cost of remediating the impact of any of CBRN accidents or incidents would be formidable.

### Chemical

Chemical releases can contaminate soil and underground water systems and eventually discharge into nearby bodies of water. In New York City, this risk includes, but is not limited to, such important waterbodies as the Hudson River, East River, Long Island Sound, Harlem River, Jamaica Bay, New York Harbor, Gowanus Canal, and Newtown Creek.

Certain chemicals may be toxic to many species of plants, animals, and invertebrates. Uncontained spills, especially those that impact surface water, can kill or injure plants, fish, and wildlife and cause damage to their habitat and food sources. After a hazardous chemical release, the remediation of the natural environment poses unique challenges and is often lengthy and costly.

If released into the natural environment, petroleum can smother, impede, and poison plants and wildlife. Due to the sheer amount of petroleum products used on a day-to-day basis, petroleum is responsible for more environmental damage and injuries than industrial and household chemicals.

### Biological

Biological releases in New York City can be devastating to plants and animals. Since different microorganisms and pathogens affect different hosts, the severity of impacts depend on the type of biological material released.

### Radiological and Nuclear

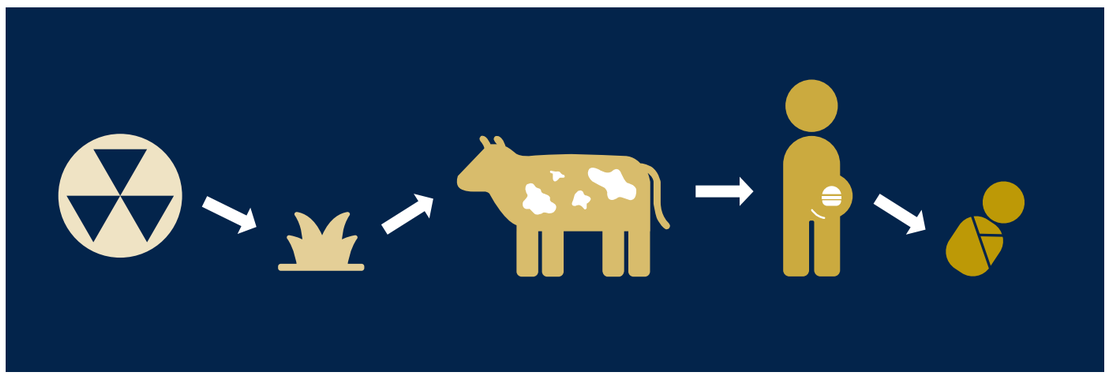
If vehicles transporting medical isotopes are involved in accidents or intentional attacks, any plant or animal exposed to high doses of radiation would be harmed. If they are exposed to short, high radiation doses, exposure could trigger death from acute radiation syndrome or genetic defects in rapidly reproducing species (for example, insects).

A critical risk associated with any radiological release is its entry into the food chain and contamination of the people's food supply. If a nuclear power plant, for example, releases radioactive iodine in sufficient quantities, it could contaminate grazing lands, accumulate over time in a cow's milk, and affect anyone drinking the milk. In the event of such an emergency, New York City and State officials may restrict the movement of food products from farms thus preventing them from reaching the marketplace.

The distance between Indian Point and New York City makes it unlikely that a nuclear power plant release would affect New York City.

Radioactive fallout from nuclear devices (nuclear weapons or improvised nuclear devices) would have severe impact upon the terrestrial and marine environment. Fallout decays rapidly, leaving longer lived radioactivity (e.g., Cesium-137 and Strontium-90), which can bioaccumulate after entering the food chain.

RADIOACTIVE IODINE INGESTION PATHWAY



## FUTURE ENVIRONMENT

### Chemical

Heavy industry, including petroleum production and storage facilities, have mostly moved out of New York City during the past 50 years and will continue to do so, but remaining small businesses and large facilities still use and store chemicals and petroleum products in bulk.

New energy storage systems have recently increased in New York City. Alternative energy, liquefied natural gas (LNG), compressed natural gas (CNG), and hydrogen fuel cells are proliferating here. Drug manufacturing, including illicit drug labs, pill production, and other new additions such as Fentanyl and Carfentanyl, has increased in New York City. These trends indicate an increase in the manufacturing of chemicals which heightens the overall risk to the environment, public health, and emergency responders.

A growing number of hostile actors are now familiar with how to create and use chemical weapons, due to their widespread use in Syria and Iraq. Access to recipes and how to develop dispersal, explosive, and exposure devices is more readily available to lone actors or self-motivated individuals via the internet and social media. The 2018 Novichok assassination in England demonstrated that hostile states are willing to use chemical weapons, although the risk of local threats can be equally concerning.

### Biological

In the future, shifts in New York City's population density and distribution could affect how many people are at risk from biological hazards and from a pathogen's transmission rate. Advances in medical technology have the potential to introduce new threats to NYC's populations. This includes the creation and manipulation of pathogens using advanced technologies to make bacteria and viruses more harmful. For more information, please see the hazard profile Emerging Diseases with Epidemic Potential on the 2019 Hazard Mitigation Plan website.

### Radiological

The use of radioactive materials in pharmaceutical and biomedical research has been undergoing a long-term decline around the nation; however, research using radioactivity, including short half-lived PET isotopes, continues in some New York City hospitals. As such, there will be an ongoing need to transport this low-level radioactive waste to repositories.

The future risk of releases in New York City will depend on whether use of radiological materials in research, medicine, industrial applications, and power generation grows or is replaced by other, safer technical solutions. One change that might decrease future risk is hospitals' preference to use linear accelerators instead of Cobalt-60 teletherapy, and the use of tube-based X-ray type blood irradiators to replace Cesium-137 blood irradiators.

### Nuclear

New York City's future level of risk from accidental nuclear releases is low. Cheaper power alternatives, such as natural gas and green energy, have already forced the closure of some nuclear power plants in the United States, including the Indian Point Nuclear Power Plant.

The Indian Point facility's two operating reactors are scheduled to cease operations in 2020 and 2021, followed by a lengthy decommissioning process. The low-level radioactive waste from used fuel is expected to remain on site in dry cask storage — a robust means of long-term control.

New York City will continue to be subject to large-scale nuclear weapons threats and terrorist activity due to its national importance. The availability of nuclear weapons materials may ebb and flow with the viability of the international nuclear security regime and its components, such as the Nuclear Proliferation Treaty. The capabilities of international terrorist groups change over time. NYPD and its federal partners conduct ongoing surveillance of domestic and international terrorist groups. These surveillance capabilities must be maintained and improved to interdict and prepare for all potential incidents.

**IN THE FUTURE, SHIFTS IN NEW YORK CITY'S POPULATION DENSITY AND DISTRIBUTION COULD AFFECT HOW MANY PEOPLE ARE AT RISK FROM BIOLOGICAL HAZARDS AND FROM A PATHOGEN'S TRANSMISSION RATE.**





## HOW TO MANAGE THE RISK?

Strategies for managing risks posed by CBRN releases include extensive regulatory controls on fixed sites and transportation; carrying out pertinent studies and industry safety initiatives, emergency planning, community preparedness, and education efforts that help workers better manage hazardous materials and help communities understand the risks.

## REGULATION AND POLICY

Many parties in New York City, at all levels of government and within the private and nonprofit sectors, contribute to safe management of hazardous materials. Since the beginning of the environmental movement in the 1960s, many federal laws have been created to regulate the storage and use of hazardous materials effectively, with state and local governments delegated to implement and enforce them.

### FEDERAL LAWS ON HAZARDOUS MATERIALS

**SEVERAL IMPORTANT FEDERAL LAWS AND PROGRAMS ESTABLISHED THE FRAMEWORK FOR MANAGEMENT OF HAZARDOUS MATERIALS RELEASE:**

- **The Clean Air Act:** Enacted in 1970, this law limits air pollution on a national level.
- **The Clean Water Act:** In 1972, this law established the basic structure to regulate pollutants discharged into the nation's waters.
- **The National Pollutant Discharge Elimination System (NPDES):** Created in 1972 by the Clean Water Act to establish a permit program that Environmental Protection Agency (EPA) often delegates to state governments. In New York State, NPDES is implemented by NYSDEC, which handles the permits, administration, and enforcement of the program.
- **The Resource Conservation and Recovery Act:** Enacted in 1976 to give the EPA authority to control hazardous waste generation, transportation, treatment, storage, and disposal. This is incorporated into New York State regulations and implemented by NYSDEC.
- **Superfund:** In 1980, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), was passed and amended in 1986 to clean up the most polluted industrial sites in the United States. EPA was given the authority to hold responsible parties accountable to fund the cost of investigation and remediation.
- **Emergency Planning and Community Right-to-Know Act (EPCRA):** In 1986, this law required industries to report their storage, use, and release of hazardous substances to federal, state, and local governments.

## Federal Regulation of Biological and Nuclear Hazards

Two agencies establish regulatory frameworks to ensure that biological and nuclear materials releases do not occur:

- **Biological Safety Levels (BSL)** were established by the **Centers for Disease Control and Prevention (CDC)** to manage risk from biological materials releases. BSL establishes protection controls to contain microbes and biological agents in specific labs. The four safety levels are based on infectivity (the ability of a pathogen to establish an infection), severity of disease, transmissibility, and the nature of the work conducted.
- **The Nuclear Regulatory Commission (NRC)** was created in 1975 to promulgate regulations for the use of radioactive materials in industry, academia, and medicine and to regulate and inspect the nuclear power industry.

## State Regulation of Hazardous Materials

NYSDEC was created in 1970 to regulate and enforce the state environmental conservation laws and to coordinate many state programs to protect communities and resources from hazardous materials releases:

- **Toxic Release Inventory:** NYS DEC collects the data that federal law requires facilities to publically report. NYS DEC requires that environmentally protective design and operational standards are maintained at storage and disposal facilities.
- **State Pollutant Discharge Elimination System (SPDES):** Designed to eliminate the New York water pollution by point sources (points of pollution discharge) and by implementing the NPDES provisions of the federal Clean Water Act to maintain the highest possible quality of water.
- **Petroleum Bulk Storage (PBS) Program:** Applies to any facility that has a combined petroleum storage capacity in excess of 1,100 gallons, for both above and below ground tanks. NYSDEC also regulates motor fuel and waste oil in underground tanks that are 100 gallons or larger. Facilities must be registered with the state and comply with petroleum handling and storage regulation.
- **Chemical Bulk Storage (CBS) Program:** Applies to any facility storing a hazardous substance (listed in 6 NYCRR Part 597) in an above-ground storage tank larger than 185 gallons, in an underground storage tank of any size, or in a non-stationary tank used to store 1,000 kg or more of a regulated substance for a period of 90 or more consecutive days. All facilities must be registered to store and handle hazardous substances.
- **Standards for Management of Used Oil:** Management and marketing standards and permit requirements for used oil generators, transporters, transfer facilities, processors and re-refiners, and facilities that burn used oil for energy recovery.
- **Major Oil Storage Facility (MOSF):** Program that licenses facilities storing 400,000 gallons of petroleum products, including (but not limited to) waste oil. Waste oil requirements apply to every size of waste-oil bulk storage on commercial premises.
- **State Superfund:** Inactive Hazardous Waste Disposal Site (IHWDS) Program identifies, investigates, categorizes, and cleans up sites having consequential amounts of hazardous waste. NYSDEC maintains the IHWDS registry. Site clean-ups are prioritized according to the threat that a site poses to human health and the environment.

## Local Laws and Hazard Materials Regulations

New York City manages hazardous material storage through a series of laws, policies, and programs:

- **Local Law 26 of 1988:** The Local Emergency Planning Committee (LEPC) and Community Right-to-Know (RTK) Law gave DEP the authority to regulate the storage, use, and handling of hazardous materials above specified thresholds. Facilities must submit a risk management plan to DEP when Extremely Hazardous Substances (EHS) or regulated toxic substances are present at or above federally determined levels.
- **Inspections:** DEP inspects facilities to determine if they comply with requirements for chemical inventory reporting, storage, and labeling. Facilities that are not in compliance receive notices of violation and are required to take corrective action. In 2018, DEP conducted 10,126 facility inspections and issued 861 Notices of Violation to facilities for non-compliance with reporting requirements.
- **Local Law 143:** DEP requires businesses to comply with spillage prevention requirements for facilities located in the Special Flood Hazard Area (SFHA). The law permits DEP to inspect facilities and issue violations for any that are not in compliance. When extreme weather threatens, DEP will notify RTK businesses in the SFHA either to secure or remove hazardous materials in advance.
- **Hazardous Substances Emergency Response Law:** The “Spill Bill” directs DEP to respond to hazardous materials releases and potential release. The City can order responsible parties to remediate hazardous conditions, issue fines, and/or hold them financially responsible for response and remediation costs.





- **FDNY Fire Code:** Updated in 2014, this stipulates the fire safety requirements for New York City buildings and businesses, and regulates the manufacture, storage, handling, use, and transportation of hazardous and combustible materials.
- **Solid Waste Transfer Station Oversight:** The New York City Department of Sanitation (DSNY) manages a program that includes specialized permitting, site plan reviews, and inspections for solid waste transfer stations within the city.

## State and Local Regulation of Radiological Materials

Several government agencies protect New York City by regulating the use of radiological materials:

- **New York State Department of Health (DOH) and Department of Environmental Conservation (DEC):** The DOH regulates the use of radioactive material in New York State through a licensing and inspection program. Licensees are required to abide by specifications that restrict the purchase of radioactive material to stipulated isotopes and total inventory amounts. Use of radioactive materials is restricted to prevent accidental releases to the occupational or public environment. The DEC has a permitting, reporting, and inspection system that restricts the release of radioactive materials into the water and atmosphere.
- **NYC Department of Health & Mental Hygiene (DOHMH):** DOHMH regulates radioactive material for medical, research and academic purposes within the five boroughs of New York City. Other licensees fall under NYS DOH jurisdiction and oversight. New York City has about 375 licensed sites that possess radioactive material for medical, academic and research purposes, which are inspected on either a one-, two-, or three-year schedule according to the type of radioactive material and/or radiation-generating machine used.

# PUBLIC AWARENESS

New York City is engaged in ongoing training and long-term projects to assist City employees, local businesses, and the public to prepare for hazardous releases. Examples include:

- **Annual Right To Know (RTK) Training:** City agency employees are required to complete annual RTK training, which explains the types of hazardous substances to which employees could be exposed and their legal rights if a CBRN release occurs.
- **NYSDEC Drum Recovery Program:** The NYSDEC Drum Recovery program focuses on the recovery of abandoned drums that contain waste oil, heating oil, diesel and other non-flammable petroleum products. The NYSDEC Spills Hotline receives reports on locations of these drums. “Drum runs” are scheduled with a NYSDEC contractor, who removes and disposes of them properly.
- **Waterfront Justice Project:** At the community level, this New York City Environmental Justice Alliance (NYC-EJA) project advocates for technical and financial resources to help waterfront businesses comply with environmental regulations, respond to the risks associated with climate change, and build more resilient working waterfronts.
- **South Bronx Community Resiliency Agenda:** Organized by NYC-EJA with THE POINT Community Development Corporation, this project engages local communities to create a comprehensive climate resiliency agenda that strengthens the physical and social resiliency of the South Bronx.

## CASE STUDY: CESIUM IRRADIATOR REMOVAL PROJECT (CIRP)

The Department of Energy's Cesium Irradiator Removal Project (CIRP) is a cost-sharing incentive program to support hospital and research facilities financially with the removal and disposal of cesium-137-based technologies and their replacement with alternative X-ray technologies. For years, cesium-137 has been the key component of self-contained irradiators for blood irradiation and research, but its widespread use is today considered a serious security risk. As a highly dispersible powder, it is considered a suitable component for dirty bombs. If deployed in a bomb, lives could be lost and billions spent on evacuation and clean-up.

Alternative X-ray technologies would significantly reduce the risks associated with the potential malevolent use of cesium sources and require far less security and shielding, eliminate liability, and eliminate expensive disposal.

When CIRP was initiated, New York City had 30 licensed blood and research irradiators. Today, 12 irradiators have been removed and replaced, and plans are underway to remove an additional 8 irradiators through collaboration between the federal government, the New York City Department of Health and Mental Hygiene (DOHMH), and law enforcement.

In 2017, the DOHMH's Office of Radiological Health convened scientists, regulators, and institutions to strategize on eliminating radiological risks by adopting alternative technologies. In December 2018, DOHMH was honored by the International Atomic Energy Agency's Nuclear Threat Initiative for keeping CIRP at the forefront of national efforts to enhance radiological security and for serving as a model for other major cities.

**TOP:**

**CESIUM IRRADIATOR REMOVAL**
SOURCE: NYC DOHMH — SETH GUTHARTZ





New York City has many communications initiatives that inform the general public about health and occupational hazards associated with hazardous materials and other CBRN risks. Examples include:

- **Plan Now NYC:** NYCEM created this website to provide New Yorkers with strategies and tactics to plan for and survive a terrorist-related event. The website includes hazard information for biological, chemical, and radiological attacks and what to do following these types of events.
- **Best Practices Guide for Storing Hazardous Materials:** After Hurricane Sandy, DEP created a brochure targeted to industrial properties in the floodplain, which recommends the best ways to store hazardous materials and to prevent spills during floods. As part of its on-site facilities inspections, DEP recommends best practices to reduce the risk of chemical spills, such as elevating chemicals off the ground, storing them in areas less likely to flood, and securing storage cabinets.
- **Environmental Best Management Practices for Auto Repair, Auto Body, and Auto Salvage Industries:** As part of the Waterfront Justice Project, NYC-EJA and NYSDEC released this publication, which provides strategies to prevent HAZMAT spills, avoid pollution, and safely manage hazardous waste.

## RESEARCH AND STUDIES

City and state agencies are working with community organizations and small businesses to carry out planning studies and implement programs to protect industrial areas and surrounding residential areas from chemical releases and to make them more resilient if one occurs. Several are profiled here.

- **Resilient Industry Initiative:** NYC DCP launched this planning initiative to assess the degree to which New York City's industrial areas were vulnerable to flooding and to propose strategies to increase the resiliency of these commercial areas and the surrounding communities.
- **NYC Industrial Waterfront Project:** This collaboration among NYSDEC, the New York State Pollution Prevention Institute, and NYC-EJA assessed the vulnerabilities, needs, and capacities of local industrial businesses in the South Bronx Significant Maritime Industrial Area. The goal is to identify technical and financial resources to help local businesses adapt to climate change and prevent environmental pollution.
- **Grassroots Research to Action in Sunset Park (GRASP):** This is a community-research partnership comprised of NYC-EJA, UPROSE, The LifeLine Group, and the RAND Corporation, the purpose of which is to develop and support community-based actions to address environmental health risks in Sunset Park. GRASP's current focus is on helping auto shops to implement chemical security practices to reduce the risk of chemical releases.

**NYC WATERFRONT**
SOURCE: TBD

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NYC Cyber 3

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Staten Island COAD

The Point

University at Buffalo

United States Army Corps of Engineers

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# NYC'S RISK LANDSCAPE: A GUIDE TO HAZARD MITIGATION WAS DEVELOPED BY NYC EMERGENCY MANAGEMENT.

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