NYC'S RISK LANDSCAPE:
A GUIDE TO HAZARD MITIGATION

NYC'S RISK LANDSCAPE: A GUIDE TO HAZARD MITIGATION was developed by NYC Emergency Management in partnership with the NYC Department of City Planning and close collaboration with the NYC Mayor's Office of Recovery and Resiliency.

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NYC'S RISK LANDSCAPE:

A GUIDE TO HAZARD MITIGATION

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NOVEMBER 2014

FOREWORD

Throughout its history, New York City has faced many hazards. From the fire of 1835, to the severe heat waves of 2006, to the devastation of Hurricane Sandy in 2012, our city has endured and recovered from a breadth of hazards - each time stronger, more informed about the risks it faces, and better able to prepare and protect for the future its many residents, buildings, infrastructure networks, and natural resources.

New York City's Risk Landscape: A Guide to Hazard Mitigation builds on that tradition to rebound, and opens a new chapter in the City's efforts to increase public awareness about the risks from a range of hazards that the City faces today and in the future.

Prepared by the New York City Emergency Management Department*, in partnership with Department of City Planning, and in close coordination with the Mayor's Office of Recovery and Resiliency, this Guide serves as a hazards risk reduction resource that:

- Outlines key features of the city's vulnerability to risk
- Assesses a wide-range of hazards, including: flooding, earthquakes, water shortages, strong windstorms, and pandemic flu
- Presents strategies for managing risks from those hazards

The *2014 Hazard Mitigation Plan*, developed in collaboration with multiple government agencies, organizations, and subject matter experts, serves as the foundation for this Guide. However, this Guide updates that information by providing the best available data on hazards in a user-friendly format to enhance public awareness about the risks that the city faces.

This Guide complements other critical efforts by the City to manage its risks, most prominently: *A Stronger, More Resilient New York*, a detailed climate resiliency action plan, and several of its recommended actions, including *Retrofitting for Flood Risk*, a comprehensive guide to retrofitting the city's most vulnerable existing buildings, and the *Resilient Neighborhoods* initiative that supports locally specific strategies, such as land use changes and infrastructure investments, for long-term community resiliency.

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.

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NYC Emergency Management Department*

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CONTENTS


Our duty is to to share with citizens knowledge that can help them better understand, prepare for, and avoid or withstand the risks that confront us.

CHAPTER 1

WHY WE WROTE THIS GUIDE AND WHAT IT OFFERS YOU

THE REASON FOR THIS GUIDE

It is our City government's priority to keep our 8.4 million residents safe, as well as our many commuters, tourists, and other daily visitors. This duty is both immediate and long term: we must be prepared to respond to emergencies today while also planning and preparing for future risks.

The City is also responsible for informing its citizens about the work we are doing on their behalf. This means notifying the public about the risks New Yorkers face, and helping residents gain insight into how our global City manages risks and continuously adapts to 21st century changes. This Guide is inspired by those commitments, and by the availability of newly updated and expanded information.

THE SOURCES OF THIS GUIDE

Our primary source is the City's *2014 Hazard Mitigation Plan*, a 551-page Federal Emergency Management Agency (FEMA) compliance document required for access to federal funding for hazard mitigation projects. The Plan, approved by FEMA and adopted by the City, must be updated every 5 years.

The 2014 Plan reflects the lessons learned from Hurricane Sandy, and it expands the scope of the preceding 2009 Plan. But because of its length and the sheer density, it is of limited practical use to busy New Yorkers who want to better understand the risks our city faces and how their government is addressing them. This Guide draws heavily from the 2014 Plan but for the sake of brevity, profiles a shorter set of hazards. It updates information. It adds information. And it is more reader friendly.

It also draws from and points to related sources produced by the City, the State, the federal government, and nongovernmental organizations, some of which are listed in "Resources" at the end of this Guide. These resources hold a tremendous store of information, analysis, and graphics. We hope you will examine them.

WHAT YOU CAN GAIN FROM THIS GUIDE

This Guide is designed to deliver the following:

- Insight into the way risk managers think about risk.
- A sense of the physical realities of the dynamic risk environment we inhabit
- A deeper understanding of specific hazards, some of which are expected to worsen with climate change
- Familiarity with a sampling of the strategies employed to manage our risks

Like the 2014 Plan, the Guide focuses on long-term hazard mitigation and not on short-term emergency response, although that subject informs it.

Hazards addressed in detail in this Guide are:

Coastal Storms
Coastal Erosion
Flooding
Strong Windstorms
Extreme Heat
Winter Weather
Water Shortage
Earthquakes
Pandemic Influenza

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 of other cities who are interested in risk reduction best practices.

While the work of updating the Hazard Mitigation Plan and producing this Guide ended in 2014, the work of managing risk is ongoing, as we continue to implement strategies, assess them, learn, confer, and then adapt and strengthen strategies as need be. The 2014 Plan will be formally updated in 2019.

We welcome your suggestions for how we can make this Guide more useful to you. Please send them to:

Hazard Mitigation Unit
NYC Emergency Management Department
mitigation@oem.nyc.gov

NEW YORK CITY'S RISK LANDSCAPE

COASTAL STORMS

COASTAL EROSION

FLOODING

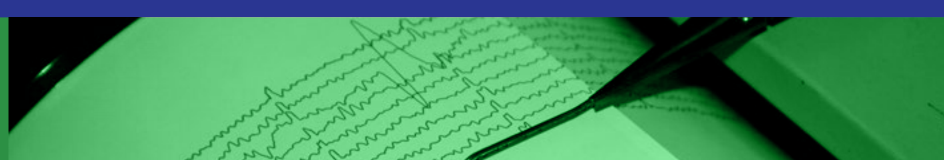
STRONG WINDSTORMS

EXTREME HEAT

WINTER WEATHER

WATER SHORTAGE

EARTHQUAKES



PANDEMIC INFLUENZA

CHAPTER 2
OVERVIEW

RISK AND RESILIENCY

Risk and uncertainty are constants in human life, and New York City has been practicing risk management for centuries. New Yorkers have been identifying, assessing, and prioritizing risks and devising measures to avoid or minimize them. For example:

- In 1657 the Dutch banned thatched roofs in what was then New Amsterdam. This effort to reduce the risk of fire was a precursor of our modern building code.

- Seawalls built to protect the shoreline were originally simple protective structures. They have benefited from the development of coastal engineering insights.

- The 1867 Tenement House Act was the country's first comprehensive housing reform law. The Act's public safety and health measures included an important requirement for fire escapes and 1 outhouse for every 20 occupants.

- In 1899, New York City enacted the first citywide building code. Previous building laws had been enacted by the State.

- The Triangle Shirtwaist Factory fire in 1911 spurred adoption of strict fire safety and labor laws for factories in New York.

- In 1954 the City committed to building a third water tunnel, to permit inspection and repair of the two existing tunnels and to add redundancy. Construction began in 1970 and should end by 2018. The $5 billion project is the largest in city history.

- In 1983, revisions to the NYC Building Code incorporated the FEMA floodplain maps and mandated flood-resistant construction standards for new or substantially improved buildings in order to qualify them for the National Flood Insurance Program.

- In 1995 our first seismic Building Code provisions were adopted.

In present times, our nation's trillion-dollar insurance industry is an immense risk management enterprise. For the insurance industry, the financial sector, engineering, and many other fields, managing risk has always been prevalent, and in the 20th century the practice of risk management has expanded to include sustainability.

In the early 21st century, the goal of resiliency – the capacity to prepare for, respond to, and recover from difficult conditions – converged with the goal of sustainability. The two are inextricably intertwined: an unsustainable way of life makes hazards more severe.

KEY CONCEPTS AND TERMS

The concepts and terms employed in risk management can vary with context. Here are key concepts and terms as used in this Guide:

- **Hazard**: A source of potential danger or an adverse condition that could harm people, our socioeconomic systems, or our built and natural environments.
    - Natural hazard: A hazard that results from conditions in the natural environment, such as flooding. Humans may contribute to or exacerbate the hazard but cannot directly cause it.
    - Non-natural hazard: A hazard directly caused by human activity, such as an intentional or accidental release of hazardous materials.
- **Risk**: The chance that a given hazard could impact people, our socioeconomic systems, or the natural and built environments.
- **Vulnerability**: The extent to which people, our socioeconomic systems, and our built and natural environments are exposed to the impacts of a hazard and are unable to quickly and easily recover.
    - That is, we are vulnerable to flooding, including aging populations that are less able to quickly and easily recovery from a disaster. The risks it carries can extend from damage to beachfront property to disruption of our transit system when subway stations flood.
- **Risk assessment**: The methodical process of (1) identifying hazards, (2) estimating how frequently hazard events could occur (3) identifying who and what is vulnerable to them, and (4) estimating how severe impacts could be.
- **Probability and consequences**: Classically, risk is calculated as the probability of an event (that is, its likelihood, or odds) times its consequences. The odds of a major earthquake in New York City are fairly low; the consequences could be devastating.
- **Uncertainties**: What cannot be understood or foreseen because the complexity of phenomena outstrips our knowledge.
- **Adaptation**: Measures taken to adapt to change; for example, moving beachfront property to higher ground in the face of rising sea level.
- **Mitigation**: Measures that avoid or reduce hazard impacts on people, our socioeconomic systems, and the built and natural environments over the long term. In this Guide, we often refer to them as "risk management strategies"; it is also similar to adaptation.
- **Risk management strategies**: Regulatory controls, plans, policies, programs, projects, initiatives, and anything else that could cost-effectively eliminate, avoid, minimize, or otherwise manage risks. In some contexts, this Guide uses the terms strategies and measures interchangeably.
- **Preparedness**: Actions that strengthen the city's capability to respond to disasters.
- **Resiliency**: The capability of preparing for, responding to, and recovering from difficult conditions; ability to bounce back after change or adversity.

INSIGHT INTO COMPLEX SYSTEMS

New York City is acutely vulnerable to compounded impacts. Embedded in a densely populated, sprawling region, we are dependent on vital energy, telecommunications, transportation, and water and wastewater systems, some of them dependent on each other and all of them aging. Our infrastructure is interconnected. Therefore damage to one system can affect other systems, in turn amplifying the impacts. For example, flooding could shut down a power substation that in turn can cripple communication and transportation systems, disrupting normal life, compromising public safety, and slowing emergency response.

A FUNDAMENTAL SHIFT IN APPROACH

As awareness of the principles of sustainability and resiliency grew, and insight into the interdependencies of complex infrastructure systems deepened, a fundamental shift occurred in the way New York City assesses and manages risk. The piecemeal, response-recovery hazard cycles that had largely prevailed in the past have evolved into a deeply informed, long-term, strategic approach.

Now we view risks as a set within an integrated, citywide risk management framework that has a long-term planning horizon. We draw expertise from a range of disciplines across the public and private sectors.

The result is a robust risk management process that directly serves sustainability and resiliency goals.

A VISION OF A RESILIENT CITY

What would a resilient, sustainable New York City look like? Measures that promote these qualities must be affordable and cost-effective. Here are just a few of a resilient city's features:

- Residents are well informed about potential risks and well prepared to deal with them.

Tightly coupled, complex systems can produce a "domino" effect.

- Resiliency goals are seamlessly integrated into City agencies' planning, budgets, and culture.
- City agencies have deep expertise, and closely coordinate with local, state, and federal stakeholders.
- All parties learn continuously, share what they learn, and modify their plans and practices accordingly.
- The built environment is designed, constructed, and retrofitted to withstand a variety of hazards and to advance sustainability goals.
- Redundancies are designed into complex systems and supply chains so that, if a critical component fails, another can function in its stead.
- The City collaborates closely with external stakeholders to promote sound risk management practices, and to coordinate recovery from emergencies.

While even this brief list is ambitious, New York City is making steady progress.

THINKING HARD ABOUT THE SUBJECT

Risk management is rooted in a cyclical process: identify hazards, assess the risks they pose, devise strategies to manage them, implement the strategies, respond if a hazard event occurs, recover as fully as possible, assess how effective strategies were, and strengthen them to the extent possible. However, real-world events are often more complex than this model suggests.

A series of questions helps illustrate how complex the subject of risk can quickly become. Because some hazards this Guide addresses are quite different from

Risk = Probability × Consequence

each other, certain questions are more applicable to some than to others, and questions may apply in different ways to different hazards. But the questions can provide useful context for the chapters ahead.

"How big is the risk?"

The common definition of risk is the probability of an event times its consequences.

An event that would be catastrophic – a 7.0 magnitude earthquake that causes destruction throughout the city – could be considered a low risk because it is so rare. On the other hand, common events such as extreme heat or snowstorms may not cause significant impacts individually, but when considered cumulatively, they constitute a high risk because they occur so often (at least once during most years). These examples reveal that categorizing the severity of a risk can be somewhat subjective.

How likely is the hazard to occur and how often?

Except for erosion, which is usually a gradual process, the hazards profiled in this Guide occur as discrete events, which makes predictions of their probability crucial. When a hazard event occurs, it is usually measured by its probability or likelihood of occurrence. For example, we can say there is a 1 percent chance that a 100-year flood event will occur in any given year.

Where is the hazard likely to occur? How large an area will be affected?

Whether at night a tornado strikes a deserted City park or a dense residential neighborhood can make a big difference to impacts. The compounding impacts of some hazard events can extend far from the place they occur – for example, power outages. Proximity to the ocean, or low elevation, or soil type, or density of infrastructure are among many factors that affect exposure to risk.

What are the hazard's potential consequences? Who and what are most vulnerable?

Consequences are a function of (1) who and what are impacted, (2) their vulnerabilities. A storm surge can destroy a beachfront bungalow that rests on sand and spare the house next door that sits on concrete pillars. An elderly person is at greater risk of heat stroke than a healthy teenager.

For certain hazards, how much warning time people have affects vulnerability. This is a function of forecasting, City agencies' communication capabilities, and individuals' abilities to receive timely information, and understand it.

Impacts can take these forms:

- Impacts on people: the potential for injury and loss of life, displacement from home, disruption of health and social services, and loss of income – with special consideration of vulnerable populations

- Economic impacts: damage to buildings and infrastructure, disruption of business, loss of revenue, recovery costs

- Disruption of critical systems – energy, telecom, transportation, water, and wastewater – and compounding impacts

- Environmental impacts on air quality, water quality, and ecosystems

How long could impacts last? How long could recovery take?

This is partly a function of the nature of the hazard. For instance, while the effects of the 2014 Polar Vortex can no longer be felt, the city is still recovering from 2012's Hurricane Sandy.

Recovery is also a function of vulnerabilities. People with scant resources whose income is disrupted by a hazard event may not recover quickly.

When thinking about risk, it is helpful to bear in mind these considerations:

- In general, the higher the consequences of an event, the lower the probability, and the higher the probability of an event, the lower the consequences.

- For a given hazard, every single event is unique, often making probability and consequences difficult to predict.

- For any one event, impacts can vary greatly across population groups and geographic areas.

- Cascading effects can vary greatly by hazard, and from event to event for any given hazard.

- The number of variables involved in risk assessments can be huge.

- Risks are dynamic – changing as the environment changes, the world around us changes, and our city continues to evolve.

- The knowledge base that informs risk assessment and risk management continues to grow; the science is still evolving.

- Experts can differ in their assessments.

OUR RISK MANAGEMENT CAPABILITIES

New York City's risk landscape, as sketched in Chapter 3 and explored in Chapter 4, can seem quite perilous. However, our City manages risk on many fronts, every day, in many ways. And Hurricane Sandy mobilized citywide risk management efforts on a scale not seen since the 9/11 attacks. Those efforts informed much of our 2014 hazard mitigation planning.

The yearlong project that produced our 2014 Plan – described in Chapter 5 – was characterized by broad representation from City, State, and federal agencies, regional organizations, the private and nonprofit sectors, academic institutions, community organizations, and citizens. The planning effort was led by New York City Emergency Management and the Department of City Planning in close collaboration with the Mayor's Office of Recovery and Resiliency. What resulted was a comprehensive approach to risk reduction. To assess risk and identify appropriate risk management strategies, the planners pursued a rigorous process of analysis and research, drawing from the historical record, the latest scientific and technical information, various City plans and reports, and consultation with many parties.

MITIGATION PLANNING TEAM

New York City Emergency Management plans and prepares for a broad range of hazards, coordinates emergency response and recovery efforts, educates the public about preparedness, and collects and disseminates critical information. To accomplish this mission, New York City Emergency Management incorporates a broad mix of disciplines, experience, and perspectives, including planning, emergency response, public health, communications, public policy, geography, and others.

The Department of City Planning is responsible for the City's long-term planning, including land-use and environmental review; preparation of plans and policies; and providing technical assistance and information to government agencies, public officials, and community boards. The Department's expertise on New York City's built, social, and natural environment contributed greatly to development of the *2014 Hazard Mitigation Plan*.

The Office of Recovery and Resiliency developed and implements *A Stronger, More Resilient New York*, a plan to advance Sandy recovery efforts and strengthen resiliency to extreme weather events and climate change. The Office – which reports directly to the Mayor – works closely with NYC Emergency Management, the Department of City Planning, and many other City agencies. Their long list of Partners indicates how comprehensive their approach is. Their teams include architects, economists, engineers, lawyers, marketing and communications experts, planners, policy analysts, and expert advisors. Climate change and adaptation, energy supply, building efficiency and resiliency, carbon emission reductions, transportation, and waste management are among their subjects.

CLEAR ACCOUNTABILITY, CONTINUOUS LEARNING, CLOSE COORDINATION

The *2014 Hazard Mitigation Plan* identifies hundreds of risk management strategies. Because risks range so broadly in nature, responsibility for managing them, responding to hazard events, and promoting resiliency is distributed across – and embedded in – over 40 agencies: it is integral to their missions and integrated into their daily work. They design and implement strategies, evaluate their effectiveness, modify them as appropriate, and investigate best practices applied by other cities, in turn sharing ours with them. This makes for a process of continuous learning, as does the fact that our city is dynamic, and risks and strategies for managing them continue to evolve.

With distribution of responsibility comes the need for close coordination. Our City government is well networked, thanks in part to our aggressive use of digital technologies. We also work closely with New York State and federal agencies, and a host of local, state, and regional stakeholders. In developing the *2014 Hazard Mitigation Plan*, our team met one-on-one with numerous agency representatives to discuss risk management strategies. Significantly, one benefit of this planning process is that it strengthened coordination among the planners.

ANALYTIC AND DECISION-SUPPORT TOOLS

As 21st century risks have become more complex, the tools we apply to assess and manage risks have become more sophisticated.

A prime example is Geographic Information System (GIS) software, an increasingly powerful way to display and explore place-based data. By linking mapping to databases and combining many layers of different kinds of data, GIS enables users to visualize, manipulate, and analyze spatial data. The results can directly inform decision making. Many of the maps in the *2014 Hazard Mitigation Plan* were created with GIS, and some of them appear in this Guide.

Computer modeling is a powerful tool that serves many functions, including weather forecasting and simulating the potential impacts of various hazard events. Loss estimate models are used widely by risk managers for catastrophic modeling to inform decision making and set insurance premiums. NYC Emergency Management ran loss-estimate models developed by FEMA to better understand the economic impacts of hurricanes winds, floods, and earthquakes.

COMMUNICATION TOOLS

Communication is crucial during an emergency in order to promote preparedness and recovery. New York City has a suite of communication tools, products, and practices. They begin with close interagency communication and range from urgent public alerts to long-term public education, outreach, and awareness campaigns. For example, NYC Emergency Management offers these services:

- Notify NYC alerts subscribers to emergency activity in all five boroughs. Subscribers can receive messages by email, text message, phone, or Twitter. The service, now reaching over a quarter-million subscribers and counting, proves its value every day.
- NYC Emergency Management's Advanced Warning System is designed to alert individuals with special needs to hazardous weather, utility or transportation disruptions, public health emergencies, and incidents requiring evacuation.
- Wireless Emergency Alerts is an emergency notification service that allows authorized government officials to send geographically targeted emergency alerts to enabled mobile devices on the AT&T, Sprint, T-Mobile, and Verizon wireless networks.
- Ready New York is a continuing campaign to encourage New Yorkers to prepare for a variety of emergencies. Its guides are available in print and online in multiple languages and formats. In 2013, NYC Emergency Management presented this program at over 1,000 events across the city.

Social media has become a primary communication tool, and on subjects related to public safety, New York City now has a presence on many social media channels. It facilitates real-time, two-way communication between the City and the public. The City's expansion of Wi-Fi hotspots further strengthens this tool.

COLLABORATION WITH THE PRIVATE SECTOR AND OTHER PARTIES

This Guide necessarily focuses on the role of government. But in hazard events, the roles of community and nongovernmental organizations, the private sector, and citizens become tremendously important as well.

We are all truly partners on the risk and resiliency frontier.

This was displayed in the wake of Sandy in the sustained outpouring of volunteerism (partially facilitated by social media) – New Yorkers at their very finest. The chapter "Sandy and Its Impacts" in ***A Stronger, More Resilient New York*** offers a vivid account of the response to one of the most severe natural disaster ever to hit New York.

The close relationships that City agencies cultivate with external parties not only strengthen our ability to respond to hazard events; they inform our planning and strengthen our preparedness. Many parties contributed to our *2014 Hazard Mitigation Plan*. Along with outreach to households, NYC Emergency Management helps the business community prepare for and recover from hazard events through programs like Partners in Preparedness, CorpNet, and Private Asset and Logistics Management Systems

THIS GUIDE'S FOCUS AND ITS SCOPE

The subject of New York City's management of risks is a large one. How can it be made manageable for readers? For reasons of brevity, we limited Chapter 4 to a subset of all hazards addressed in the *2014 Hazard Mitigation Plan* and we updated and expanded some information.

The fact that some hazards are not formally addressed in this Guide does not mean they are not considered to be serious. We urge readers to consult our 2014 Plan for information on hazards not profiled here.

For every $1 invested in hazard mitigation, an average of $4 dollars is saved

Terrorism is not formally treated in this Guide or in the 2014 Plan, because it is beyond their scope: terrorism is an intentional act and managed as a Homeland Security threat, at all levels of government. The consequences of terrorism come in many forms, some of which are not dissimilar to the impacts from the hazards profiled in this Guide. Because of this, some risk management strategies for hazards help protect us against terrorist acts. For example, redundant components of critical systems could help us withstand both a natural disaster and a terrorist attack.

FISCAL CONSTRAINTS AS A RISK FACTOR

The potential for investments in risk management and resiliency is immense, and the nature of risk and our city are continually evolving. The *2014 Hazard Mitigation Plan* devotes a page (page 284) to a list of funding sources that can be tapped for mitigation measures. It is a long list, but that funding is finite.

Moreover, for State and federal funding, every jurisdiction is in a sense in competition with every other. New York City's roster of potential hazards is paralleled by, for example, California's roster, which includes earthquakes, mudslides, flash floods, wildfires, and drought.

The devastation caused by natural disasters over the past several years – Sandy alone is estimated to have caused $19 billion in damages – raises the possibility of future recovery costs breaking the bank.

Thus, a driving principle in devising risk management strategies is cost-effectiveness: How can we get the most from the resources available to us?

Another principle: By reducing risk, investments in risk management measures can reduce the costs of disaster recovery. It is estimated that for every dollar invested in hazard mitigation, an average of four dollars is saved. A July 2014 report by the President's Council of Economic Advisors estimates that delaying climate policy actions by a decade could increase total climate change mitigation costs by about 40 percent. Taking no action would risk substantial economic damage.

Another principle: Every dollar not spent on recovery is a dollar available for something else – another expenditure or a tax reduction. The opportunity costs of disaster recovery expenditures have been substantial.

New York City's ability to manage and adapt to future risks will be significantly shaped by the availability of funding. Protecting our city requires investment in risk management measures, and by reducing risk, that investment protects our budget from recovery costs.

Thus, lack of investment and budget shortfalls become themselves risk factors.

We hope readers will carry these considerations into their appraisal of the following chapters.

CHAPTER 3
AN INTRODUCTION TO NEW YORK CITY'S RISK LANDSCAPE

New York City is a global coastal city. It is densely packed with diverse communities, complex infrastructure systems, and dynamic natural resources. The future our city will be shaped by our growing population, aging infrastructure, and changing climate. New York City's resiliency will require preparedness for hazard events and the capacity to rebound quickly from them.

This chapter sets the stage for the next chapter's discussion of specific hazards, risks, and risk management strategies.

The impact of hazard events on people is of paramount concern. In examining features of our built environment, we pay closest attention to critical infrastructure systems – energy, telecommunications, transportation, and water and wastewater – upon which so much of our city's functioning depends. We conclude with a look at what climate change portends.

Resiliency requires both preparedness for hazard events and the capacity to rebound quickly from them. Damage to and disruption of some vulnerable features of our city can be repaired in mere hours; in extreme cases, recovery can take years.

AT A GLANCE

Complex and dynamic, New York is the most populous city in the United States. It is a global, coastal city and the nation's largest metropolitan area. Here's a sampling of key features that put us at risk:

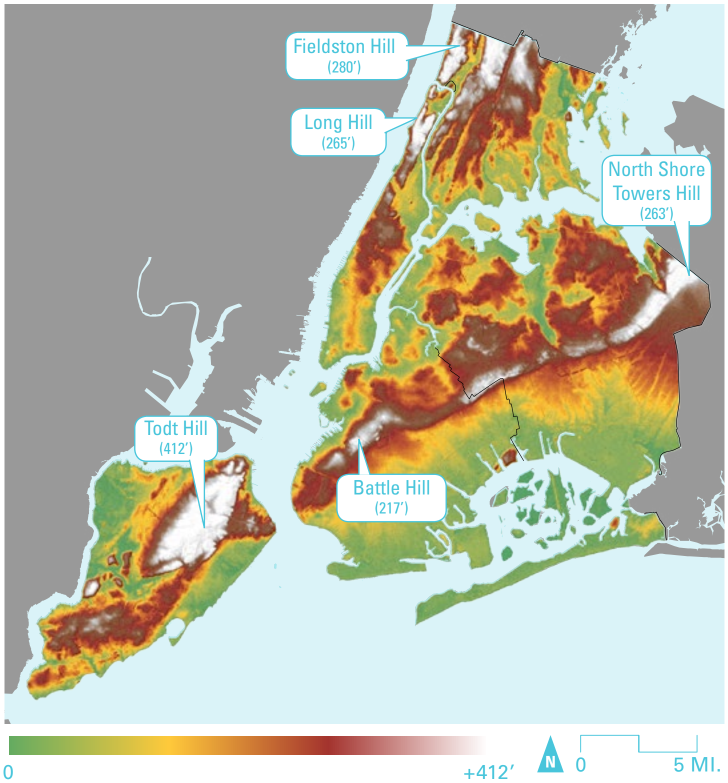
- We are located on a coastline that is 520 miles long – longer than those of Miami, Boston, Los Angeles, and San Francisco combined. Bordering an ocean, rivers, bays, tidal straits, inlets, and a harbor, parts of the coast is low-lying, making us vulnerable to coastal storms, erosion and different types of flooding.
- We have roughly 8.4 million residents. Commuters, tourists, and other visitors boost our numbers to approximately 9 million on an average day. Our population is projected to grow in the coming decades.
- We occupy only 305 square miles, with population density varying significantly across the city. Each neighborhood's characteristics create a unique set of risk and exposure factors.
- We are embedded in a metro region with a population of roughly 22 million people, and we are heavily dependent on complex, interdependent

MAP OF FIVE BOROUGHS

SOURCE: NYC DCP

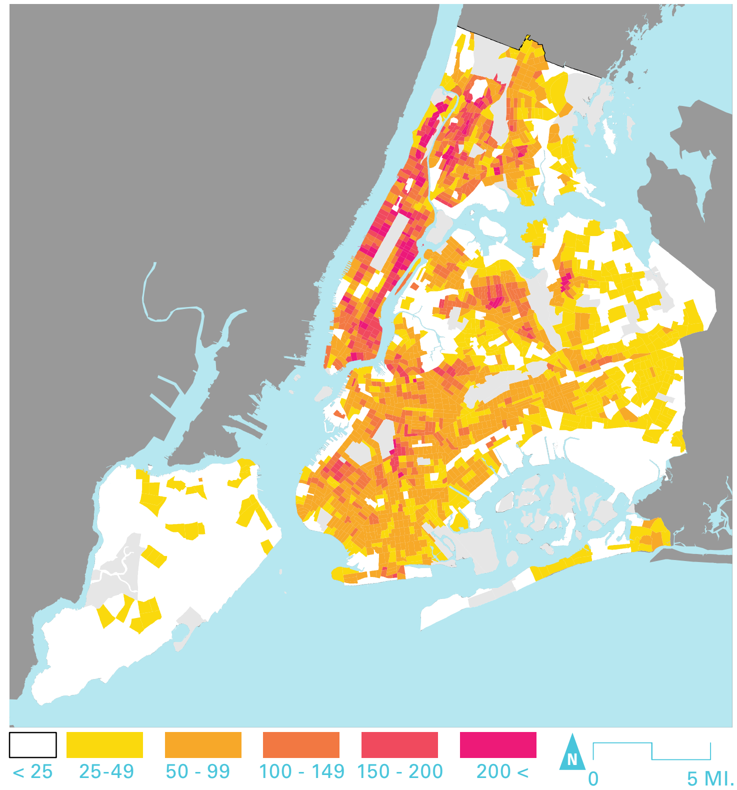
Borough	BRONX	BROOKLYN	MANHATTAN	QUEENS	STATEN ISLAND	TOTAL ALL 5 BOROUGHS
Population	1,419,000	2,592,000	1,626,000	2,296,000	473,000	8,400,000
person / acre	52	57	111	32	13	43

SOURCE: CENSUS BUREAU CURRENT ESTIMATES PROGRAM, 2013



TOPOGRAPHY

DATA SOURCE: NYC DOITT



POPULATION DENSITY PER CENSUS TRACT

SOURCE: US CENSUS BUREAU, 2008-2012 ACS 5-YEAR ESTIMATE, AND NYC DCP

critical systems – energy, telecommunications, transportation, and water and wastewater – some regional in scope. Much of this infrastructure is aging and requires continued and extensive maintenance, which can be a risk factor in itself.

- Our building stock is immense, totaling approximately 1 million buildings. They constitute an enormous financial asset. Many were built prior to newer, stricter Construction Code standards.

- For some New Yorkers, factors such as age, disability, chronic health conditions, poverty, and language barriers can increase vulnerability to certain hazards. With population growth, the number of vulnerable New Yorkers will also likely grow.

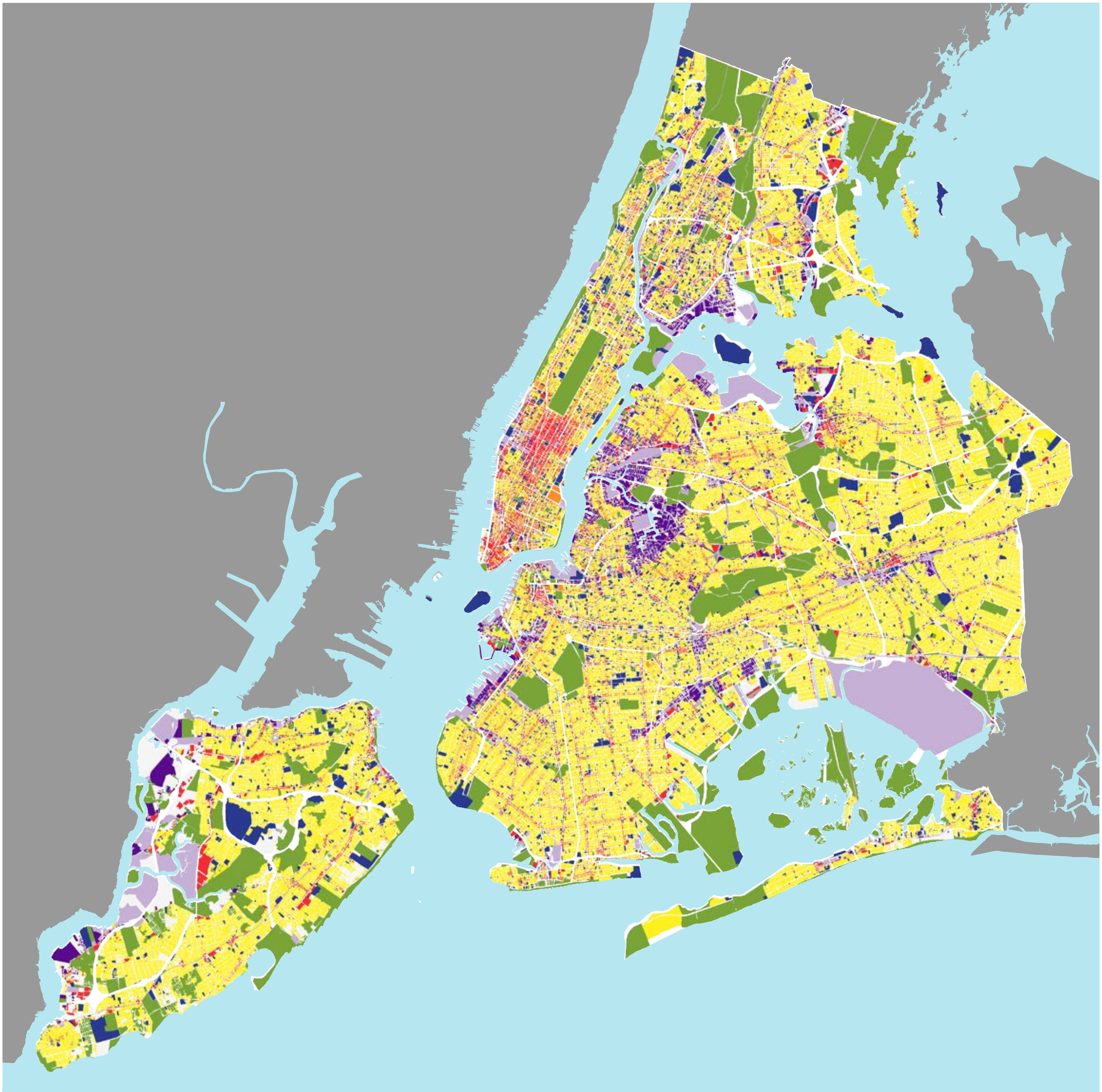
The demands of a growing population on aging infrastructure and critical systems – coupled with the effects of climate change – make our portfolio of hazards particularly serious. The size of New York City's financial assets and economy and our role in the regional, national, and global economies mean that damage to us can reverberate well beyond our borders.

GEOGRAPHY AND LAND USE

New York is a coastal city. Each borough has extensive stretches of shoreline, and all except the Bronx are islands unto themselves (Manhattan and Staten Island) or part of one (Brooklyn and Queens are part of Long Island). The water bodies we border and contain are as diverse as our urban landscape: canals, creeks, ponds, inlets, straits, rivers, estuaries, bays, a sound, and an ocean. Perhaps nothing has more powerfully shaped our city than the relationship between its land and water.

Over the centuries, the city's topography was altered as waterways were dredged for shipping, piers and bulkheads were constructed, and landfill extended the shoreline to create more usable land. These changes helped the city flourish. But some natural features that once protected landmasses were lost in the process, exposing people and assets to greater risk.

New York City's land area covers approximately 305 square miles. Historically, land-use patterns and development trends were driven by economic forces and population growth. As urban planning became a profession and a moderating force, City government

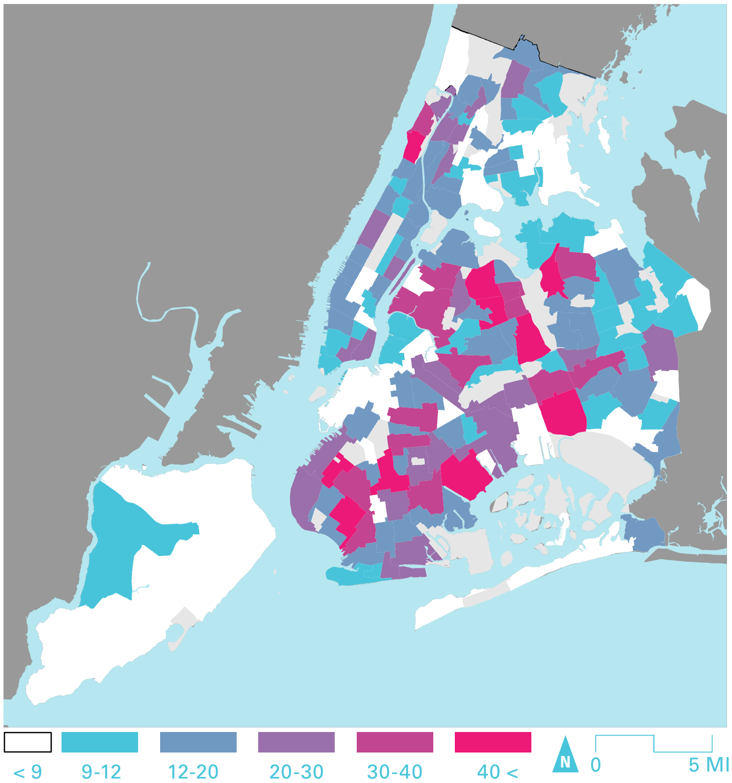


LAND USE

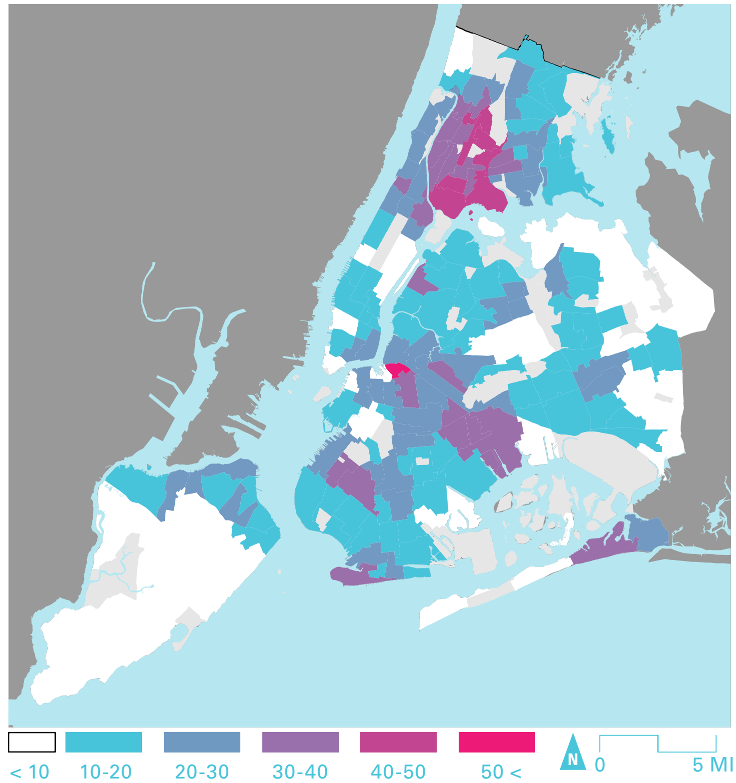
SOURCE: MAPPLUTO 14V1, NYC DCP, 2013

N 0 5 10 MILES

RESIDENTIAL
COMMERCIAL
INDUSTRIAL
PARKING FACILITIES
MIXED-USE RESIDENTIAL
INSTITUTIONAL
TRANSPORTATION AND UTILITIES
OPEN SPACE & OUTDOOR RECREATION



FOREIGN-BORN POPULATION BY NEIGHBORHOOD TABULATION AREA (IN THOUSANDS)
SOURCE: US CENSUS BUREAU, 2008-2012 ACS 5-YEAR ESTIMATES, AND NYC DCP



% PERSONS BELOW POVERTY LEVEL BY NEIGHBORHOOD TABULATION
SOURCE: US CENSUS BUREAU, 2008-2012 ACS 5-YEAR ESTIMATES, AND NYC DCP

developed tools to manage growth. Collectively New York City's zoning regulations, Construction Codes, and planning policies now shape development toward the long-term goals of sustainability and resiliency.

PEOPLE

More people are living in, working in, and visiting New York City than ever before. More than 8.4 million people live in New York City– an average of roughly 43 people per acre. This makes us by far the most populous and densest city in the country, with twice the population of the second-largest, Los Angeles.

Swelling our numbers are commuters, tourists, business travelers, and other visitors. On average, approximately 9 million people may be in the city at any one time. That number can spike on holidays and for special events such as New Year's Eve, the New York Marathon, and major parades.

While all New Yorkers are potentially at risk of hazards, groups that tend to be most vulnerable are young children, the elderly, people with disabilities and serious health conditions, people who are socially isolated, and households with limited English proficiency. Also, for many hazards, poverty amplifies risk.

CHILDREN AT RISK

Children are particularly vulnerable to natural disasters because they are dependent on parents or adult caretakers for food, shelter, transportation, and guidance. And the stress that follows a natural disaster may linger longer in children than in adults, according to the Federal Emergency Management Agency's mental health experts.

Our city's youth population is growing in number. The 2012 U.S. Census data show that about 21 percent of New Yorkers are under the age of 18, and 6.5 percent are under 5. Over 30 percent of all households have children under 18.

SPECIAL FOCUS: SOCIAL ISOLATION

Social isolation can be difficult to identify and hard to asses, making it a serious risk factor. It relates to the kinds of social safety nets that keep us connected and informed, ultimately making us safer.

Isolation can be a function of poverty that limits access to information technologies. It can be a function of limited literacy and/or linguistic isolation. It may be a function of disability, chronic or mental health conditions. Whatever the cause, when a hazard strikes, social isolation can increase vulnerability.

VULNERABLE POPULATIONS

- Children
- Seniors
- People with disabilities
- People with language constraints
- Socialy isolated people
- People with low income

Children are at even greater risk if they are poor or disabled. In New York City, approximately 31 percent of young people 18 years old and under live below the federal poverty level, and more than 100,000 of those children are under the age of 5. The 2012 American Community Survey found that roughly 4 percent of the city's children under age 18 have some form of disability.

SENIORS AT RISK

Older adults who have chronic health conditions or disabilities, live alone or otherwise experience isolation, or have limited access to emergency services face higher risks. Seniors generally depend more heavily on medical services at hospitals and nursing homes than other people do, and if their mobility is limited, they may depend on special needs transportation or other special assistance; for example, help in getting prescriptions refilled. For seniors who rely on medications that require refrigeration, on power-dependent medical equipment like oxygen tanks and motorized wheelchairs, and on elevators, power outages can be particularly dangerous.

Seniors with mental health conditions, such as disorientation, anxiety, or depression, are likely to be more at risk during and after a serious hazard event.

The last 30 years have seen the share of senior New Yorkers grow. According to the 2012 American Community Survey, more than 12 percent of New Yorkers — roughly 1 million residents — are over the age of 65. This group has been growing much more rapidly (12.4 percent since 2000) than the city's overall population (2.1 percent since 2000).

The 2012 American Community survey counted approximately 300,000 seniors—or roughly 10 percent of all New York City households—living alone, and it found that almost 50 percent of New York City's older residents are foreign-born. Isolation can be more acute among immigrant seniors: nearly two-thirds of them have limited English proficiency.

DISABILITIES AND CHRONIC HEALTH PROBLEMS AS RISK FACTORS

Some problems that seniors experience are not exclusive to them. The U.S. Census defines four major categories of disabilities:

- **Sensory disabilities** include blindness, deafness, or a severe vision or hearing impairment.
- **Physical disabilities** are 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** are conditions lasting six or more months that make dressing, bathing, or getting around inside the home challenging.
- **Go-outside-the-home disabilities** are conditions lasting 6 or more months that make it difficult to shop or visit a doctor's office on one's own.

According to American Community Survey, approximately 10 percent of New Yorkers are estimated to have a disability, as defined by the above categories. The rate increases with age. The ACS estimates that almost 38 percent of New Yorkers aged 65 and over have at least one type of disability. Approximately 45 percent of the city's seniors with disabilities live within the 1 percent annual chance floodplain in communities such as the Rockaways, Coney Island, and Brighton Beach. Some of the city's hospitals, senior centers, nursing homes, and assisted care facilities are located within the floodplain.

LANGUAGE CONSTRAINTS AS A RISK FACTOR

New York boasts one of the most diverse populations of any major U.S. city. Our 2012 foreign-born population of 3.14 million was the largest in the nation and a historical high for us, representing 38 percent of our population. Queens (with 1.09 million) and Brooklyn (nearly 1 million) together account for two-thirds of all foreign-born residents. Nearly half of Queens' residents were foreign-born in 2012.

Over 200 languages are spoken here. Nearly half of all New Yorkers speak a language other than English at home. As defined by the U.S. Census Bureau, in 2012 an estimated 23 percent of New Yorkers spoke English less than very well.

To reach such a diverse population, the City relies on many forms of communication including, social media, printed literature, web sites, radio, TV, and word-of-mouth outreach through community organizations. Municipal agencies such as the New York City Emergency Management Department provide hazard warning and evacuation notices in multiple languages and accessible formats.

LOW INCOME AS A RISK FACTOR

The U.S. government's official poverty measure is pre-tax cash income. In 2014, the poverty threshold was set at $11,670 for a one-person household and $23,859 for a four-person household. Because those levels are not regionally adjusted, U.S. Census numbers may not fully reflect the number of people living with economic hardships in New York City.

The 2012 American Community Survey found over 21 percent of the city's population, or approximately 1,750,000 people, living below the federal poverty line, including over 30 percent of all children under the age of 18. The greatest concentrations of low-income populations are in the South Bronx and Upper Manhattan, and scattered throughout Brooklyn.

Approximately 45 percent of the city's population is "rent-burdened," spending more than 35 percent, a standard established by the Federal government, of household income on rent. This leaves limited margin for unexpected expenses and even less for loss of income due to hazard events.

Most New Yorkers rent their housing. If it is damaged by a hazard event, finding affordable alternative housing to occupy while repairs are made – even temporarily – can be a serious challenge, given the city's limited supply of affordable housing. To avoid higher rent or homelessness, some low-income people may continue to occupy damaged homes.

The New York City Housing Authority, the largest landlord in the city and the largest public housing authority in the country, provides housing to over 400,000 low-income tenants. Public housing complexes were hard hit by Hurricane Sandy, which left approximately 80,000 NYCHA residents in over 400 buildings without power, heat, and/or hot water.

While the scope is large and budget limited, NYCHA is working aggressively to make its buildings more resilient to weather events.

WHO WILL BE THE NEW YORKERS OF THE FUTURE?

The 1990, 2000, and 2010 U.S. Census all reported net increases in our population. It is expected this pattern will continue into the future. By 2040, population is projected to increase by almost 10 percent and surpass 9 million for the first time in our history, with the Bronx, Brooklyn, Queens, and Staten Island home to more residents than ever before. About 62 percent of the total net population increase is expected to take place in Brooklyn and the Bronx.

For a low-income wage earner with little or no savings, a disaster that disrupts employment and therefore income can produce its own cascade of hardships.

By 2040, the age profile of New Yorkers will differ from todays. The most dramatic change is projected for people who will be 65 years or older: this group will grow by approximately 40 percent, varying by borough. This is mainly due to the aging of the large baby boomer cohort, who will all be at least 75 years old by that date, as well as an expected lower fertility rate and longer life expectancy. Currently, this age group makes up approximately 12 percent of our population. The portion of that group that is foreign-born is projected to grow, too.

Compared with growth in the total population, the share of school-age children (ages 5-17) is projected to decrease slightly by 2040. But the number is projected to increase by approximately 6 percent, varying by borough.

OUR ECONOMY

Our economy is large, interconnected and dependent on regional resources. It is no surprise than that it is also vulnerable to disruption by hazard events, and the costs of recovering from such events can constitute a secondary hazard impact of its own.

ECONOMIC SECTORS AND OUR WORKFORCE

New York City is a global economic capital and the center of a regional economy that generates upwards of $1.5 trillion in goods and services annually. Home to Wall Street and two of the world's largest stock exchanges, it is also headquarters to more Fortune 500 and 1,000 companies – including top securities firms, law firms, and banks – than any other U.S. city. Highly skilled professionals from around the country and the world come here to pursue their careers, and their dreams. This intellectual and creative "capital" is among our city's greatest assets.

Real estate is New York's largest sector, adding $220 billion to the economy each year, followed by finance, insurance, and professional and technical services. Tourism continues to grow. It generated over $55 billion in revenue in 2012 and employed approximately 400,000 workers. Our world-class cultural institutions and sports facilities are also important sources of revenue and employment as well.

Among many other sectors are construction, retail, arts and entertainment (theater, TV, film), higher education (including leading research institutions), health care and social assistance, old and new media (publishing, TV, radio, the Internet), marketing, and advertising. Over half a million people work for federal, state, and local government.

Technology-based industries, making up "Silicon Alley", rely on fiber-optic cable for high-speed communication and constitute a burgeoning sector. As measured by venture capital investments in 2013, the city's fastest-growing sectors are software, financial services, and biotechnology.

The local businesses and branches of larger businesses that provide goods and services throughout the city are a vital part of our economy. Grocery stores, convenience stores (often referred to as "bodegas"), pharmacies, banks, laundromats, restaurants, beauty salons, hardware stores, and many other kinds of establishments meet basic needs, add to local quality of life, promote social interaction and social bonds, and contribute to the character of neighborhoods.

Our economy sustains over 4 million jobs. However, in 2012 approximately 400,000 New Yorkers – 1 in 10 working adults – earned below the federal poverty line. While many new jobs are low-paying, the overall rate of job growth in New York City is on the rise and was higher than the state's and the nation's in 2013.

MOVING PEOPLE, FREIGHT, AND INFORMATION

Much of our economic activity takes place inside buildings and depends on critical infrastructure systems – energy, telecommunications, transportation,

PROJECTED TOTAL NEW YORK CITY POPULATION BY BOROUGH, 2010-2040

	2010	2020	2030	2040	Change from 2010 to 2040	PCT Change
NYC	8,242,624	8,550,971	8,821,027	9,025,145	782,521	10%
Bronx	1,385,108	1,446,788	1,518,998	1,579,245	194,137	14%
Brooklyn	2,552,911	2,648,452	2,754,009	2,840,525	287,614	11%
Manhattan	1,585,873	1,638,281	1,676,720	1,691,617	105,744	7%
Queens	2,250,002	2,330,295	2,373,551	2,412,649	162,647	7%
Staten Island	468,730	487,155	497,749	501,109	32,379	7%

SOURCE: NYC DCP

water supply, and wastewater. The following discussion explores the connection between buildings, critical systems and prominent features of our city that make their vulnerabilities acute.

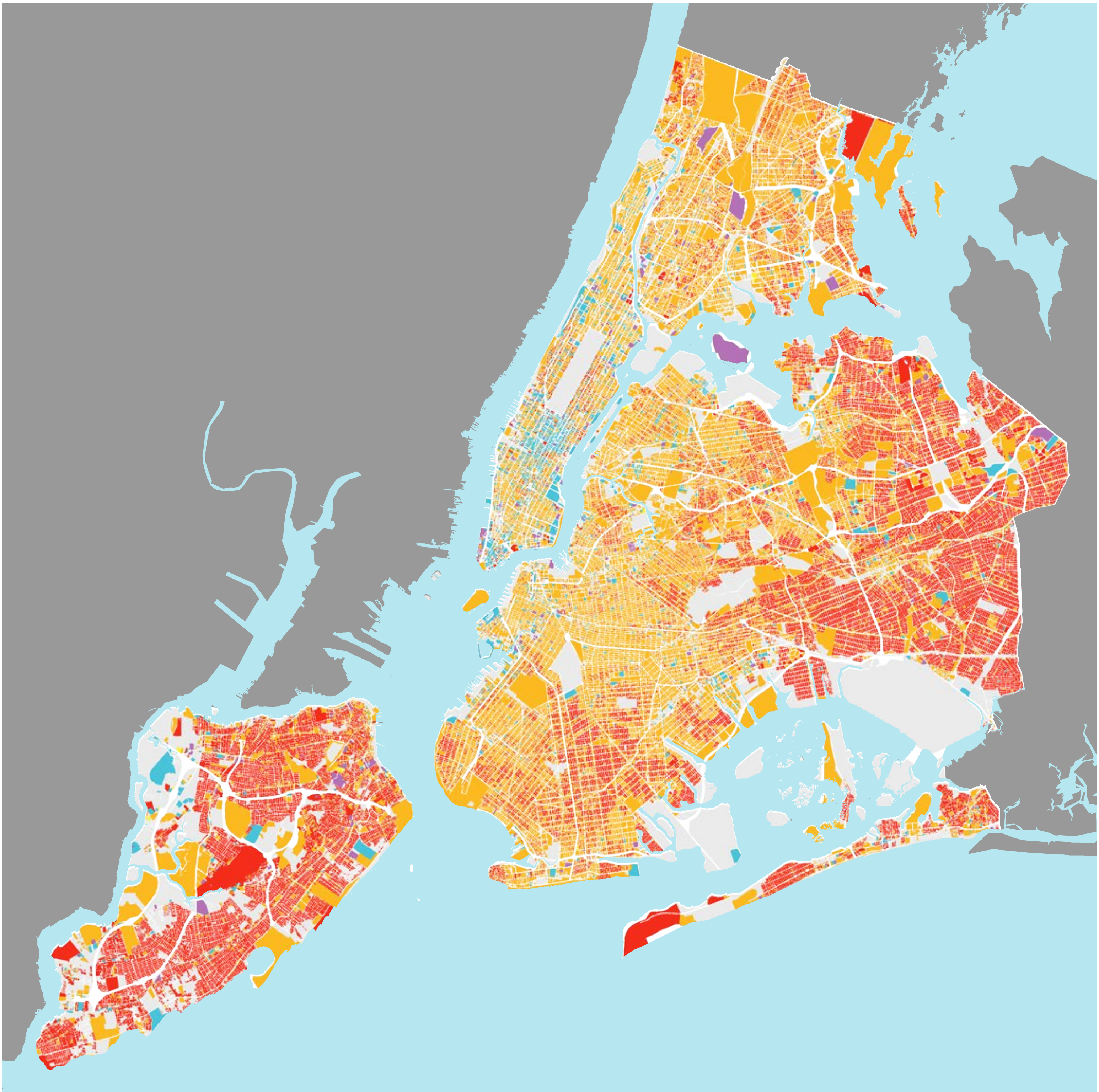
New York City's sprawling, complex transportation system is essential to our economy. Among its heaviest users is the sizeable workforce, who travels within and between boroughs and from neighboring towns and cities, by way of trains, subways, buses, taxis, cars, and ferries. Visitors, who in 2013 numbered more than 54 million people, rely upon the system, too.

Also essential are the trucks that deliver goods and inventory to our huge retail sector and to households, which are increasingly relying on online purchases that must be shipped. Trucks also ship products manufactured here to markets within the city and beyond.

New York could not be a global city without our region's three major airports – John F. Kennedy, LaGuardia, and Newark Liberty – which constitute the largest air travel market in the world and bring an endless stream of tourists and business travelers to us. JFK and La Guardia contribute $37.3 billion to the regional economy and provide about 256,000 jobs. Visitors and businesspeople travel here from other cities by train, as well. Grand Central Station, Atlantic Terminal, and Penn Station are major transportation nodes. The Port of New York and New Jersey, the largest port on the East Coast, handled cargo with an estimated value of $172 billion in 2013.

Various components of our transportation system are vulnerable to natural hazards and to hazard impacts on energy and telecommunications systems. Most vehicles rely on the liquid fuel supply system.

Some of our most valuable businesses rely on fiber-optic cable for high-speed communication. Most small businesses now rely on information technology (IT), some of them heavily. Clearly, our economy's growth will depend heavily on IT and reliable connectivity. New York City's Department of Information Technology and Telecommunications serves City agencies and also ensures that innovative technology is reliably available for residents, businesses, and visitors. All of this technology depends upon the grid.



CONSTRUCTION TYPE
SOURCE: NYC DOF, 2013

CONCRETE
MANUFACTURED HOUSING
STEEL
MASONRY
WOOD FRAME
UNKNOWN

OUR BUILDING STOCK

Our building stock encompasses approximately one million structures that vary by typology – construction type, age, and use – ranging from single-family, freestanding wood frame structures to attached masonry row houses to public housing projects to mid and high-rise apartment complexes to low-rise retail districts to massive commercial buildings and skyscrapers.

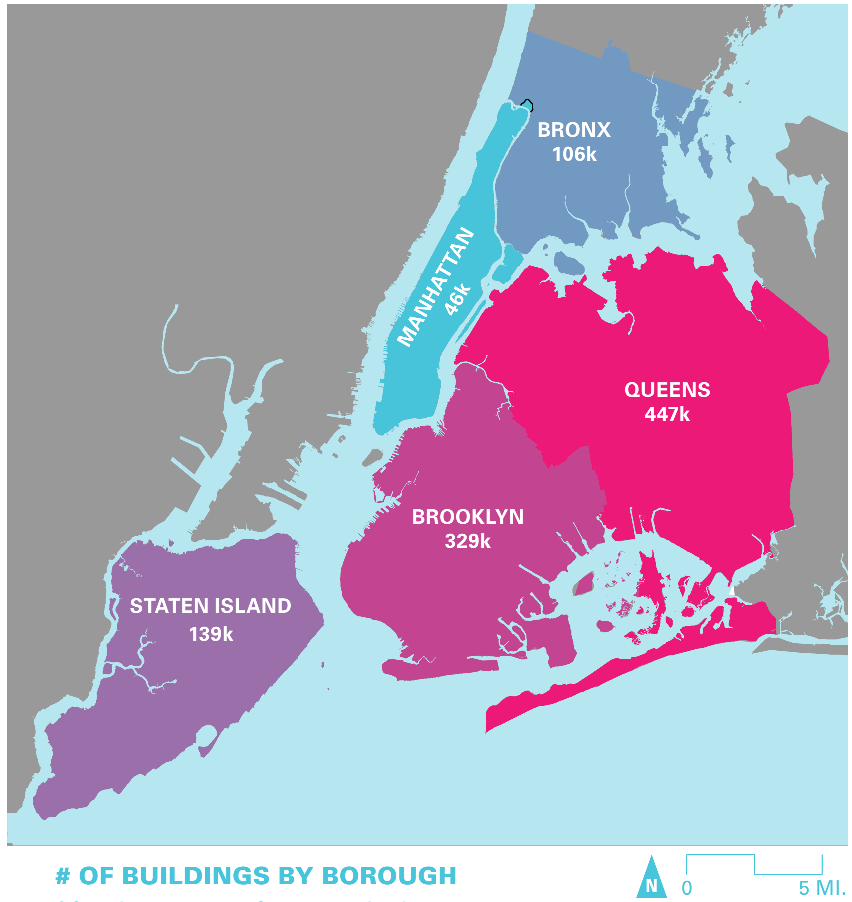
The City's Zoning Resolution and Construction Codes control the built environment. The Zoning Resolution operates on many levels, regulating building size, use, location, and density to shape the character of neighborhoods and quality of life. The Construction Codes specify standards for design, construction, and maintenance of individual buildings, with the aims of protecting public safety, health, and welfare. Both advance sustainability and resiliency goals.

Our built environment has become safer and structurally sounder over the years as zoning laws and Construction Codes have evolved and modernized. However, much of our building stock was built before stricter codes were adopted therefore potentially more vulnerable to certain hazards. The costs of retrofitting older buildings to safer standards can be prohibitive. And even new buildings are not immune from some hazards.

RISK FACTORS: LOCATION, CONSTRUCTION TYPE, AGE, AND MAINTENANCE

Where a building is located can be an important risk factor. Most obviously, buildings in the floodplain are vulnerable to flooding and coastal storms. Hurricane Sandy exposed constraints in codes and zoning law that limited some re-construction needed for recovery and long term resiliency. Many of the constraints have since been removed.

Construction type makes a difference, too. Unreinforced buildings are at a higher risk of earthquake damage than buildings that are reinforced. And buildings attached to each other gain stability: a row of unreinforced masonry buildings interspersed with vacant lots is even more at risk.



 # OF BUILDINGS BY BOROUGH
SOURCE: MAPPLUTO 14V1, NYC DCP, 2013

Light-frame buildings built decades ago according to less stringent codes tend to sustain more structural damage than newer, heavier buildings made with non-combustible materials like steel, concrete, and masonry. One to two story, low-rise buildings tend to be constructed of wood frame construction type and during a flood, this construction type is more prone to structural damage from flood water forces and fire from electrical shorts than are steel, masonry, or concrete frames.

For all buildings, lack of adequate maintenance can increase vulnerability.

CRITICAL INFRASTRUCTURE SYSTEMS

Anyone who has ever been unable to charge a cell phone is keenly aware of how heavily dependent we are on 21st century energy and telecommunications systems. Transportation, water supply, and wastewater systems are on the list of critical infrastructure, too. All are vital to public health and safety, our economy, our way of life. In the event of a disaster, they must continue operating to support emergency response and recovery.

Each is vulnerable to multiple hazards, and because they are interdependent, disruption of one can disrupt others. The fact that some are regional in nature adds to the complexities of maintaining, strengthening, and protecting them. So does the fact that, at the same time that they are subject to age-related deterioration.

Who, exactly, is responsible for these critical systems we depend on so heavily? How complex are they? Parts of them are out of public view, in secure facilities or underground. What do they look like? Because hazard impacts on critical systems crosscut Chapter 4, we describe the systems in some detail here to make their physical realities better understood and to identify key players. A sampling of strategies for managing risks associated with them is presented in the next chapter. Please see *A Stronger More Resilient New York* for more details.

ENERGY SYSTEMS

New Yorkers spend roughly $19 billion a year on energy to power, heat, and cool the city. Our energy infrastructure – electric, natural gas, and steam networks – is one of the oldest and most concentrated in the nation. Yet it is still among the most reliable. Every day, pipelines bring in natural gas from across the country. Power lines link the city to the larger regional grid. Generators burn gas to produce electricity. Steam travels from large boilers and cogeneration facilities to buildings through miles of underground pipes.

Electricity

This system consists of electricity generation, transmission at high voltages to large substations, and distribution from large substations to smaller ones and on to customers. The transmission and distribution system consists of underground networks and overhead utility lines. Approximately 70 percent of the 130,000 miles of power lines are underground.

Because transmission lines cannot carry enough electricity into the city to meet its peak load, regulations require that in-city generation supply 80 percent of forecasted demand. Transmission lines connecting us to upstate New York, Long Island, and New Jersey import the balance.

Many parties own and operate the in-city generation system. In-city transmission and distribution systems are owned and operated by Con Edison (which serves the majority of New York City electric customers) and PSEG (which serves customers on the Rockaway Peninsula, Queens).

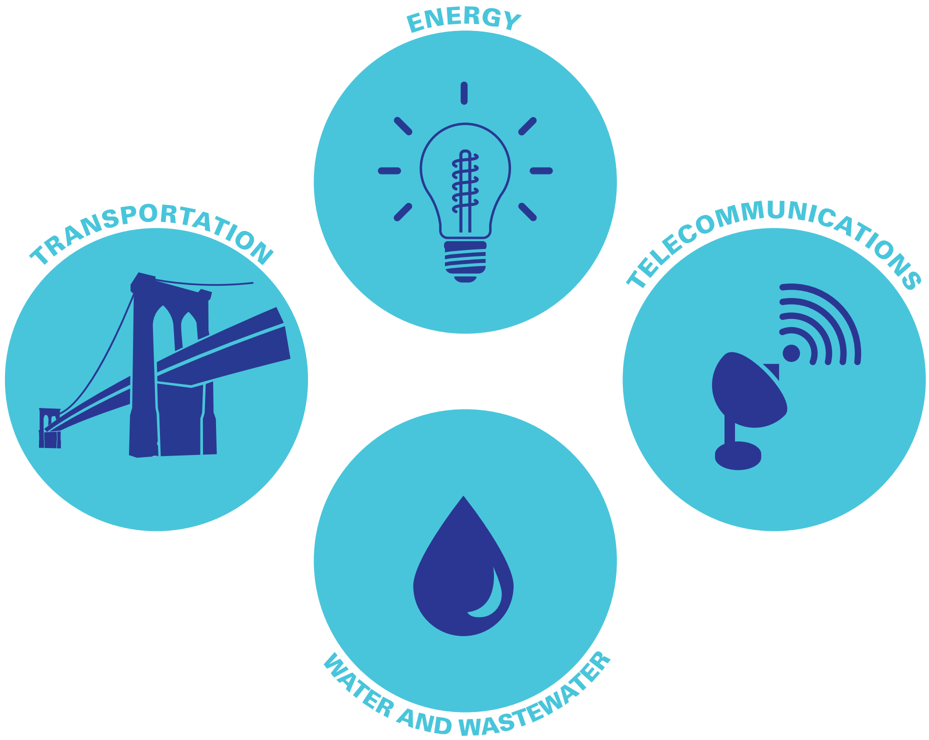
Electricity systems are vulnerable to weather extremes. For example, high winds and ice storms can down overhead power lines, directly or by toppling trees onto them. Flooding is another threat: many of our power generation plants are located in the 1 percent annual chance floodplain. Extreme heat can drive demand for air conditioning beyond the grid's capacity to deliver it, potentially causing outages that in turn can contribute to wide-ranging and severe impacts.

Natural gas

Natural gas meets about 65 percent of our heating needs and a significant percentage of cooking needs. It also fuels more than 98 percent of in-city electricity production by power plants.

Con Edison owns and operates the gas distribution system in Manhattan, the Bronx, and parts of Northern Queens. National Grid owns and operates the system in the rest of the city.

Four privately owned pipelines transport natural gas from the Gulf Coast, Western Canada, and other production areas to interconnection points here called "city gates." From them, high-pressure gas flows through an intra-city transmission system. Power plants generally draw gas directly from it.



To reach most other customers, gas is delivered through regulator stations that reduce its pressure and send it into a vast network of underground distribution mains. The low-pressure system consists of cast-iron and bare-steel mains—outdated infrastructure that's gradually being replaced. It is located mostly in the oldest parts of the city. Newer, high-pressure mains tend to be made of coated steel and plastic.

The system can be subject to leaks due to the age of equipment or lack of maintenance. Human error, for example leaving on the gas when the pilot is out, can also cause leaks. Explosions are rare but do occur.

Steam

The Con Edison steam system is one of the largest district steam systems in the United States. Six natural gas- and fuel oil-fired steam-generating facilities in Manhattan, Brooklyn, and Queens cogenerate steam along with electricity, or produce it alone in massive boilers.

A network of 105 miles of underground pipes transports steam to over 1,700 customers in Manhattan south of 96th Street—including 10 hospitals, which depend on steam to sterilize equipment, and many of the city's largest institutions. Steam provides energy for heat, hot water, and, in some cases, air conditioning. For customers, steam's advantage is that they do not have to own and maintain their own boilers. The most concentrated distribution centers are in the Financial District and Midtown Manhattan.

Steam pipes are stressed by high temperatures and high pressure. Explosions are rare but can cause injuries and fatalities, and can release asbestos (legacy insulation on very old pipes). They can damage street infrastructure, disrupt telecommunications, and compromise the structural stability of surrounding buildings.

TELECOMMUNICATION SYSTEMS

New York City's telecom sector–which includes the Internet, information services, phone, and cable TV–serves our 8.4 million residents, approximately 4 million workers, 250,000 businesses, and over 50 million annual visitors.

The physical system

The system's main components are these:

- Large distribution and switching centers provide connectivity across all major services.
- Cabling can be strung overhead via utility poles or run underground. New York's oldest cabling is lead-encased copper, with sections ranging from 10 to 90 years old. Most cable is threaded through conduit, underground pipe that's used in the densest areas in all five boroughs.
- Cell sites, typically placed on roofs, include an antenna, electronics, and backhaul circuits (cables that connect the cell site to the larger telecommunications network).
- Equipment in homes, offices, and other buildings distributes signals transmitted via cabling from critical facilities to individual customers.

Many companies provide voice, data, and video services, and many provide wireless, cable, and Internet service. The primary fixed-line telephone provider is Verizon, whose landline business is rapidly shrinking.

The regulatory scheme

This seemingly innocuous topic turns out to be a risk factor of its own. The Federal Communications Commission (FCC) regulates interstate and international communications by radio, television, wire, satellite and cable. Our State Public Service Commission regulates landline telephone service. The City Departments of Information Technology and Telecommunications, Transportation, and Buildings exercise authority over aspects of local physical telecom infrastructure.

Crucially, although federal, State, and City agencies share authority, none is responsible for the entire telecom system, and none must ensure that required service remain available during emergencies. The FCC promotes best practices for resiliency but doesn't require compliance. No single entity prioritizes or enforces measures to promote resiliency across the entire system.

New York City's telecom systems are generally very reliable, but they're vulnerable at a number of points. Telecom is powered by electricity and thus vulnerable to power outages. While critical facilities have back-up batteries and generators, 13 percent of critical telecom facilities are located in flood plains. Rooftop cell sites have limited backup battery power.

Computer-controlled digital and fiber optic equipment is sensitive to heat, humidity, and dust. A prolonged power outage can shorten this equipment's lifespan. High winds, tornadoes, and ice storms can damage overhead cabling. Underground cabling is vulnerable to flooding. A large volume of traffic is routed through a small number of collocation facilities in Lower Manhattan, some near the shoreline and at risk of flooding, as happened during Hurricane Sandy. This centralization increases network vulnerability.

TRANSPORTATION SYSTEMS

New York City's transportation system is sprawling and complex, comprising large, interconnected rail, roadway, air, and waterway networks, all essential for daily travel and transport. Disruption of the system can dislocate families and prevent workers from reaching work, disrupting the operations of businesses, government agencies, healthcare providers, and institutions. Students, shoppers, and tourists can be affected; emergency response could be hindered.

Rail network

Our rail system is one of the most complex in the country. Its interconnected subway and railroad networks carry two-thirds of all U.S. rail riders. Approximately 5.3 million subway riders and approximately 850,000 rail riders commute into and within New York City each day. Rail also carries freight.

The State-run Metropolitan Transportation Authority (MTA), the nation's largest transit authority, operates the main rail systems: New York City Transit, which operates the subway; Long Island Rail Road; and Metro-North Railroad, with Grand Central Station its hub. The Port Authority of New York and New Jersey (Port Authority) provides commuter rail service between New Jersey and New York City on PATH trains. Amtrak's rail system helps connect us to other major cities: Penn Station is Amtrak's busiest hub.

The city's rail transportation runs on electricity. The subway system alone consumes 1.8 billion kilowatt hours each year. Power outages can shut rail down.

Due to historical development patterns and operational needs, much rail and subway infrastructure is near the waterfront or in low-lying areas, making it vulnerable to storms and to flooding above ground and underground. Above ground, high winds could tip railcars over or derail them. Extreme cold can cause steel tracks to shrink; extreme heat can cause them to buckle. Both conditions could cause derailments.

Roadway network

Bridges and tunnels provide interborough connections for vehicles and public transit, as well as access to and from New York City. The city has more than 2,000 bridges, many of them over a century old. The City Department of Transportation manages approximately 800 bridge structures and 6 tunnels, and maintains over 6,000 miles of streets, 12,000 traffic signals, sidewalks, and retaining walls.

The MTA also manages roadways, and it operates 304 bus routes and oversees 7 bridges and 2 tunnels used by more than 300 million vehicles each year. Port Authority manages most transportation between New York and New Jersey, including four bridges, two tunnels, and two bus terminals.

All roadway infrastructure is vulnerable to hazards such as flooding of tunnels and low-lying roadways, and to weather extremes.

No single entity prioritizes or enforces measures to promote resiliency across the entire telecom system.

Air transportation

In 2013, 77 million passengers traveled through LaGuardia and JFK International Airports in Queens. Newark Liberty International Airport in New Jersey also serves the New York City area. The Port Authority operates all three, which together make up the world's largest air travel market. LaGuardia and JFK contribute $37.3 billion to the regional economy and provide about 256,000 jobs.

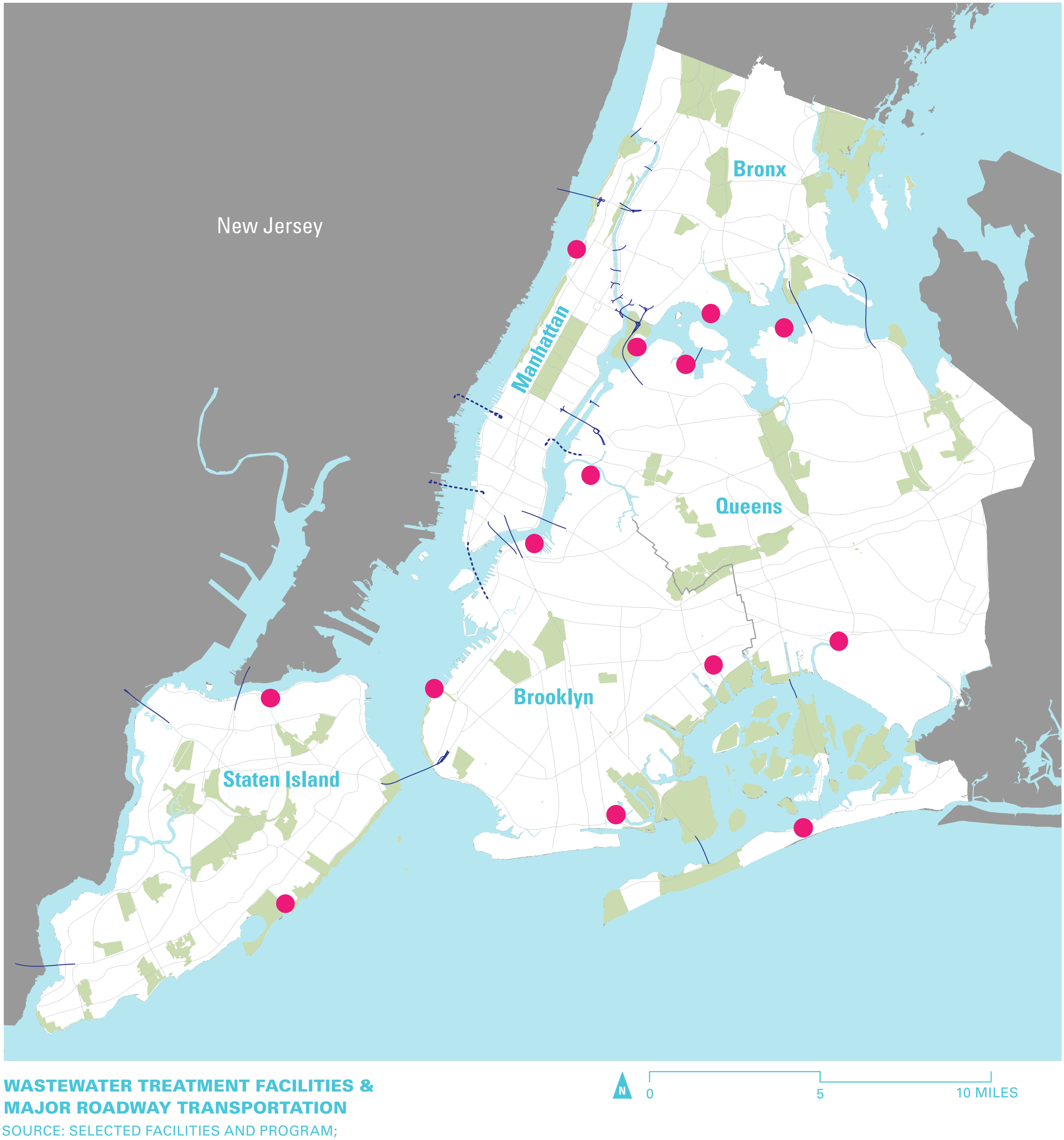
Both airports are located in floodplains and are already subject to flooding.

Maritime transportation

The Port of New York and New Jersey, managed by the Port Authority and used by private and public operators, is the largest and busiest port complex on the East Coast. In 2013, more than 34 million tons of cargo with an estimated value of $172 billion moved through it. It supports nearly 300,000 regional jobs. The port includes three passenger cruise terminals—two in New York and one in New Jersey.

More than 50 piers, docks, and ferry terminals are owned by New York City agencies. Ferry service by private and publicly operated vessels between New Jersey and New York City and between boroughs has expanded. The city now has 47 active ferry landings, and ferries are regularly used by many commuters. The largest commuter ferry is the Staten Island Ferry, operated by the City's Department of Transportation. It reports more than 22 million passenger trips a year between Staten Island and Lower Manhattan.

Storm-related waterfront risks are obvious. Less obvious, but critically important: waterfront operations depend on vulnerable energy and telecommunications systems.



WASTEWATER TREATMENT FACILITIES & MAJOR ROADWAY TRANSPORTATION

SOURCE: SELECTED FACILITIES AND PROGRAM; SITES DATABASE (DEC. 2012), NYC DCP

WASTEWATER TREATMENT FACILITIES
MAJOR BRIDGES
MAJOR TUNNELS
MAJOR ROADS

WATER SUPPLY

Each day, more than 1 billion gallons of drinking water are delivered to us. The Department of Environmental Protection manages our water supply system, ensuring the steady flow of water from large upstate watersheds through a complex network of aqueducts and tunnels. Within the city, Tunnel 1, completed in 1917, and Tunnel 2, completed in 1936, have been in continuous service since they were built. To increase redundancy and enable inspection and repairs, in 1970 the City began constructing Tunnel 3. This $5 billion project is scheduled for completion in 2018.

Citywide, water is distributed through 7,000 miles of water mains and pipes that are buried and pressurized to protect them from flooding. Redundancy is built into the system so that water can be diverted to different pipes as needed to ensure constant flow.

The distribution system depends almost entirely on gravity. Water travels from reservoirs with sufficient pressure to reach to the sixth floor of most buildings. High-rise buildings rely on rooftop water towers or electrical pump systems to provide water to upper floors. In a power outage, those pumps cannot pump.

The adequacy of our drinking water supply depends on adequate precipitation upstate to fill our reservoirs, continued good water quality, and the continued reliable performance of our water infrastructure.

WASTEWATER TREATMENT SYSTEM

Sewers collect 1.3 billion gallons of wastewater each day from drains and toilets citywide. Like most old urban centers, the city relies heavily on a combined sewer system to collect sanitary and industrial wastewater, rainwater, and street runoff and convey all of it to wastewater treatment plants. Sanitary waste enters the system through direct connections from buildings. Stormwater enters from catch basins that direct flow to the sewer system. In some neighborhoods, separate storm sewers carry runoff from streets directly to local streams, rivers, and bays.

Wastewater treatment plants require large amounts of electricity, making them vulnerable to power outages. All of our 14 wastewater plants are located along the waterfront at relatively low elevations that are at risk of flooding.

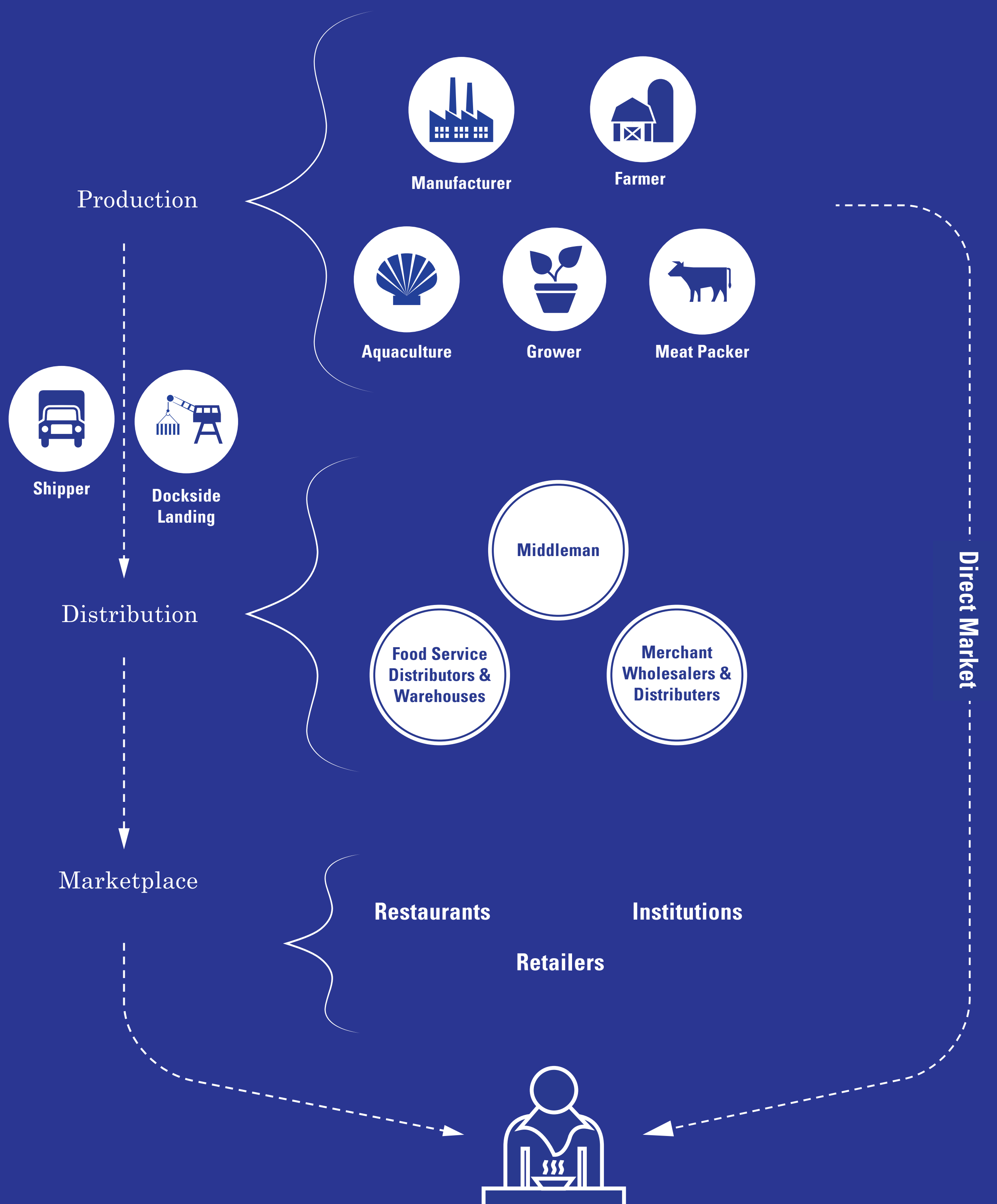
Waterfront locations significantly reduce the cost and environmental impact of treating wastewater. Under normal conditions, the wastewater system can fully treat the combined volume of sewage and stormwater. But when heavy rain or snowmelt swell that volume to beyond twice a plant's dry-weather capacity, the mix of excess stormwater and untreated sewage flows directly into the waterways in "combined sewer overflows" (CSOs).

Over many years, the City has invested billions of dollars in infrastructure to reduce CSO events. Recently it adopted an innovative Green Infrastructure Plan that relies on new natural and low-tech features around the city to absorb rain and snowmelt. Complementing it is the City's Bluebelt program, which engineers natural drainage corridors to slow the flow of water, and uses vegetation and other elements to absorb and filter impurities.

FOOD SUPPLY SYSTEM

Most of the food we consume comes from beyond our borders, about 95 percent of it arriving by truck; the rest by ship, air, and rail. 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. Almost 13,000 trucks travel to it every day. Three out of ten trucks that cross the George Washington Bridge are bound for it. With the East River is on two sides and the Bronx River on another, it is no surprise that nearly 30 percent of the site lies within the 1 percent annual chance floodplain.

Perishable food is sold at roughly 10,000 stores in our city, the majority of which are small establishments. Perishable and non-perishable food items are distributed through supermarkets, grocery stores, Each day, almost 13,000 trucks travel to and from the Hunts Point Food Distribution Center in the Bronx. Part of it lies in a floodplain.



convenience stores, bodegas, farmers markets, food coops, over 24,000 restaurants, nonprofit meal delivery services, soup kitchens, food pantries, and street vendors, as well as institutional kitchens in hospitals, public and private schools and universities and colleges, prisons, and senior centers. (Our institutional kitchens have a food budget estimated as second only to that of the U.S. military.)

This highly decentralized retail system, coupled with our city's scale, makes transportation infrastructure – roads, bridges, and tunnels – and liquid fuel supplies crucial to our food supply system.

Energy is essential, too. It is estimated that at least 70 percent of all food Americans eat each year passes through "the cold chain," requiring refrigeration or freezing at every stage. Electricity is also needed for lighting, computer systems that track inventory, cash registers and electronic transactions, ATM machines, and other functions. Telecom, which depends upon electricity, is essential for communication between distributers and retailers. Both electricity and telecommunication enable transactions using Electronic Benefit Transfer cards used by the city to distribute funds for purchasing food to low-income residents as part of the Supplemental Nutrition Assistance Program (SNAP, formerly called food stamps).

OTHER ASSETS AND FEATURES AT RISK

This category is very large and could include, for example, the liquid fuel supply chain that many City vehicles, ambulances, buses, taxis, trucks, and private vehicles depend on. What follows is a sampling of a few key features at risk.

SOLID WASTE MANAGEMENT

This function is fundamental to public health. Every day, nearly 1,000 Department of Sanitation trucks collect over 12,000 tons of waste and recyclables from buildings throughout the city. After Hurricane Sandy struck, employees worked 12-hour shifts around the clock, seven days a week, to collect more than 400,000 tons of Sandy-related debris.

Hospitals are heavily energy dependent. Uses range from laundry to sophisticated diagnostic equipment.

The City is shifting its waste collection network from roadways to more environmentally friendly marine routes, and is working to protect critical waterfront facilities from storm impacts. It is also working to strengthen the resiliency of the broader solid waste network – both City- and third-party owned. The performance of this network depends in part on the availability of fuel for trucks, and on functioning roadways.

HEALTHCARE FACILITIES

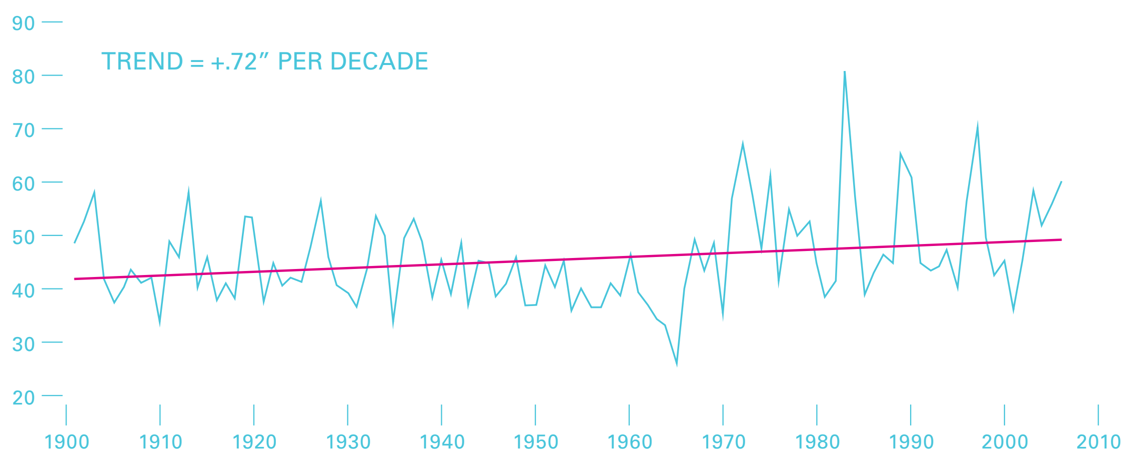
New York City has one of the greatest concentrations of healthcare facilities in the country, with over 60 hospitals, 170 nursing homes, and 75 adult day care centers. The City's Health and Hospitals Corporation operates almost a dozen hospitals, 6 diagnostic and treatment centers, 5 long-term care centers, 31 community healthcare centers, and 21 school-based health centers.

At any given time, some 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.

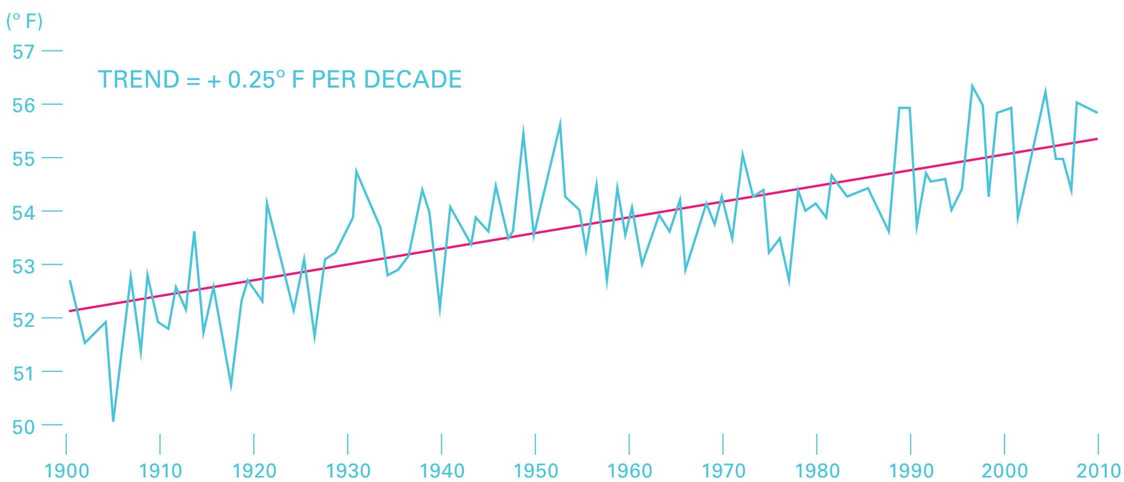
Community-based healthcare providers operate from over 10,000 buildings across the five boroughs. Pharmacies are integral to our healthcare system, too.

During and after emergencies, these facilities function as critical assets. They, too, are at risk, as we saw during Hurricane Sandy when hospitals next to the East River flooded and had to be evacuated. If healthcare workers cannot get to work because transportation has been disrupted, patients are impacted.

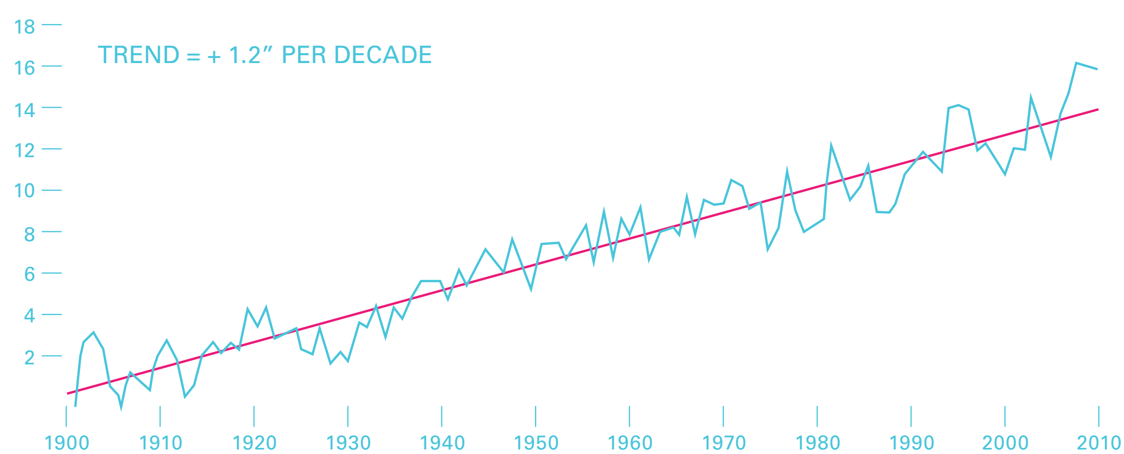
OBSERVED ANNUAL PRECIPITATION IN CENTRAL PARK (INCHES) (Source: NPCC, 2013)



OBSERVED ANNUAL TEMPERATURE IN CENTRAL PARK (1900 - 2011) (Source: NPCC, 2013)



OBSERVED ANNUAL SEA LEVEL RISE AT THE BATTERY, NEW YORK CITY (INCHES) (Source: NPCC, 2013)



Hospitals are major consumers of energy, depending on it not only for basic heating, cooling, ventilation, lighting, and hot water, but to operate sophisticated medical equipment and sterilization units, and for refrigeration, laundry, kitchens, and maintaining and accessing digital health records. During Sandy backup generators in some areas were flooded and unable to provide power.

EDUCATIONAL AND RESEARCH INSTITUTIONS

New York City has more than 2,700 accredited educational institutions including over 100 colleges and universities, just under 850 private schools, and over 1,800 public schools. The intellectual capital represented by the faculty, scholars, and researchers at our colleges, universities, and research institutions is an invaluable asset.

According to the U.S. Census Bureau's 2012 American Community Survey, over 1 million students attend New York City's private and public schools. Our public schools not only educate; they serve a public safety function as emergency shelters during hazard events.

OTHER FEATURES AND CONDITIONS EXPOSED TO HAZARDS

Certain activities or environmental conditions are more vulnerable to hazards events, and may expose communities to hazardous materials or debris.

Examples of this include construction projects and partially completed buildings which are vulnerable to strong windstorms when items such as small tools, lumber and cranes are exposed. The New York City Department of Buildings and State Department of Environmental Conservation regulate activity at construction sites to minimize environmental contamination of water and air, but due to the temporary nature of construction work, materials may be dispersed. Hazardous materials transported by truck, rail, air and water may be exposed to accidents during shipment. To prevent accidental releases, their storage and transport are tightly regulated, but releases do occur.

Piles of unenclosed materials such as non-putrescible waste, recycling, salt, sand and asphalt are permitted to be stored outdoors, and may be vulnerable to dispersion by air or water during storm events, especially if stored in flood zones. Brownfields are vacant or under-used lots that may be contaminated by previous industrial uses; heavy downpours, flooding, and high winds that disturb contaminated soil can disperse contaminants from these sites. The State has designated 17 brownfields in New York City; many are near residential neighborhoods or in flood zones.

OPEN SPACE AND THE NATURAL ENVIRONMENT

New York City's public parks range from wild to manicured, shoreline to inland, and large to vest pocket – playgrounds, waterfront esplanades, wetlands, hiking trails, dog runs, boating and kayaking areas, athletic courts and fields, beaches and swimming pools, monuments and historic buildings. Parks and open spaces managed by the City's Department of Parks & Recreation span over 29,000 acres, covering 14 percent of the city and encompassing approximately 2,000 sites.

Among these assets, beaches, boardwalks, and waterfront parks cover over 7,300 acres, or 30 percent of the Department's total land area and occupy 150 miles—almost 30 percent—of our coastline. The city's 9,900 acres of natural areas—over a third of the acreage in the system—include grasslands, wetlands, streams, and other natural areas that play a critical role in absorbing runoff and reducing the impacts of extreme weather events.

The City's trees, managed by the Parks Department, moderate temperatures, remove carbon dioxide and pollutants from the air, enhance sidewalks and other settings, protect waterways by reducing stormwater runoff, and help reduce the urban heat island effect (explained in Chapter 4). Since the *MillionTreesNYC* initiative was announced in PlaNYC in 2007, the City has planted nearly 760,000 trees.

HOW FUTURE CLIMATE WILL SHAPE OUR CITY

While no one can reliably predict the future of New York City, we can identify key factors that will shape it. Among them are: population growth and demographic trends, land-use development, new technologies, economic conditions, and City, State, and federal fiscal capacities, including the size of public investment in aging infrastructure – and the interplay among these factors.

Yet another key issue that will shape our city in the future is climate change. Its impacts crosscut a number of hazards that New Yorkers face.

THE CITY MARSHALS ITS EXPERTS

The New York City Panel on Climate Change (NPCC), a body of leading climate and social scientists and risk management experts, was convened by the City in 2008 to produce climate projections for New York City and inform City government's decision making and the public.

In January 2013, to inform planning for rebuilding and resiliency after Hurricane Sandy, the NPCC updated its projections by drawing on the latest climate models, recent observations about climate trends, and new information about greenhouse gas emissions.

The resulting report, *Climate Risk Information 2013*, forecasts more severe weather. More high winds, more hot days and longer heat waves. More heavy downpours, and more frequent storms.

FORECAST: SEA LEVEL WILL CONTINUE TO RISE, AS WILL THE RISK OF FLOODING

New York City's sea levels have been rising, and this trend is expected to continue.

- Middle-range projections for the 2020s indicate a four to eight inch rise, while high-end projections show as much as 11 inches.
- By mid-century, high range projections indicate sea levels could rise as much as 2.5 feet (31 inches), especially if the polar ice sheets melt faster than previously anticipated. This would threaten low-lying communities with regular tidal flooding. At the Battery (the southern tip of Manhattan), flooding as severe as that from today's 100-year storm would be up to five times more likely.
- By the 2020s, the area that could be flooded in a 100-year storm could expand to 59 square miles and encompass approximately 88,000 buildings.
- By the 2050s, with more than 2.5 feet of sea level rise, New York City's 1 percent annual chance floodplain could be 72 square miles—a staggering 24 percent of the city—an area that today contains approximately 114,000 buildings and currently accounts for 97 percent of the city's power generation capacity, 20 percent of its hospital beds, and a large share of its public housing.

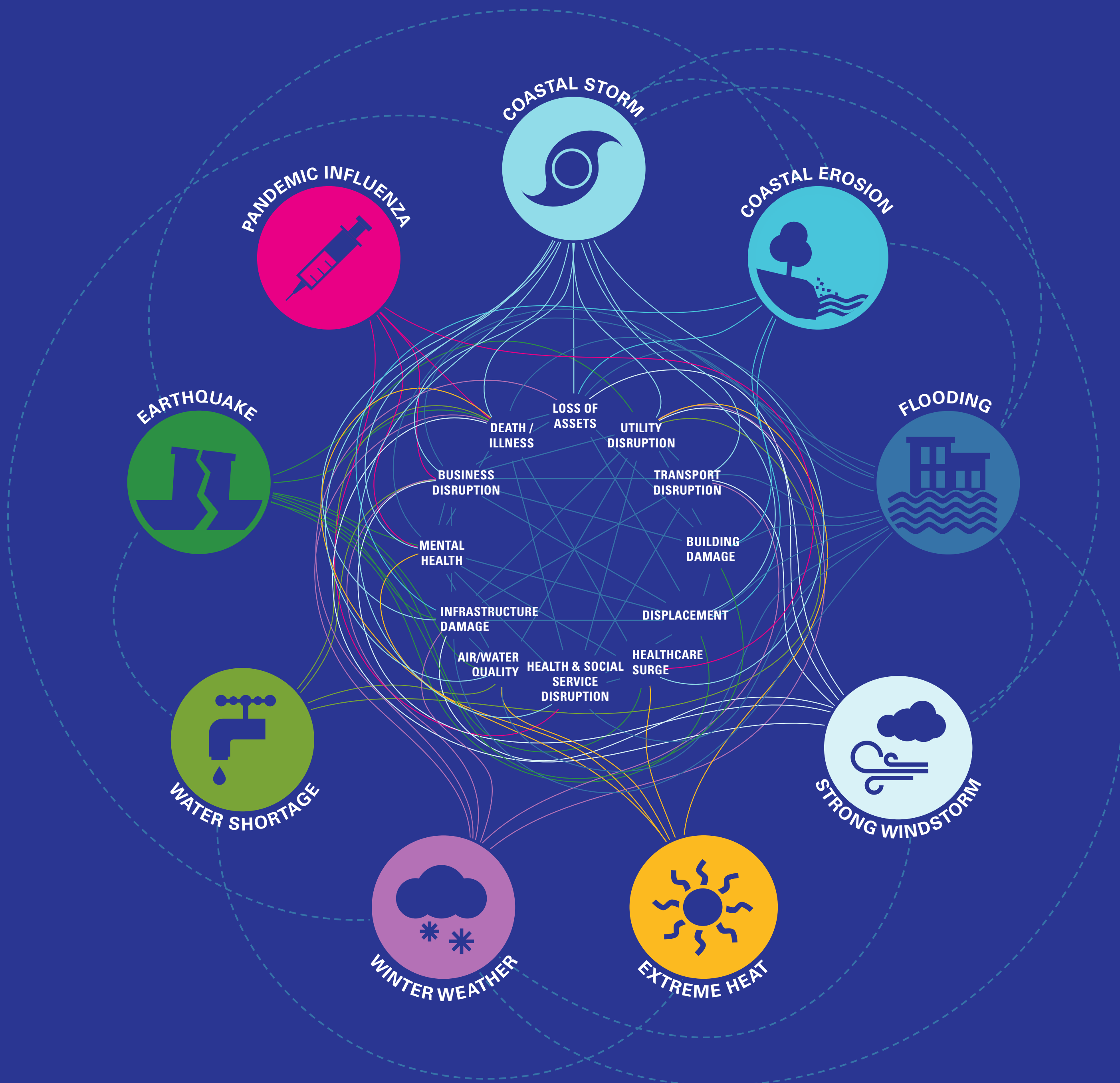
FORECAST: MORE HEAT WAVES AND HEAVY DOWNPOURS

The New York Panel on Climate Change predicts that by the 2050s heat waves–three or more consecutive days of daily high temperatures at or above 90 degrees—could more than triple in frequency, lasting on average one and a half times longer than they do today.

Total annual precipitation will increase slightly: up to 10 percent by the 2020s and up to 15 percent by mid-century. It is more than 90 percent probable that the New York City area will see an increase in heavy downpours by mid-century.

Hurricane Sandy is an example of how extreme weather events and the cascade of impacts they trigger can affect our densely populated, 21st century coastal city. In the future, extreme heat, flooding due to coastal storms and heavy downpours, high winds, and ice storms may impact our critical infrastructure systems. Much of our energy generation, transmission, and distribution system is located in the preliminary Flood Insurance Rate Maps 1 percent annual chance floodplain, as is 13 percent of our telecom system.

Climate change boosts risk, and looking back over this chapter, it is clear that – given the extent of New York City's vulnerabilities to natural and non-natural hazards and their potential severity – the stakes at the risk and resiliency table are high and warrant the broad array of risk management strategies that our City and its partners now employ and are working aggressively to strengthen.



The complexity of hazards underscores the importance of an integrated approach to risk management.

Redundancies are inherent in our subject. Many features of our risk landscape are vulnerable to more than one type of hazard, and some hazards are dramatically diverse, while others are closely interrelated.

CHAPTER 4

SELECTED HAZARDS AND RISK MANAGEMENT STRATEGIES

HAZARD PROFILES

This chapter profiles selected hazards that pose a risk to our city. Each hazard profile describes the nature of the hazard, identifies key risks it poses, and presents a sampling of strategies for managing the risks. The focus is generally on long-term risk management, but the subject of short-term emergency response informs the profiles, as well.

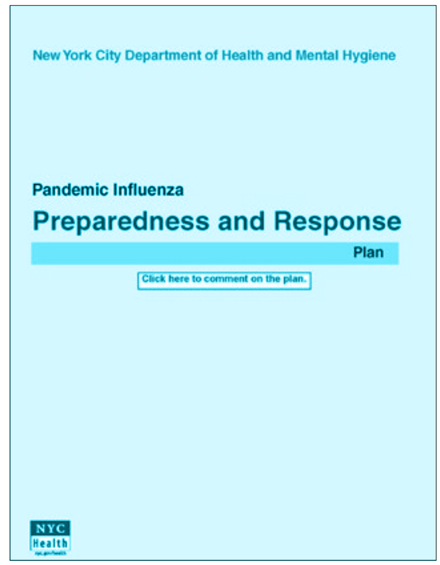
For each hazard, a tremendous body of knowledge exists, along with fields of research that continue to evolve. We hope our profiles will motivate readers to learn more. Good places to start are "Resources," at the end of this Guide, and the *2014 Hazard Mitigation Plan*.

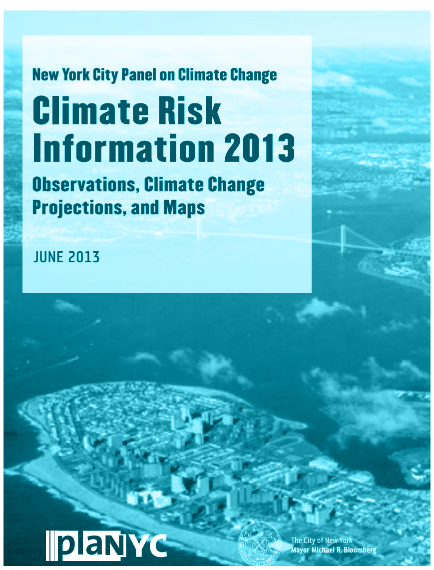
Hazards profiled below are:

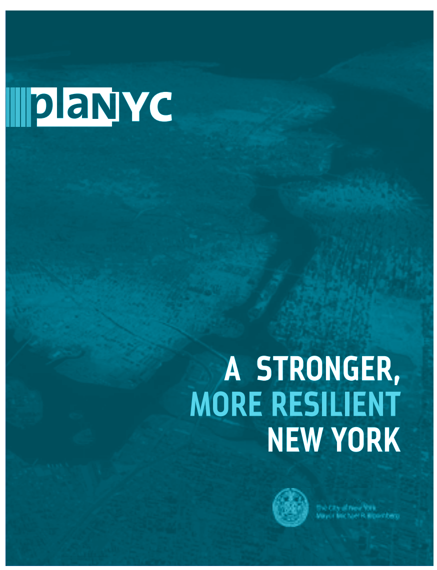
- Coastal Storms
- Coastal Erosion
- Flooding
- Strong Windstorms
- Extreme Heat
- Winter Weather
- Water Shortage
- Earthquakes
- Pandemic Influenza

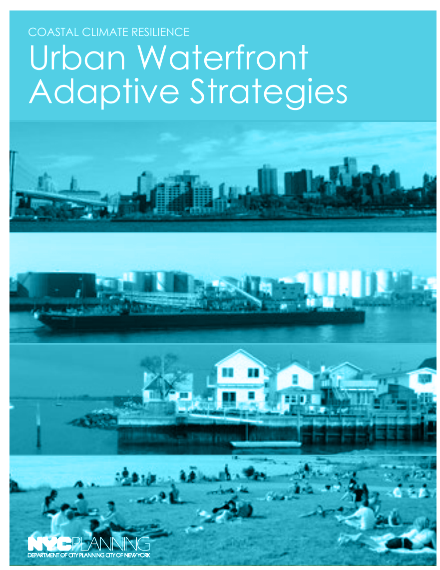
Note that we have sequenced hazards somewhat thematically, with Coastal Storms, Coastal Erosion, Flooding, and Strong Windstorms being most closely related. The length of the text devoted to any one hazard is not a proxy for importance.

This Guide builds on a comprehensive set of resources developed by the City and its partners to manage the risks we face.









CROSS-REFERENCING, AND CROSSCUTTING INFORMATION

Redundancies are inherent in our subject. Many features of our risk landscape are vulnerable to more than one type of hazard, and some hazards are dramatically diverse, while others are closely interrelated. For example, coastal storms flooding, strong windstorms, and coastal erosion have similar risks and hazard management strategies. Similarly, our built environment constitutes an immense risk exposure, and our Building Code helps protect against a variety of weather-related hazards.

Most hazards occur independently of each other, but some occur as a result of others. For example, coastal storms can result in flooding. Some hazards that are unrelated, such as coastal storms and earthquakes, could produce similar impacts, such as fatalities, power outages, and transportation disruptions.

This complexity underscores how important an integrated approach to risk management is, and why the City continues to expand and strengthen collaborations among the public and private sector parties responsible for long-term hazard mitigation.

To reduce redundancy, we present crosscutting background information about building protections and City response capabilities.

PROTECTING BUILDINGS: EVOLVING LAWS, REGULATIONS, AND GUIDELINES

The City uses its Zoning Resolution and Construction Codes to control the built environment and create a safer, healthier, more resilient city. Zoning, developed and written by the Department of City Planning and enforced by Department of Buildings, regulates building size, use, location, and density, thereby shaping the character of neighborhoods and quality of life. Individual buildings are governed by New York City's Construction Codes which is administered by the Department of Buildings. The Codes specify standards for design, construction, and maintenance of individual buildings, with the aims of protecting public safety, health, and welfare, and advancing sustainability and resiliency goals.

As displayed in the timeline, New York City's building codes are continuously evolving. About 80 percent of our building stock was built before the 1961 Zoning Resolution established modern rules for building design, reducing residential densities and requiring more open space. Because Building Code requirements became stricter over time, older buildings can affect vulnerability. Light-frame buildings built to less stringent codes tend to sustain more structural damage from a hazard than newer, heavier buildings made with non-combustible materials like steel, concrete, and masonry that meet modern standards.

When enacted in 1968, the New York City Building Code was one of the Country's most stringent. But decades of piecemeal modifications produced a long, cumbersome code that was hard to interpret. In 2008, the City adopted New York City Construction Codes, an updated, comprehensive set of rules adapted from International Code Council (ICC) model codes. The new Codes were designed to meet present and future challenges of our dense urban environment, and to embody the latest professional scientific and engineering knowledge. They govern building, plumbing, mechanical, fuel gas, and energy conservation, and they introduced new standards for construction that help protect buildings from earthquakes, extreme temperatures, flooding, wind, and winter weather.

Hurricane Sandy exposed constraints in codes and zoning law that limited the ability to perform construction needed after the storm. Shortly after the storm, the Mayor enacted an Executive Order to lift zoning requirements to enable people to rebuild higher. This became law with the 2013 Flood Resilient Zoning Text Amendment and new Construction Code regulations. In addition, the 2014 Codes incorporate recommendations from the City's Building Resiliency Task Force and Green Codes Task Force, effective December 31, 2014.

Like the ICC Codes, our Codes must be updated every three years to capture new safety and technological advances. Future hazard events may test the codes. They will be updated as needed.

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

2013
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.

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

1998
Dept. of Transportation Seismic Criteria Guidelines for bridges are adopted by all local bridge owners. Guidelines are revisited every 3 to 4 years.

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 Feb. 1996).

1983
Revisions incorporate FEMA floodplain maps and mandate flood-resistant construction standards (for new or substantially improved buildings) that residents must meet to be eligible for National Flood Insurance Program.

1968
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).

1961
2nd Zoning Resolution focuses on reducing densities and requires open space. Introduces Floor Area Ratio, limiting building height based on size of lot.

1938
Revisions address wind loads for skyscrapers and standards for multi-family buildings.

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

1916
Revisions requires one stairwell for each 2,500 sq. ft. of floor area in office buildings.

1st Zoning Resolution (the first in the nation) establishes rules for “land use and bulk” to separate residential, commercial, and manufacturing districts, and control building heights.

1913
Strict fire safety and labor laws established for factories.

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

1899
City enacts first citywide building code. Previous building laws were enacted by the State.

1879
The Second Tenement House Act (“Old Law”) requires that all rooms open onto a street, rear yard, or air shaft.

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

1860
First comprehensive building regulations enacted for the city.

2012

Hurricane Sandy prompts changes to the zoning Resolution and Building codes

2001

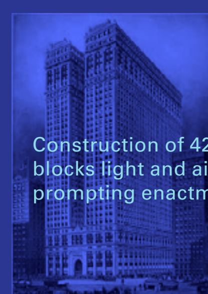
Collapse of World Trade Center reveals safety issues related to outdated 1968 Building Code

1988

Widely felt Quebec earthquake and 1989 Loma Prieta earthquake in California prompt adoption of federal seismic guidelines for bridges and NYC seismic Building Code provisions and seismic Bridge Design guidelines

New York City is shaped by its hazard history and its ability to continuously adapt to risk.

1916

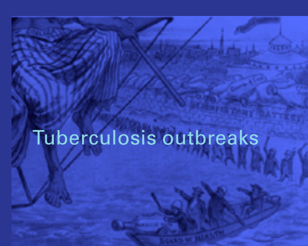


Construction of 42-story Equitable Building blocks light and air for surrounding environment, prompting enactment of Zoning Resolution

1911

Triangle Shirtwaist Factory fire kills 146 people, spurring adoption of many building safety codes

1900



Tuberculosis outbreaks

1860

Tenement fire takes 20 lives

OPERATIONAL PLANS FOR PREPAREDNESS, RESPONSE, AND RECOVERY

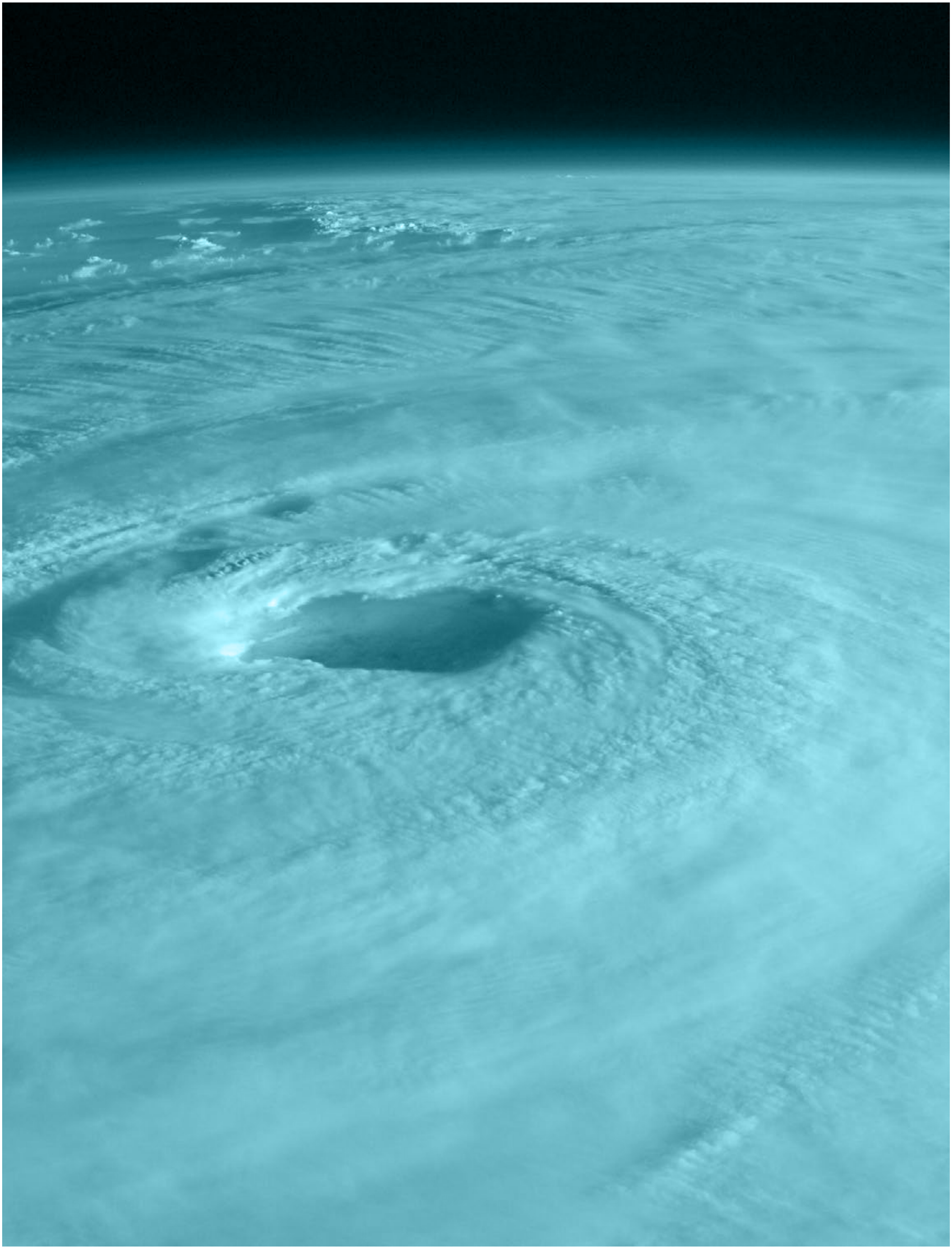
In some hazard events, the ability to respond quickly is an essential strategy for managing the risks. The type of responders varies according to the nature and extent of the impacts, but the foundation for a coordinated response is the following:

- Our Citywide Incident Management System is the City's framework for managing and coordinating response and recovery operations at emergency incidents. All parties participating in emergency responses – public agencies and private and nonprofit organizations – must operate within this structure.

- New York City's frontline emergency responders are the Police Department, Fire Department, and New York City Emergency Management. Other City agencies—such as the Department of Health and Mental Hygiene, the Department of Environmental Protection, the Department of Housing and Preservation Development, and the Department of Buildings—perform emergency-response functions, too.

- Continuity of Operations plans establish operational procedures which ensure that an organization can continue to provide essential services to the public during an emergency or other incident that may disrupt normal agency operations. All Mayoral agencies have developed continuity plans for providing essential services, reducing disruptions to operations, protecting personnel and assets, and ensuring a timely and orderly recovery from an emergency.

- Comprehensive Emergency Plans: Emergency plans help prepare NYC to respond effectively during an incident in order to reduce the disruption to people and services. NYC Emergency Management creates and updates the City's emergency plans for a range of natural and man-made hazards. These plans are either operation specific, such as debris management, or hazard specific, such as the Coastal Storm Plan.



COASTAL STORMS
CHAPTER 4.1

Coastal storms are a reality for New York City, arriving as hurricanes, tropical cyclones ,and nor'easters when certain meteorological conditions converge. Not only dangerous, these storms can be deadly, sustaining destructive winds, heavy rainfall, storm surge, coastal flooding, and erosion. Climate change and rising sea levels are likely to worsen their impacts.

WHAT IS THE HAZARD?

TROPICAL CYCLONES

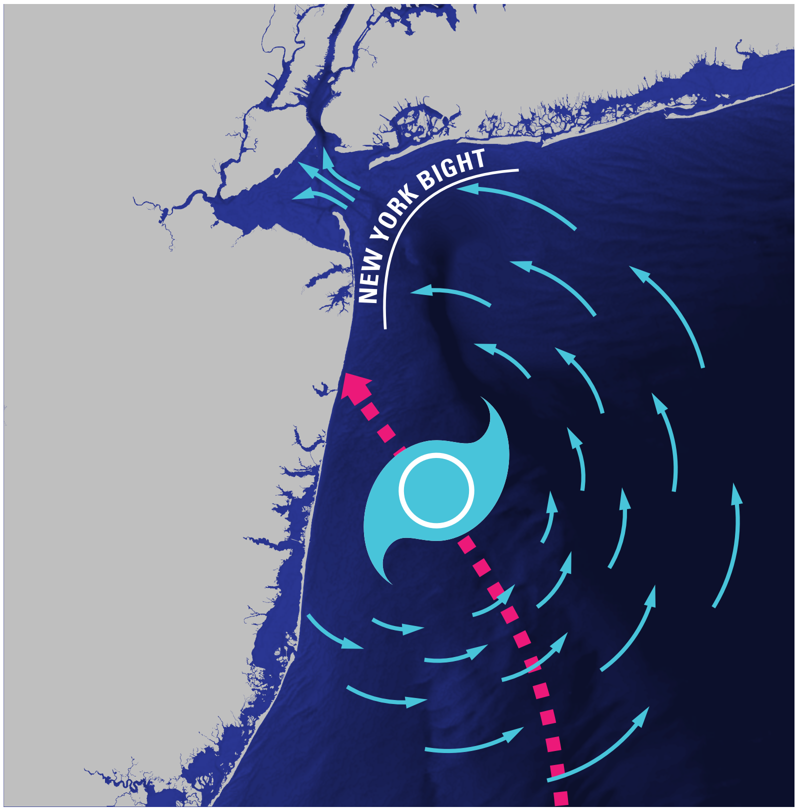
Tropical cyclones are organized areas of precipitation and thunderstorms that form over warm tropical ocean waters and rotate counterclockwise around a low pressure center. Such storms are classified as follows:

- A **tropical depression** is an organized system of clouds and thunderstorms with a defined low pressure center and maximum sustained winds of 38 miles per hour (mph) or less.
- A **tropical storm** is an organized system of strong thunderstorms with a defined low pressure center and maximum sustained winds of 39 to 73 mph.
- A **hurricane** is an intense tropical weather system of strong thunderstorms, a well-defined low pressure center ("eye"), and maximum sustained winds of 74 mph or more.

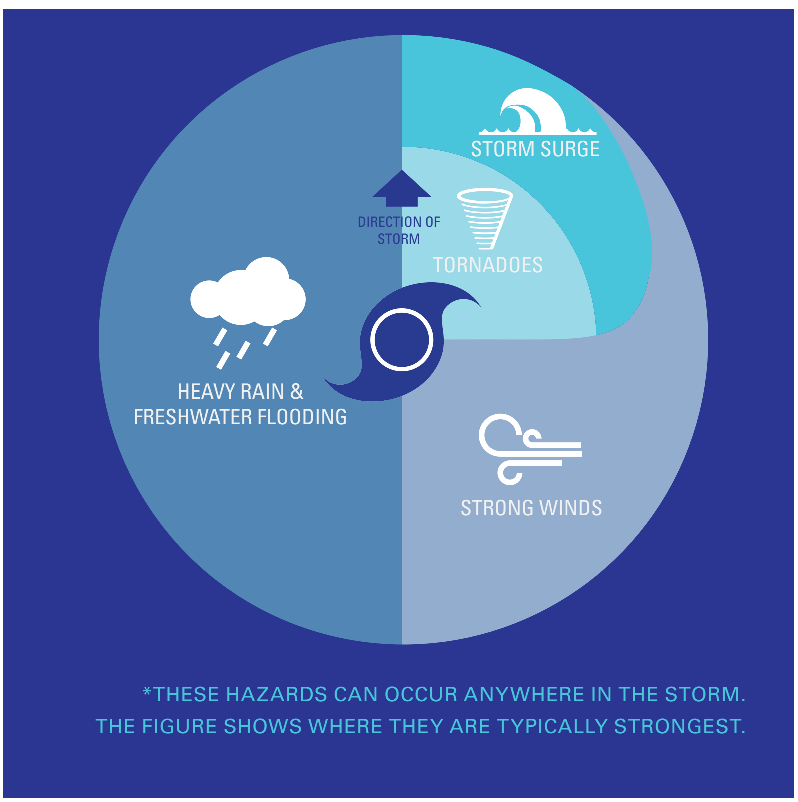
In the North Atlantic Basin—where New York City is located—tropical cyclones often form in the Atlantic Ocean between Africa and the Lesser Antilles, in the Caribbean Sea, or in the Gulf of Mexico. Typically, they first track in a westerly or northwesterly direction. They are then pushed northward and eventually eastward by the force of the Earth's rotation. They may track up the East Coast of the United States and reach New York City if water temperatures are warm enough and the prevailing winds steer them in this direction.

The Atlantic hurricane season lasts from June through November and features an average of 11 tropical storms and six hurricanes annually. New York City is at highest risk between August and October, when ocean temperatures are warmest.

The primary hazards associated with coastal storms are flooding (both inland and coastal) and wind. Inland flooding may result from heavy rain. The amount of rainfall depends on a storm's speed, size, and local geography. Heavy rain can cause freshwater flooding from rivers or in low-lying areas with poor drainage. Urban flash flooding is an acute form of the latter.



A HYPOTHETICAL STORM APPROACHING NEW JERSEY
SOURCE: NYC OEM



PRIMARY HAZARDS ASSOCIATED WITH HURRICANES
SOURCE: NYC OEM

Of all hazards associated with coastal storms, coastal flooding from storm surge causes the greatest damage and the most deaths. Storm surge is the rise in water level caused by a storm's strong winds and low pressure. The most significant storm surge typically occurs near the storm's eye wall (the region of clouds and intense thunderstorms surrounding the eye) and in the right-front quadrant of the storm, where the storm's speed of forward motion accelerates the counterclockwise rotating winds. During periods of high tide, the water levels can be even higher, causing severe flooding. The observed water level resulting from the combination of storm surge and the astronomical tide is known as the storm tide: that is, the highest water level reached during a storm. The shoreline along the open ocean and in wide estuaries is also exposed to powerful wave action in addition to flooding from rainfall, storm surge, and tides.

Wind-related hazards from coastal storms are straight-line winds and tornadoes. They are generally strong enough to snap or uproot trees and utility poles and cause structural damage to buildings. Flying debris becomes another hazard. Tornadoes are usually relatively low on the Enhanced Fujita Scale, which measures tornado strength (see "Strong Windstorms"), and are short in duration, but they may still pose a significant risk.

NOR'EASTERS

A nor'easter is a type of coastal storm that occurs most often between October and April in the Mid-Atlantic and Northeast United States, where counterclockwise circulation brings winds from a northeasterly direction. Like tropical cyclones, these storms are associated with heavy precipitation and wind. However, they form outside of the tropics (often over the Carolinas or southeast coast of the United States) during cooler months, and they can maintain their strength over land.

These storms also differ from hurricanes in that they bring the threat of heavy snow, sleet, and/or freezing rain but are rarely associated with tornadoes. Although nor'easters typically have weaker surface winds than hurricanes, they occur more often, may develop more quickly, and may affect larger geographic areas.

WHAT IS THE DIFFERENCE BETWEEN A TROPICAL STORM AND A NOR'EASTER?

TROPICAL CYCLONES	NOR'EASTERS
Form in tropics or subtropics	Form outside of the tropics
Can only form and maintain strength over warm water	Can form and maintain strength over land or water
Energy source is warm ocean water	Energy source is temperature contrasts in the atmosphere
Occur between June and November	Occur between October and April
Are often associated with bands of severe thunderstorms and possibly tornadoes	Are rarely associated with severe thunderstorms and tornadoes
Are not associated with wintry precipitation (snow, sleet, freezing rain)	Are often associated with wintry precipitation (snow, sleet, freezing rain)

NOTABLE STORMS IN THE NEW YORK CITY AREA

September 1821: A large hurricane hits Long Island with a 13-foot storm tide in parts of New York City.

September 1938: The most powerful hurricane on record to ever impact the region makes landfall near Fire Island

August 1954: Hurricane Carol makes landfall in eastern Long Island with sustained winds over 100 mph.

March 1962: Nor'easter caused extensive damage along much of the East Coast between North Carolina and southern New England.

September 1985: Hurricane Gloria makes landfall on Long Island as a Category 1.

December 1992: A powerful nor'easter causes extensive damage to structures, utilities, and roads across New York City.

September 1999: Tropical Storm Floyd dumps between 10 and 15 inches of rain causing extensive flooding and damage.

October 2012: Hurricane Sandy makes landfall in southern New Jersey, devastating New York City and much of the metropolitan area.

WHAT IS THE RISK?

STORM SEVERITY AND OUR PHYSICAL EXPOSURE

The severity of a coastal storm depends on multiple factors. Storms are formally categorized on the basis of wind speed as measured by the Saffir-Simpson Hurricane Wind Scale.

Other factors that affect a storm's severity are its size and speed of forward motion. A larger, slower-moving Category 1 storm may cause more widespread damage than a smaller, faster-moving Category 2 storm because the winds will impact the region for a longer time and total rainfall will be greater.

The storm's size determines the wind field (the area impacted by storm winds), and thus affects wave heights and storm surge. In general, larger storms produce larger waves and higher storm surge. In a fast-moving storm, winds on the right side are amplified by the storm's forward speed, but slow-moving storms will impact an area for a longer period of time, generally producing more rainfall and inland flooding. On the open coast, a faster storm will produce higher surge. However, a higher surge is produced in bays, sounds, and other enclosed bodies of water with a slower storm.

The direction that the storm is moving when it reaches New York City—its "bearing"—also contributes to its consequences. A storm moving in a westerly direction that is south of the city at landfall will put New York City on the right side, meaning stronger winds and higher storm surge for the city. If a storm is moving in an easterly direction and makes landfall east of the city, we will be on left side of the storm, which could mean higher rainfall totals but less significant winds and storm surge.

The geography of the local coastline amplifies storm surge impacts. The New York Bight—the nearly 90-degree angle formed by the shorelines of Long Island and New Jersey—can direct a storm surge into New York Harbor. The worst-case-scenario hurricane for New York City is moving in a northwest direction with landfall just to the south along the

Saffir-Simpson Hurricane Wind Scale

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 damage to power lines and poles likely will result in power outages that could 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.

coast of New Jersey. This track puts the city in the right-front quadrant of the storm and directs the highest storm surge into the New York Bight.

This is what happened during Hurricane Sandy in 2012, and it is one reason the storm had such a significant impact on the city. Tropical Storm Irene made landfall over Brooklyn the year before but was a very different storm. Its bearing at landfall was a north-northeast direction, resulting in fewer direct surge impacts on the city.

A CLOSER LOOK AT STORM SURGE

While the entire city is at risk of high winds and freshwater flooding, only locations close to tidally influenced water bodies will experience storm surge. The extent and severity of storm surge flooding also depends on local topography. Locations right on the shore are also at risk from severe wave action, which is often accompanied by debris impact. While waves are generally highest along the open ocean, also at risk are bay, sound, and wide river estuary shorelines.

To predict storm surge and help guide the City's planning for coastal storms, New York City Emergency Management Department uses a National Hurricane Center computer model called Sea, Lake, and Overland Surges from Hurricanes (SLOSH). SLOSH takes into account a number of variables for storms moving in different directions and varying in strength from Category 1 to Category 4. The model then calculates surge levels for a worst-case scenario for each storm category.

The National Hurricane Center forecasts storm tide heights for tropical storms and hurricanes on a probabilistic basis (a range of likely storm tide levels) and updates its forecasts regularly as the storm approaches landfall. The National Oceanic and Atmospheric Administration provides timely storm tide forecasts for non-tropical storms (including nor'easters) on a deterministic basis (a single value for each tide gauge location). Some academic institutions, including Stevens Institute of Technology and SUNY Stony Brook, provide similar forecasting services. While intended purely for research purposes, these forecasts can be valuable supplements to official forecasts.

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 numerous 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.

STORM FREQUENCY

According to the National Hurricane Center, on average, hurricanes winds have impacted the New York City area every 19 years, and major hurricanes (Category 3 or higher) every 74 years. A Category 5 hurricane is not expected to occur here under current climate conditions. This has no relation to the storm surge estimates produced from the SLOSH model.

New York City is typically hit by several nor'easters each year. They range in intensity. While severe nor'easters do strike the city occasionally, most nor'easters are relatively weak. But even those can produce significant rainfall or snowfall and minor-to-moderate coastal storm tides and related damage.

VULNERABILITY

Many factors make our coastal city particularly vulnerable to major coastal storms and their secondary impacts. Notably, nearly 2.5 million city residents live in storm surge inundation zones, and a great deal of valuable real estate and critical infrastructure is located in those zones.

HOW IS DEPTH OF FLOODING DETERMINED?

The amount of flooding a storm causes is one of the most important characteristics of the event. Meteorologists often report this as the amount of storm surge: that is, the additional water above mean (average) sea level that results directly from the coastal storm.

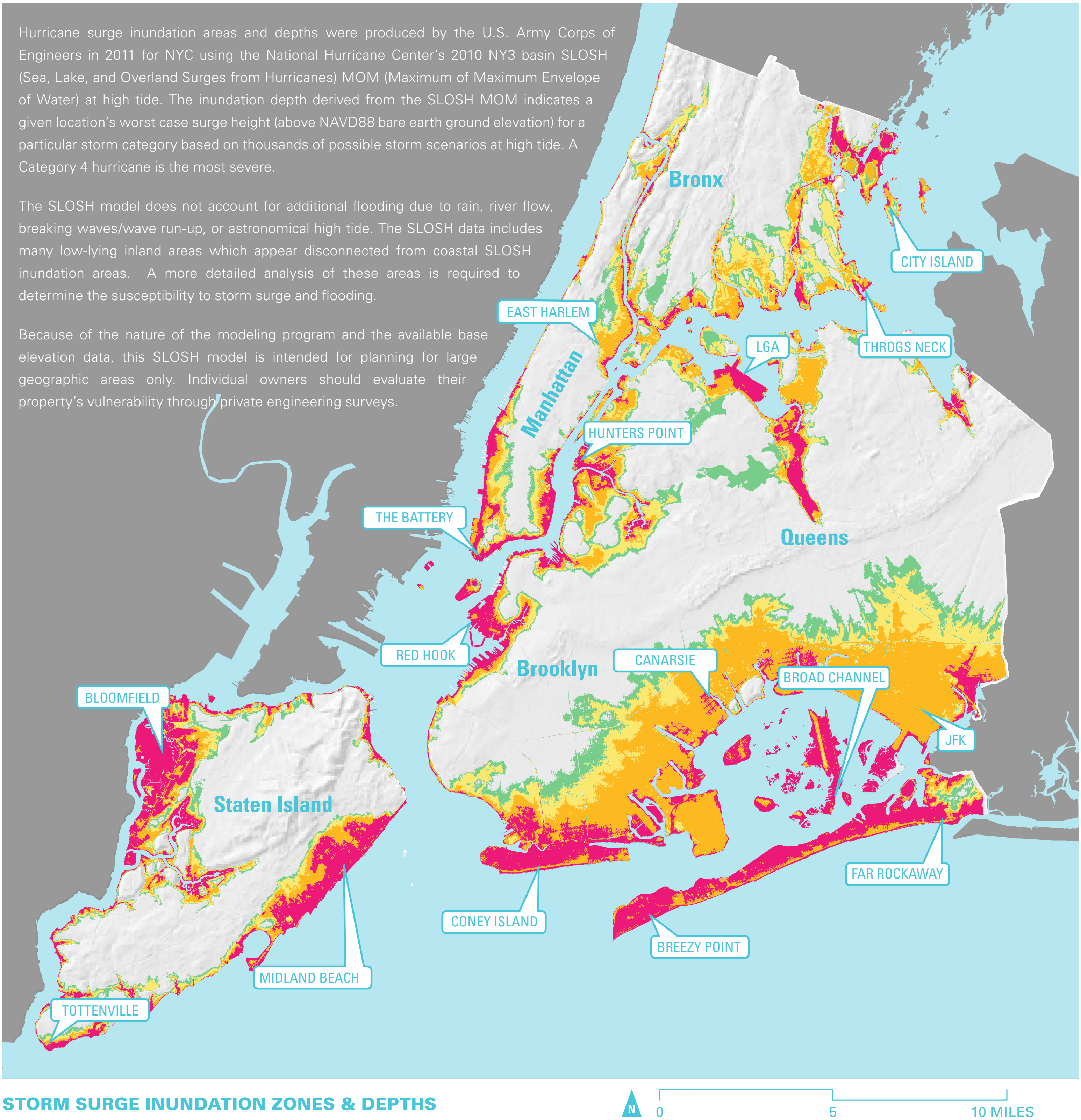
But reporting storm surge can misrepresent the amount of flooding if — for the specific location for which depth of flooding is determined — elevation above mean sea level and tide are not taken into account. That is because factors that determine the amount of flooding at a specific point include tide levels at the time of the storm's landfall, which can range up to eight feet in the New York City area, and land elevation – how high above mean sea level a location is on land. This was a point of confusion among public officials, the media, and the general public during Hurricane Sandy.

To more simply communicate information about predicted storm surge flooding, the National Hurricane Center has developed an experimental *Potential Storm Surge Flooding Map*. Launched for the 2014 hurricane season, this tool shows on a map the potential depth of flooding forecasted during a storm, taking into account uncertainties in the forecast, with periodic updates as the storm progresses.

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 Maximum Envelope of Water) 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 thousands of possible storm scenarios at high tide. A Category 4 hurricane is the most severe.

The SLOSH model does not account for additional flooding due to rain, river flow, breaking waves/wave run-up, or astronomical high tide. The SLOSH data includes many low-lying inland areas which appear disconnected from coastal SLOSH inundation areas. A more detailed analysis of these areas is required to determine the susceptibility to storm surge and flooding.

Because of the nature of the modeling program and the available base elevation data, this SLOSH model is intended for planning for large geographic areas only. Individual owners should evaluate their property's vulnerability through private engineering surveys.



STORM SURGE INUNDATION ZONES & DEPTHS

SOURCE: NHC; USACE

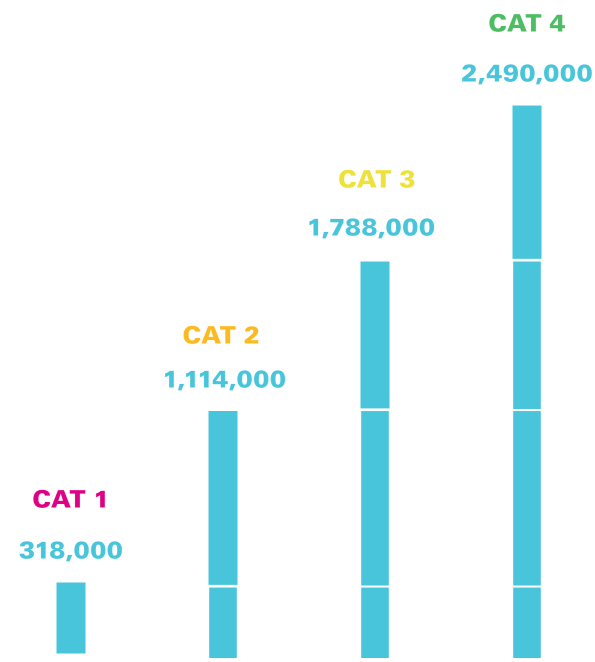
SLOSH MOM CATEGORY

CAT. 1 CAT. 2 CAT. 3 CAT. 4

INNUNDATION DEPTH (SEE MAP ON PG. 52)

SAMPLE LOCATION	CAT 1	CAT 2	CAT 3	CAT 4
The Battery	3′	10′	16′	21′
Bloomfield	8′	14′	20′	27′
Breezy Point	3′	10′	15′	21′
Broad Channel	3′	11′	17′	23′
Canarsie	2′	12′	19′	25′
City Island	4′	10′	16′	21′
Coney Island	3′	10′	16′	21′
East Harlem	0′	4′	10′	15′
Far Rockaway	2′	8′	14′	20′
Hunters Point	3′	9′	15′	20′
JFK	0′	7′	15′	22′
LGA	5′	11′	17′	23′
Midland Beach	10′	16′	23′	28′
Red Hook	3′	10′	16′	21′
Throgs Neck	3;	9′	15′	21′
Tottenville	7′	13′	20′	26′

NUMBER OF NEW YORKERS LIVING IN EACH STORM SURGE INUNDATION ZONE



* Expressed as Cumulative Total

SOURCE: NHC; USACE; US CENSUS

New York City's role as a global financial center and the fact that we are embedded in a large, complex regional economy mean damage to us can reverberate beyond our borders. Conversely, if a major storm were to primarily impact Northern New Jersey or Long Island, its secondary consequences could reverberate here.

The following presents a small sampling of the consequences of major coastal storms. Others are detailed in the Flooding and Strong Windstorms profiles in this chapter. For a more detailed account of the catastrophic damage caused by Sandy, see the chapter "Sandy and Its Impacts" in *A Stronger, More Resilient New York* and the Hurricane Sandy Retrospective Analysis in the *2014 New York City Hazard Mitigation Plan*.

PEOPLE AT RISK

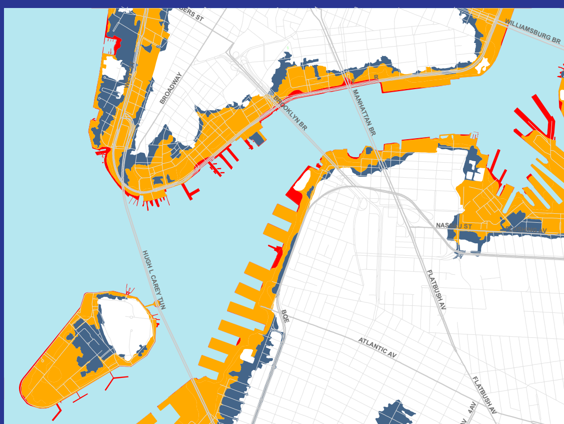
Coastal storms pose dangers to human health and safety both during and after a storm. During a storm, dangers include floodwaters in which people may drown, flying debris, downed trees and power lines, and power loss that may disrupt basic services. If people do not heed evacuation orders, sheltering in inadequate or surge-prone locations carries its own risks. Risks are compounded for vulnerable populations.

Floodwaters, debris on roadways, or damaged public transportation may leave people stranded for a long time. People who are stranded and need medical care will be at increased risk if medical personnel cannot respond promptly and if medical facilities are not operational.

Power outages can disable lighting, refrigerators, air conditioning and heating, hot water, and kitchen appliances. Without electricity, phones cannot be charged. Various types of life support equipment, such as ventilators and oxygen concentrators depend on electricity. Without working elevators, people may be stranded on upper floors of high-rise buildings. Residents stranded in flooded or otherwise damaged homes may be exposed to contaminated floodwaters and the growth of toxic mold, and to food spoilage if power is out for a long time.

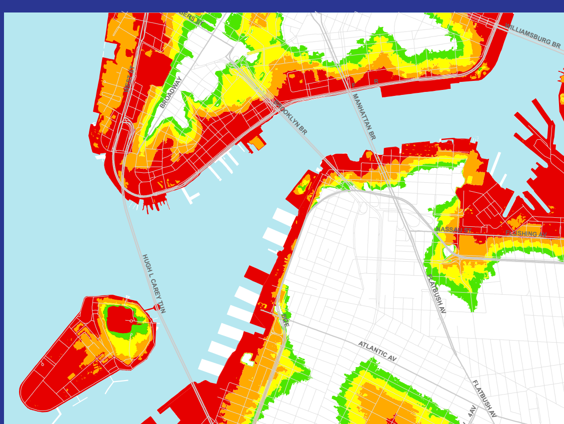
Coastal Flood Maps:
An Overview of Flood, SLOSH, and Evacuation Zones

The Federal Emergency Management Agency (FEMA) Flood Zones are different than SLOSH Storm Surge Inundation Zones and the New York City Hurricane Evacuation Zones. Each set of zones is intended to show areas at risk of storm surge, but the zones are created using different methods for different purposes. FEMA's Flood Zones are developed for flood insurance and building code requirements. SLOSH Storm Surge Inundation Zones and Evacuation Zones determine areas at risk of storm surge for life safety.



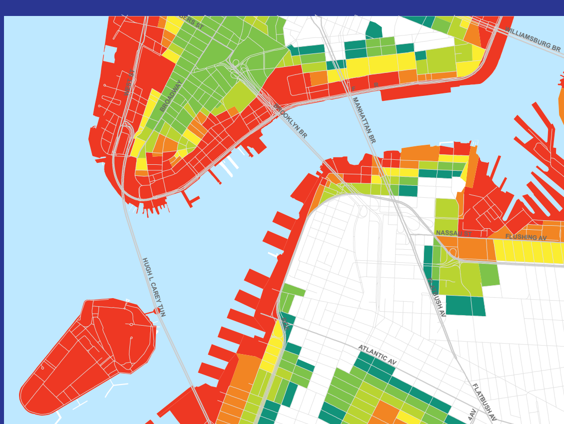
FEMA Flood Zones

FEMA creates Flood Insurance Rate Maps (FIRMs) as part of the National Flood Insurance Program (NFIP) to demonstrate flood risk and determine flood insurance requirements. FEMA models a set of storms that determine flood risk and the probability of flooding for a region. This flood risk is represented by different flood zones on a FIRM. These flood zones (V, A and Shaded X zones) inform property owners of the annual risk of flooding of their property. For example, the V and A zones (the 100-year floodplain) have a 1 percent annual chance of flooding in any given year. Properties located in this high risk area are required to carry flood insurance if the property has a federal mortgage. These maps also determine building code requirements and zoning regulations.



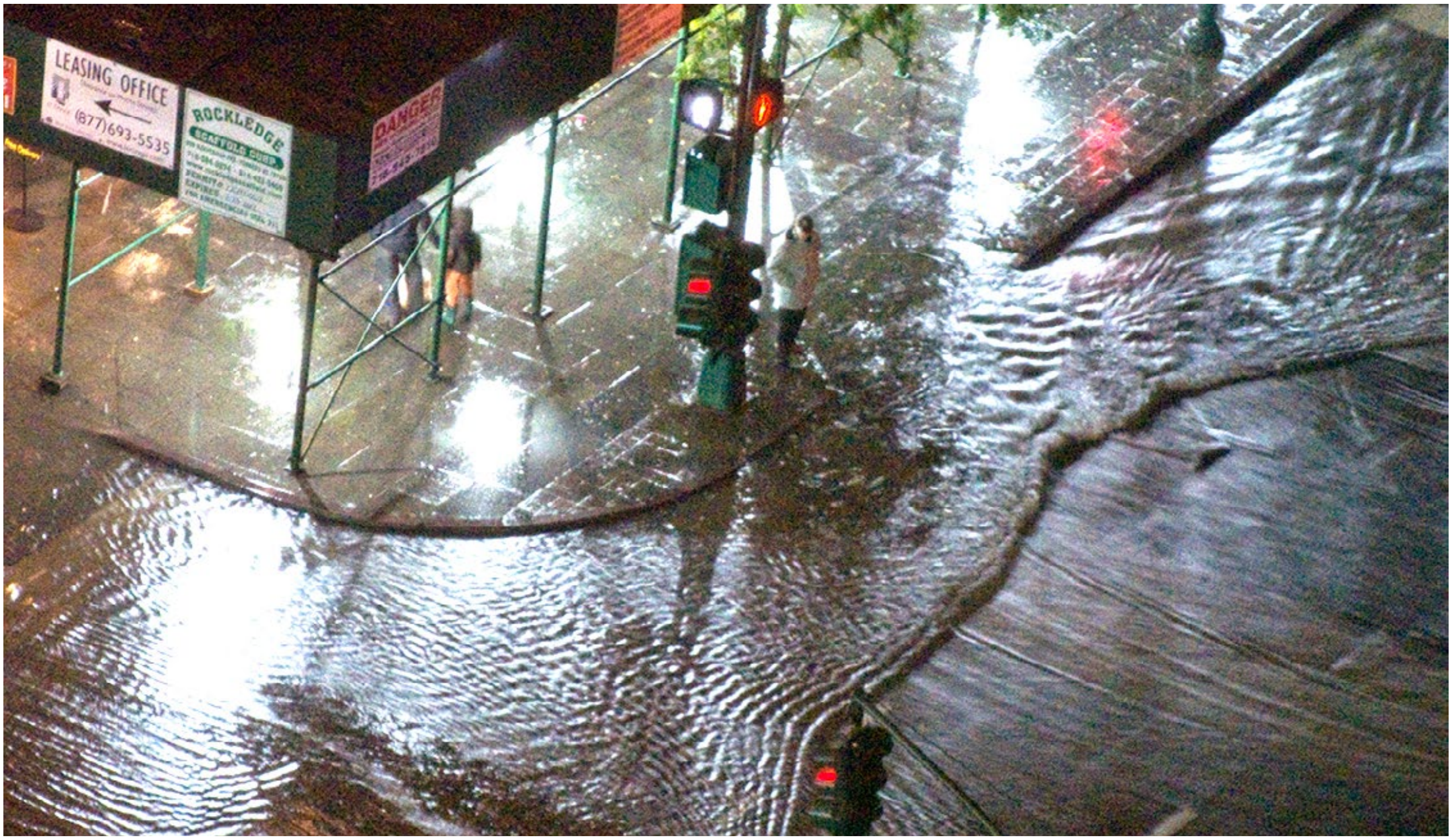
SLOSH Storm Surge Inundation Zones

The National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is used to calculate the risk of flooding from hurricane storm surge. SLOSH models thousands of storm scenarios for the region, creating storm surge inundation zones that show the worst case flooding for each hurricane storm category (1-4). SLOSH does not include wave action or rainfall and does not assign a probability, or likelihood, that this worst case storm surge will occur at any given location. SLOSH is used to develop evacuation zones for localities throughout the country.



New York City Hurricane Evacuation Zones

The New York City Emergency Management Department uses the storm surge inundation zones from SLOSH to create evacuation zones. New York City has six evacuation zones, zones 1-6, which were updated in 2013. These zones represent areas that may be inundated by or isolated by storm surge. The evacuation zones take into account different storm characteristics, including the bearing of the storm as it approaches the region, the storm intensity, characteristics of the community and built environment, and evacuation considerations. Hurricane Evacuation Zones are specifically used for life safety purposes and do not apply to building, zoning, or insurance regulations.



SANDY WEST ST FLOODING
SOURCE: MTA

BUILDINGS AT RISK

During coastal storms, buildings are at risk of damage from wind, flooding due to heavy rain or storm surge, and wave action. Flying or floating debris can cause additional damage. Mechanical systems, utilities such as electricity and natural gas, fire suppression systems, and telecommunications can all be compromised by flooding and wind. (For more information on vulnerable building types, see Flooding and Strong Windstorms.)

Potential wind damage to buildings resulting from various storm scenarios was calculated by New York City Emergency Management's GIS unit using the FEMA HAZUS-MH model. This analysis predicted that winds from a coastal storm that would be expected to occur on average once every 100 years would damage nearly 40,000 buildings and cause over $3.5 billion in damage. Winds from a storm that would occur on average every 1,000 years would be expected to damage nearly 450,000 buildings – almost half of the city's building stock – and result in nearly $53.6 billion in damage.

INFRASTRUCTURE AND ESSENTIAL SERVICES AT RISK

According to SLOSH model analysis conducted by NYC Emergency Management's GIS unit, nearly 40 percent of the city's critical facilities and infrastructure are located within a storm surge zone (see table 3.6.33 in the *2014 New York City Hazard Mitigation Plan*). This includes healthcare facilities, schools, power plants, wastewater treatment plants, and emergency response facilities.

Much of New York City's aging transportation and utility infrastructure is vulnerable to coastal storm damage. This includes subway tunnels and stations, bus depots in low-lying areas, bridges, and vehicle tunnels. Breakdown of public transportation could leave many people stranded, which would cause a number of secondary social and economic impacts, particularly for people who must travel to work or school, or obtain medical care.

Due to sea level rise, coastal flooding from a future Sandy-like storm is likely to cause even more extensive damage. Lesser storms will reach the same flood elevations as Sandy more readily and more often.

Shortages of liquid fuels may result if supply chains are disrupted by damage to fuel terminals, pipelines, and storage tanks. This can lead to long lines at the limited number of gas stations where fuel is available. Fuel shortages could also impede emergency response.

Vulnerable utilities include aboveground telecommunications and power distribution infrastructure, such as power lines and electric substations that are directly exposed to wind, flooding, or falling trees and debris. Underground power and telecommunications equipment is not exposed to wind but is at risk of flooding in some locations.

All of the City's 26 power generation facilities are located in storm surge inundation zones, which increases the risk of a citywide outage during a major storm.

ECONOMY AT RISK

The impacts of a major coastal storm could cause economic damage extending far beyond our city and our region. Locally, businesses could lose revenue because of damage to the buildings they occupy and the contents of those buildings, including inventories and equipment. Storm damage to energy and telecommunications systems could disrupt business operations. Employees could be stranded and unable to get to work. Customers could be forced to stay home. Tourism could suffer.

A global financial capital, New York City has tremendous assets in Lower Manhattan, home to Wall Street and two of the world's largest stock exchanges. That area is particularly vulnerable to storm surge flooding.

Huge quantities of goods enter and exit the United States through the Port of New York and New Jersey. Damage to port facilities can restrict the flow of imported goods to other parts of the country and delay U.S. exports.

THE ENVIRONMENT AT RISK

Intense storms can permanently submerge wetlands, cause barrier islands to narrow or split, and erode beaches and dunes. The loss of these natural storm barriers leaves wooded areas and parks farther inland more exposed to the impacts of wind and storm surge.

If facilities that store toxic or hazardous materials are flooded, those materials could be dispersed and threaten marine habitats.

Other environmental impacts include the loss of coastal vegetation due to saltwater flooding and tree damage due to high winds.

FUTURE RISK

In determining how to prepare for and respond to coastal storms, we must understand how climate change could affect those storms.

For the North Atlantic, climate scientists predict that warmer ocean temperatures will cause the most intense tropical cyclones to become more frequent, while the overall frequency of storms may decrease slightly. While these projections carry a significant degree of uncertainty, emergency managers and planners know that, independent of climate change's effects on storms, the fact that climate change is raising sea levels will make coastal storms' consequences more severe. This is because, as ocean water warms, it expands and increases in volume, causing the water level to rise. Global warming is also causing land glaciers and polar land-based ice caps (the Greenland and Antarctic ice sheets) to melt at a faster rate, which increases the amount of water in the oceans. This additional height boosts storm surge, and it floods some areas that would otherwise have remained dry.

Thus, as sea levels continue to rise, storm surge flooding will cause more frequent, more severe, and more extensive damage than it does today.

Since 1900, local sea level has risen over 1 foot in New York City. During Sandy, that extra foot of storm surge flooded locations that would have previously remained dry. Taking sea level at the beginning of the 21st century as the baseline, sea level rise around New York City is projected to rise as much as 2.5 more feet by the middle of the century, and possibly over 6 more feet by the end of the century. Thus, coastal flooding from a future Sandy-like storm is likely to cause even more extensive damage, while storm tides from lesser storms will reach elevations as high as Sandy more readily and more often.

Note: Selected strategies for reducing the risks identified above are discussed in the Flooding and Strong Windstorms profiles of this chapter.

HURRICANE SANDY

Hurricane Sandy, which made landfall on October 29, 2012, was not in any way a typical storm. It was a hybrid, with characteristics of both a hurricane and a nor'easter, which is very unusual. A number of factors contributed to the record storm surge experienced in parts of the city. Although its winds were only the equivalent of a Category 1 hurricane, Sandy's massive size – nearly three times that of an average hurricane – increased the height of the waves and storm surge, causing extensive damage over an extremely large area.

Never before had any storm followed a track that featured such an abrupt westward turn: it put the entire region's dense concentration of people, property, and infrastructure in harm's way. Sandy's coincidence with the full moon, and thus tides which were already higher than normal, added an additional 3 feet to the 11-foot storm surge experienced at the Battery, the southern tip of Manhattan.

Hurricane Sandy was the costliest natural disaster in New York City's history. Winds of up to 90 mph combined with a storm surge that reached more than 14 feet (as recorded at the Battery), caused 44 deaths and approximately $19 billion in economic losses. Nearly 70,000 housing units were damaged, displacing roughly 150,000 residents.

The city also suffered extensive flooding of subway, PATH, commuter train, and Amtrak tunnels; the Hugh Carey Brooklyn-Battery and Queens-Midtown vehicular tunnels; and critical facilities including power substations, hospitals, and wastewater treatment plants. Power outages affected many homes and businesses, causing significant economic losses.

The liquid-fuels supply chain experienced widespread failure, due mainly to reduced output at refineries and damaged storage tanks, terminals, pipelines, and other infrastructure.

Since Sandy, much progress has been made to restore the city, but in some areas recovery will continue for years. What has been learned from that storm is already, in many ways, making us better prepared for the next one, as evidenced in the $20 billion plan for making the city more resilient that is detailed in *A Stronger, More Resilient New York*.

COASTAL EROSION
CHAPTER 4.2

Coastal erosion plays a significant role in New York City's retreating coastlines. It also amplifies the city's vulnerability to a variety of hazards including coastal storms, which deplete natural resources, damage infrastructure and expose New Yorkers to the risk of physical harm as well as economic hardship.

WHAT IS THE HAZARD?

In its natural state, our coastline is in dynamic equilibrium. Wind and waves move sand and sediment from one location to another, and what is eroded is replaced with sand and sediment from somewhere else. Coastal storms may remove significant amounts of sand, creating steep, narrow beaches. As long as sand and sediment are not removed from the entire system during storms, waves will return them during calmer periods, widening beaches and creating gentle slopes.

However, human activities such as dredging, construction, and land use management may permanently remove sand and sediment. In some cases, even ill-conceived erosion control structures built to prevent erosion in one location may actually increase it in adjacent locations by blocking sand movement, deflecting or increasing wave energies, and removing vegetation, thus disrupting the natural balance of shoreline change.

Long-term shoreline change can occur gradually or rapidly—as it does during storms. During the most intense storms, entire beaches may be eroded, while other portions of the shoreline, such as bluffs, may become unstable and collapse. How quickly a shoreline erodes can be hard to measure over time, as rates vary from one year to the next and may be masked in areas that undergo periodic beach nourishment. One way that geologists measure erosion is as a rate of shoreline loss per year.

WHAT IS THE RISK?

Erosion has already diminished portions of New York City's 520-mile coastline. While much of the city's coastline is densely developed and engineered, around 30 percent of it consists of parks and recreational areas.

Along our coastline, erosion rates vary significantly depending on the exact location and type of geology. Areas along the city's southern shore are at greatest risk, as they are exposed to wave action from the Atlantic Ocean. Some of the highest erosion rates have been observed near stabilized inlets and engineered structures – like groins or seawalls – that disrupt the natural movement of sand and sediment.

AREAS AT RISK

The New York State Department of Environmental Conservation's Coastal Erosion Management Permit Program identifies and regulates areas particularly vulnerable to coastal erosion. The State has identified three such Coastal Erosion Hazard Areas in New York City:

- Coney Island, in Brooklyn
- Rockaway Peninsula, in Queens
- The south shore of Staten Island

SEAGATE GROIN

SOURCE: USACE/BROOKLYNDAILY.COM

Since its construction in 1995 (before photo), the groin that extends into the water perpendicular to the shore, has worsened erosion on the western side (after photo), exposing property, while the beach on the east side has remained intact.

NYC COASTAL EROSION HAZARD AREAS
SOURCE: OEM; NYS DEC (CEHA)

LOCATION OF BUILDINGS IN NYC COASTAL EROSION HAZARD AREAS
SOURCE: OEM; NYS DEC (CEHA)

The New York State Department of Environmental Conservation is currently evaluating and updating the State's Coastal Erosion Hazard Area maps to reflect changes in hazard area boundaries that have occurred since the current maps were developed in the 1980s. These maps will provide a more accurate identification of shoreline features and historical erosion rates than was attainable when the current maps were developed. New maps are currently under development for Coney Island and the south shore of Staten Island, and drafts of these maps are expected to be released for public review in 2015. For the Rockaway Peninsula, the map revision process will begin after the U.S. Army Corps of Engineers (Army Corps) completes the ongoing beach restoration project in late 2014.

Erosion occurs at a much faster rate during coastal storms, when large sections of beaches, dunes, and bluffs may be lost in a matter of days or even hours. For example, according to the Army Corps, 3.5 million cubic yards of sand in the Rockaway Peninsula and 679,000 cubic yards of sand in Coney Island were lost during Hurricane Sandy.

VULNERABILITY

Coastal erosion can damage public and private property and infrastructure because it brings the water's edge closer. Unchecked, erosion may eventually result in structures becoming flooded or the ground beneath them giving way. This could undermine foundations, resulting in structural failure or collapse.

GIS analysis shows approximately 1,428 acres and roughly 135 buildings and other structures located within New York City's Coastal Erosion Hazard Areas. The majority of these structures, with the exception of one hotel complex on the Rockaway Peninsula, are not permanently occupied or of high market value (for example, they include public bathrooms and beach concession stands). But as natural buffers and recreational areas – such as wetlands, dunes, beaches, bluffs, sand bars, and barrier islands or spits – are eroded, the Coastal Erosion Hazard Area boundaries may migrate landward, putting structures not currently threatened at greater risk. Significantly, those natural features also protect property and structures from other hazards such as storm surge and wave action.

SHORELINE CHANGE IN ANNADALE, STATEN ISLAND 1924-2012
SOURCE: NYC DOITT (IMAGERY), NYC OEM

Sea level rise is expected to worsen coastal erosion, especially during significant storms. According to the New York City Panel on Climate Change, sea level around New York City has risen 1.1 feet since 1900 and is projected to rise up to an additional 2.5 feet by 2050. However, it is not currently possible to determine exactly how much erosion is directly attributable to sea level rise.

HOW DO WE MANAGE THIS RISK?

Much of our shoreline has already been engineered to protect against erosion. However, areas highlighted on the map still face a chronic threat. Much of our shoreline is owned and managed by public entities, although several private sector parties also play roles. An integrated approach for managing coastal erosion risks involves a combination of major structural protections, environmental controls, and regulatory and policy controls. The following section identifies a sampling of the strategies.

MAJOR STRUCTURAL PROTECTIONS

As mentioned above, structures intended to prevent erosion may in fact increase it. But in many cases, such structures remain the only feasible option for significantly reducing erosion and flooding during major storms, given the financial and political realities of the real estate landscape and environmental concerns. Engineered structures that are properly sited and sized, on the shore or in the water, can help limit the forces of coastal erosion and hold the shoreline in place. Which kind of structure to build depends on the specific features of the location.

On-shore structures

- **Seawalls** are massive stone, rock, or concrete structures built parallel to the shoreline and designed to hold the shoreline in place while resisting the force of waves and erosion.

- **Revetments** are structures typically made of stone rubble or concrete blocks (also known as riprap)

GROINS ALONG THE ROCKAWAY PENINSULA
SOURCE: NYC DCP, 2013

placed on a sloped surface to protect underlying soil from erosion and to reduce wave forces.

- **Bulkheads** are vertical retaining walls, typically made of wood or sheet steel, intended to hold soil in place and allow for a stable shoreline.

In-water structures

- **Groins** are structures that extend perpendicular from the shore into the water to trap sand, prevent erosion, and break waves.
- **Breakwaters** are offshore structures parallel to the shoreline that are typically made of rock. By breaking waves, they reduce erosive forces on the shoreline.
- **Artificial reefs** are fully or partially submerged structures made of rock, concrete, or other materials that are designed to break waves, reduce erosive forces on the shoreline, and provide marine habitat.

As a result of collaborations among New York City, the Army Corps, and the New York State Department of Environmental Conservation, many engineered erosion-control structures are in place along our coastline. For example, along the Rockaway Peninsula, groin construction began between 1922 and 1927, and today there are 48 groins in Jacob Riis Park/Fort Tilden towards the western end of the peninsula. There are also series of bulkheads and riprap revetments along inland waterways like the East River.

Other areas targeted for such measures include Riker's Island in the East River – where the City's Department of Corrections is designing a project to harden the erosion-prone northern shoreline – and Plumb Beach in Brooklyn, where the Army Corps, in partnership with the City's Department of Parks and Recreation, is completing the construction of groins and a breakwater to protect the Belt Parkway.

WATER EDGE TYPE
SOURCE: NYC DCP, 2011

EDGE CLASSIFICATION

NATURAL

- SANDY
- MARSHY
- ROCKY
- UNDEFINED

ENGINEERED

- BULKHEAD
- RIPRAP
- PIERS FILLED
- PIERS ON PILES

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

ENVIRONMENTAL CONTROLS

Placing natural buffers and protective features on the shore or in the water can help hold the shoreline in place.

On-shore controls

- **Beach nourishment** is the process of placing sand (typically dredged from nearby ocean bottoms) on engineered beaches to increase the elevation and distance between upland areas and the shoreline. This creates a buffer that dissipates storm and wave energy away from formerly eroding areas.
- **Vegetation** is often planted on beaches, dunes, and unstable shorelines to anchor sand or soil in place.
- **Living shorelines** consist of plants, sand, or soil, often combined with hard structures, to stabilize the shoreline, prevent erosion, and maintain habitats.

In-water controls

- **Constructed wetlands** are new or restored tidal wetlands that use plants to anchor the soil in place, prevent erosion, and create wildlife habitat.
- **Vegetated islands** are offshore floating or fixed structures, such as anchored mats or infill islands, that can prevent erosive forces by breaking waves. They provide ecological benefits as well.

New York City has been pursuing beach nourishment since the early twentieth century. For example, an estimated 25 million cubic yards of sand were placed on Rockaway Peninsula beaches between 1922 and 1999. The City continues to pursue beach nourishment and other "soft" stabilization projects along open ocean shorelines.

On the Rockaway Peninsula, the Army Corps and the State, with the support of the City's Department of Parks and Recreation, are completing restoration activities on beaches devastated by

BEACH NOURISHMENT AT ROCKAWAY BEACH
SOURCE: USACE, 2013

Hurricane Sandy to their originally authorized profiles. Future beach maintenance is being evaluated as part of a reformulation study.

On Coney Island, repair and restoration activities have been completed. Upcoming project modifications are being implemented to reduce rapid erosion and undesirable migration of placed fill.

The City is also beginning to explore environmental alternatives such as living shorelines and constructed wetlands. Brooklyn Bridge Park has become a laboratory for innovative softer shoreline design, including living shorelines with wetlands, a sand beach, and offshore reefs.

REGULATORY AND POLICY CONTROLS

Coastal erosion can also be reduced through smarter land use methods and by limiting development in erosion hazard areas. The New York City Department of City Planning is the local lead in managing and protecting our waterfront. It manages the *NYC Waterfront Revitalization Program*, which provides guidance for ensuring projects are consistent with local goals and State and Federal policies.

For new development, the State Department of Environmental Conservation enforces regulations within all State-designated Coastal Erosion Hazard Areas. Properties in those areas are regulated under the State's Environmental Conservation Law, which limits coastal development in order to protect sensitive areas. The Coastal Erosion Management Regulations (6 NYCRR Part 505) provide for a permitting program that addresses all proposed construction in the Coastal Erosion Hazard Areas. The construction or placement of a structure, or any action or use of land which materially alters the condition of land, including grading, excavating, dumping, mining, dredging, filling or any disturbance of soil, is a regulated activity which may require a Coastal Erosion Management Permit from the Department.

There are two separate jurisdictions that make up the Coastal Erosion Hazard Areas. They are as follows:

- Natural Protective Feature Areas – These areas protect New York State's natural protective features (which include nearshore areas, beaches, bluffs, and dunes). Alterations of these areas may reduce or eliminate their protection, and lower the reserves of sand or other natural materials available to replenish storm losses through natural processes. The landward limit of the Natural Protective Feature Area is delineated on the Coastal Erosion Hazard Area Maps.

- Structural Hazard Areas – These are regulated areas landward of the Natural Protective Feature Areas, and are only delineated along shorelines that are receding at an average rate of one foot or more per year. The landward limit of the Structural Hazard Area, if applicable, is delineated on Coastal Erosion Hazard Area Maps. Currently, no there are no Structural Hazard Areas within New York City, although this may change with the updated maps currently under development.

Other types of regulatory measures include the following:

- **Construction permits** are often required by coastal erosion management regulations for new construction or modification of existing structures, to ensure they will not worsen erosion.

- **Setbacks or buffers** specify a minimum distance from the erosion hazard area for land use or development of new structures along the shoreline. Regulatory setbacks are identified on the State's Coastal Erosion Hazard Area maps. The setbacks are only marked in areas with a long-term average erosion rate of 1 foot or greater per year.


30
MPH

FLOODING

CHAPTER 4.3

New York City's 520 miles of shoreline border the ocean, rivers, inlets and bays, and a harbor that is home to the largest port on the East Coast. Our coastline has been a defining characteristic of our way of life and given way to diverse waterfront communities. Yet, it also makes us vulnerable to various types of flooding. Climate change is likely to increase these flood risks.

WHAT IS THE HAZARD?

A flood is an overflow of water from oceans, rivers, groundwater, or rainfall that submerges areas that are usually dry. This natural phenomenon results from a combination of weather and hydrologic processes that can be exacerbated by features of the built environment.

Floods can damage and destroy property and natural resources, and cause loss of life. New York City is subject to four kinds of flooding:

FLOOD TYPES IN NEW YORK CITY

Coastal flooding

Coastal flooding is primarily caused by storm surge – the rise in water levels caused by a storm's strong winds and low atmospheric pressure. Storm surge occurs when a strong coastal storm, such as a tropical storm, hurricane, or nor'easter, approaches land, the surge "piles" up at the water's edge, raising water levels and flooding coastal areas.

A storm's impact can increase significantly when a storm hits at high tide.

Wave energy, particularly when combined with wind energy, can cause sudden erosion of beaches, bluffs and can significantly damage buildings. With or without waves, coastal flooding can cause extensive damage, for example, due to salt water corrosion.

Tidal flooding

Tidal flooding is caused by normal variations in the lunar cycle. Sea levels fluctuate daily due to gravitational forces and the orbital cycles of the moon and Earth. Every day brings two high tides and two low tides. Due to our city's size and geography, cycles of high and low tides vary – it could be low tide at the Battery in Lower Manhattan while it is high tide at Kings Point on the Long Island Sound. Daily high tides are at their highest twice a month, during what are known as "spring tides," when the Earth, sun, and moon are aligned.

Some portions of the city are so low-lying that they flood from high tides today. With projected sea level rise, these areas will likely experience more flooding from normal daily and monthly high tides in the near future.

FLOOD TYPES

Many critical infrastructure systems and services are located along the waterfront out of operational necessity.

Inland flooding

Commonly called "flash floods" or "urban floods," inland floods can be caused by short-term, high-intensity rainfall (torrential downpours) often associated with sudden thunderstorms or hurricanes and other large-scale storms. Inland floods can also be caused by moderate rainfall over several days, typically brought on by weaker storms that drift slowly or stall over an area.

The characteristics of New York City's built environment – dense, heavily paved, and built on landfill in what were once wetland areas – limit the ground's capacity to absorb or drain water, raising the risk of inland flooding. Localized floods typically result when the design capacity of sewer and stormwater infrastructure is exceeded. Natural drainage conditions and the surface characteristics of an area, including topography and imperviousness, also influence how easily water can flow and drain.

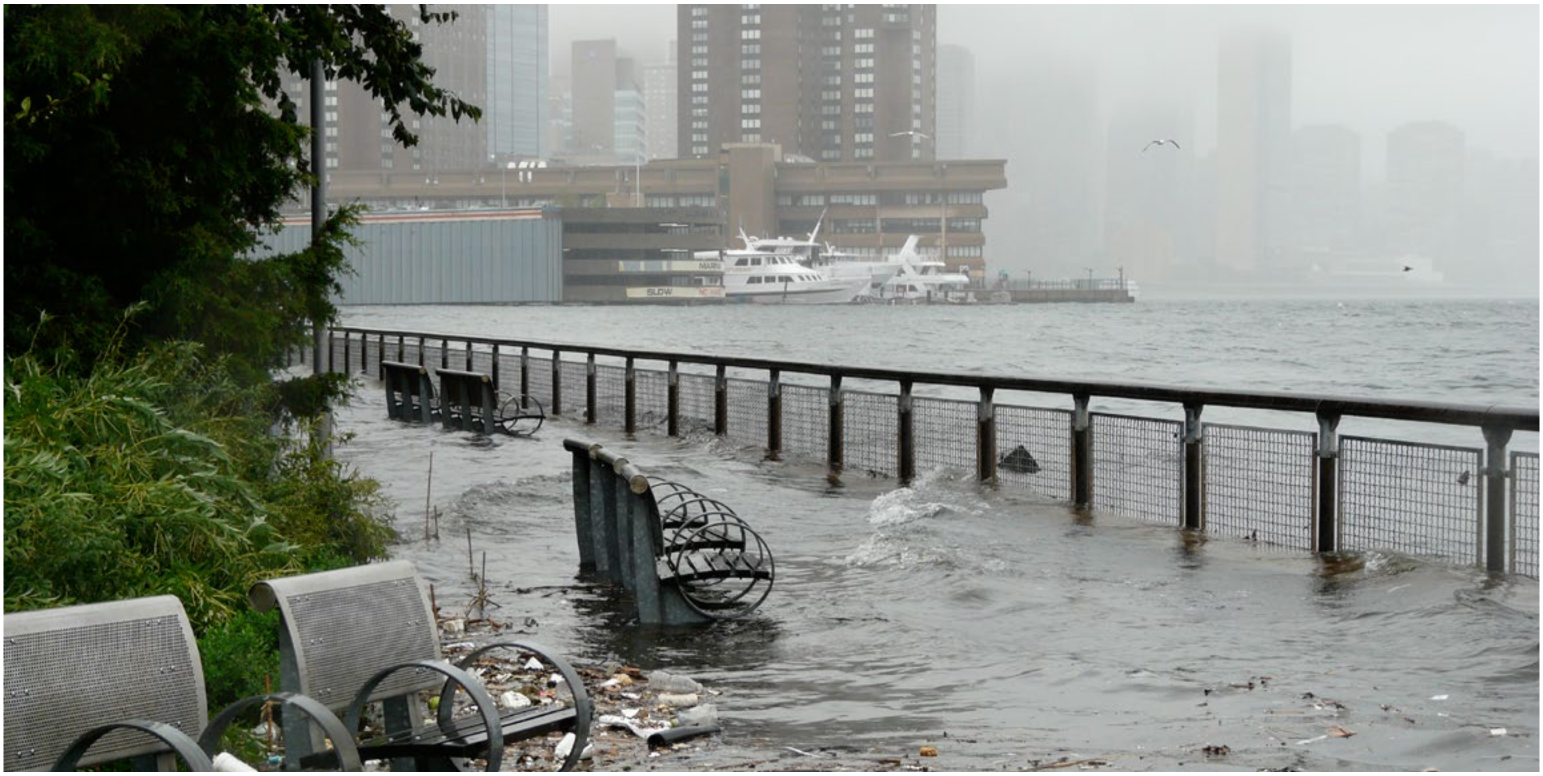
Riverine flooding

A riverine flood occurs when a heavy rain or storm causes rivers and streams to overflow their natural or artificial channels, spilling into adjacent, low-lying areas. Erosion of riverbanks and stream banks will likely increase our risk of riverine flooding.

WHAT IS THE RISK?

NEW YORK CITY'S UNIQUE FLOOD RISK LANDSCAPE

The impact of each flood type is shaped by the unique features and conditions of our city's coastline and landscape. A set of factors, many of which converge, makes us particularly vulnerable to flooding.



STUYVESANT COVE FLOODING FROM EAST RIVER SURGE DURING SANDY

The elevation and slope of the shoreline can influence how storm surge behaves and how sea level rise will affect an area. Shoreline conditions include soft edges that are marshy or sandy as well as hardened edges that are reinforced with rock and/or concrete. Proximity to the open ocean exposes the coastline to wave action. Low-lying areas, whether on the coast or inland, are at risk of flooding. The geography of the New York Bight – the right angle formed by Long Island and New Jersey – can increase the effects of storm surge by funneling the water into the New York Harbor.

New York City's incremental development over the centuries has resulted in a mosaic of building types, infrastructure networks, and land uses along its coast. This includes stretches of coastal marshland in Jamaica Bay, residential neighborhoods consisting of small wood-frame bungalows along oceanfront beaches, Manhattan's dense commercial districts, and industrial and post-industrial areas along the New York Harbor. Many critical infrastructure systems and services are located along the waterfront out of operational necessity.

Much of our city was built before modern flood-proofing design regulations were developed, making them particularly vulnerable to flooding`.

UNDERSTANDING FLOOD RISK NOW AND IN THE FUTURE

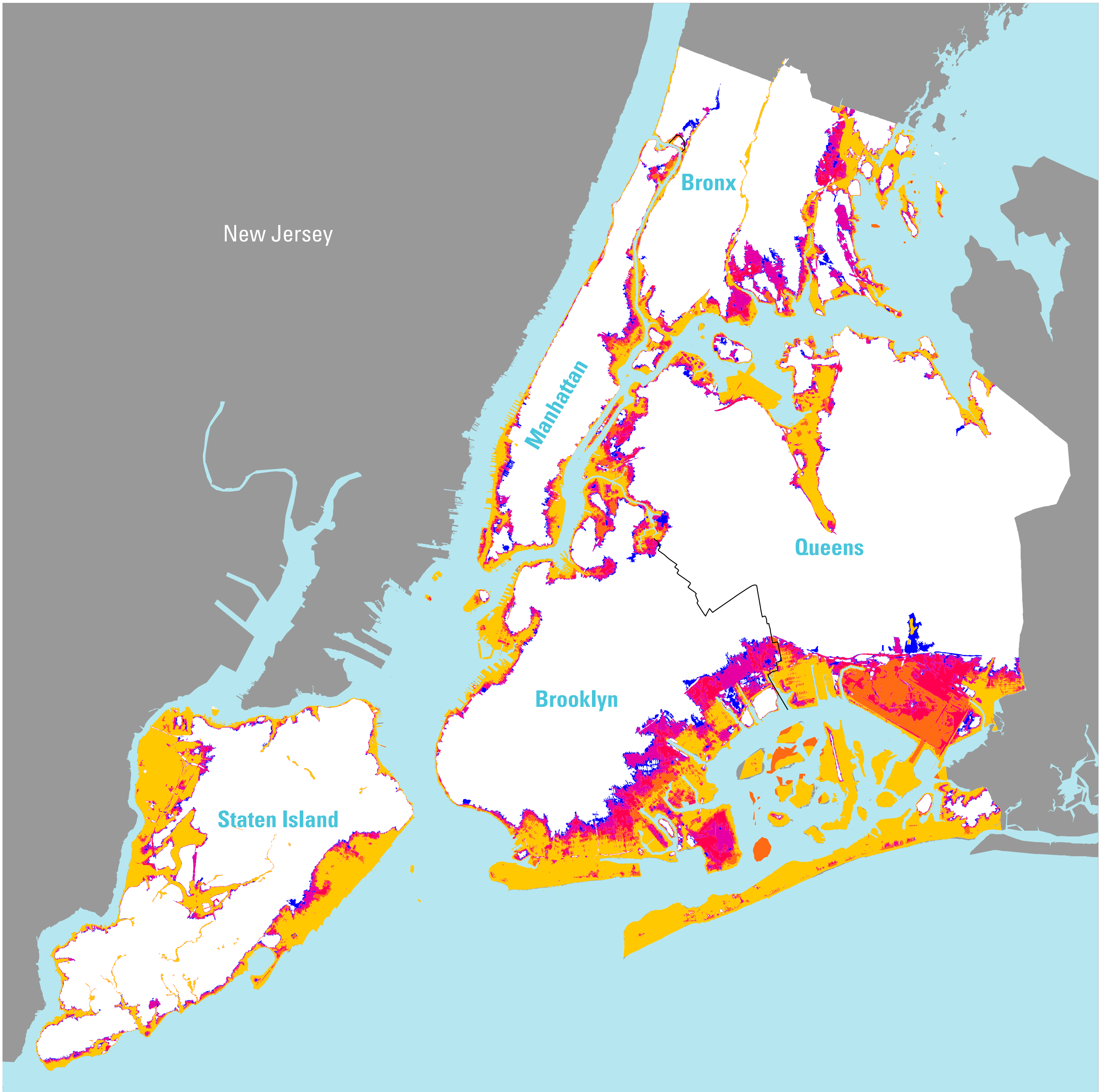
To understand our flood risk, we need to understand the likelihood of flood events, the extent of our exposure, and the potential impact of each flood type.

New York City is most at risk of flooding from coastal, tidal, and inland floods. Riverine flooding is most common across New York State, but occurs less often and less severely here, where our rivers and stream networks are limited and drain small areas. It is possible for two or more kinds of flooding to occur simultaneously.

The likelihood of each type of flood occurring can change over time as a result of climate change and the dynamic nature of shorelines. The built environment is dynamic, too, as design and maintenance of flood protection systems and drainage infrastructure evolve, and neighborhood composition and land uses change.

COASTAL FLOODING

To determine coastal and riverine flood risk, as well as flood insurance and building code requirements,



CURRENT AND PROJECTED 1 PERCENT ANNUAL CHANCE FLOODPLAIN

SOURCE: FEMA; CUNY INSTITUTE FOR SUSTAINABLE CITIES

* DATA REFLECTS NPCC'S HIGH-END (90TH PERCENTILE) PROJECTIONS

N 0 5 10 MILES

PRELIMINARY FEMA FIRM	1 PERCENT ANNUAL CHANCE FLOODPLAIN			
2013	2020's	2050's	2080's	2100's

New York City primarily relies on FEMA's Flood Insurance Rate Maps (FIRMs), which define the federal government's assessment of flood risk for the National Flood Insurance Program (NFIP). Until recently, FEMA's maps had not been significantly updated since they were first created in 1983. A new flood study was conducted by the FEMA in 2009, and new Preliminary Flood Insurance Rate Maps (PFIRMs) were released in December 2013. Roughly 400,000 New Yorkers, 71,500 buildings, and 532 million square feet of floor area are located within the updated 100-year floodplain, also known as the 1 percent annual chance floodplain (because there is a 1 percent or greater chance of flooding in any given year).

New York City uses a hurricane storm surge model, developed by the National Hurricane Center and United States Army Corps of Engineers, to develop the City's hurricane evacuation zones. These zones are used for life safety purposes and are not the same as the FEMA flood zones. Additional information about evacuation zones can be found in the Coastal Storms section.

The FEMA flood maps only reflect current flood risk. It is likely that our floodplains will extend even further in the future. Sea levels have already risen roughly 1 foot in the last century. The New York City Panel on Climate Change, a group of leading scientists and risk management experts convened by the city, developed a range of sea level rise projections (low, medium, and high estimates) over the next century (2020s, 2050s, 2080s and 2100) and found higher sea levels are very likely for New York City in the coming decades. Middle-range projections range from 4 to 8 inches by the 2020's, 11 to 21 inches by the 2050s, 18 to 39 inches by the 2080s, and by the 2100s, as much as 50 inches.

Flooding of coastal areas can also result from high tide. Low-lying neighborhoods throughout the city are already affected by flooding from daily and monthly high tides. As sea levels rise, these low-lying neighborhoods will gradually become more vulnerable to regular flooding from high tides, and parts of the city that currently do not flood will begin to.

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

The terms "100-year" and "500-year" flood can provide a false sense of security. A 100-year flood is not the flood that happens once every 100 years. Rather, it has a 1 percent or greater chance of occurring in any given year. Experiencing a 100-year flood does not decrease the chance of a second 100-year flood occurring that same year or any year that follows.

Even the 1 percent concept can be misleading because, when the years add up, so does the probability. A 100-year flood today, independent of future sea level rise and other climate change effects, has a 26 percent chance of occurring over the life of a 30-year mortgage. Similarly, a 100-year flood today has a 45 percent chance of occurring over the 60-year life of a power substation.

INLAND FLOODING

Unlike coastal and tidal floods, inland ("flash") floods can strike with little or no warning. Their probability can be hard to predict, because the storms and other weather events that are usually responsible for heavy rainfall are often localized. Inland flooding is unrelated to the 1 percent annual chance floodplain designation.

Also, the local topography and nature of the surface area – such as whether it is paved or not; whether it is flat or contains depressions – can help create or exacerbate an inland flood. These local features can make it harder to determine exactly when or where an inland flood might occur, even if the storm or rain event has been forecast.

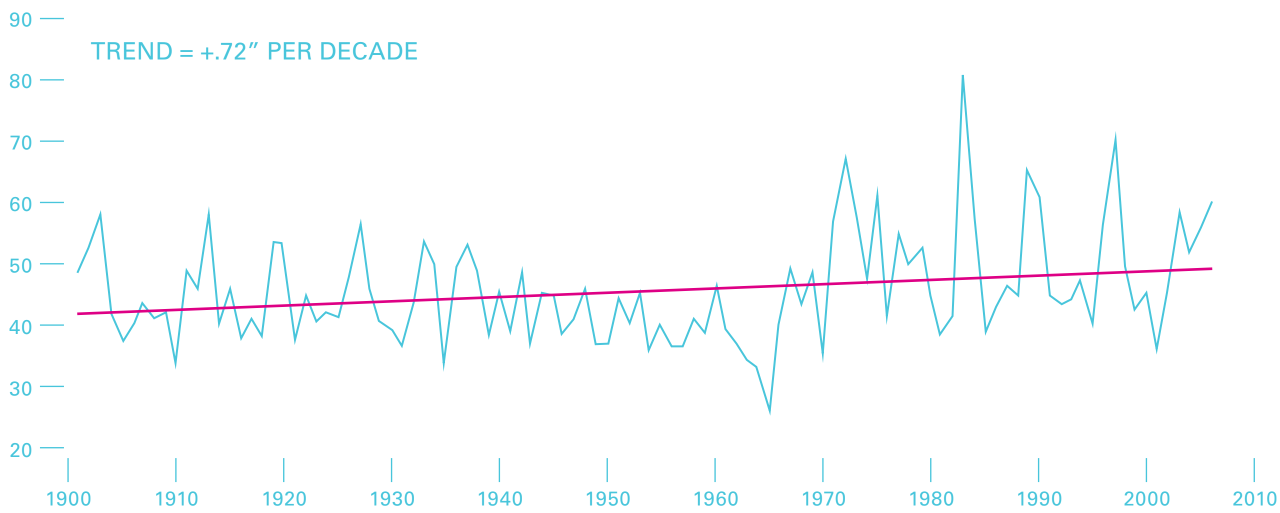
Another complicating factor is the City's sewer system, much of which collects and conveys runoff from rainstorms and snowmelt in the same sewer lines that carry wastewater from buildings and industrial facilities. The system was designed to meet an engineering assumption about rainfall intensity for a 5-year storm base: that 1.75 inches of rain would fall per hour. However, the climate trend toward more and heavier rainfall is taxing the sewer system's capacity.

RIVERINE FLOODING

For Staten Island and parts of the Bronx, where the city's riverine areas are primarily located, heavy precipitation has overwhelmed the flow capacity of rivers and streams, as well as local storm sewers, increasing inland floods.

ANNUAL PRECIPITATION IN CENTRAL PARK (INCHES)

Source: NPCC, 2013



Middle-range projections for annual precipitation show an increase of 1 to 8 percent in the 2020s, 4 to 11 percent in the 2050s, 5 to 13 percent in the 2080s, and up to 19 percent by 2100.

NEW YORK CITY'S EXTREME RAINFALL TRENDS

Rainfall data from gauges at Central Park, JFK, LaGuardia and Newark airports, the stations with the longest data record in and around New York City, show some of the heaviest rainfall events in the city's history occurred in just the last three decades:

- Three of the five largest precipitation events occurred at JFK airport
- Four of the five largest precipitation events occurred at LaGuardia and Newark; and
- All five of the largest precipitation events occurred at Central Park

While these statistics suggest a dramatic shift in the climate towards more extreme rainfall events, it is difficult to draw very definitive conclusions. However, overall the data show a gradual trend towards increased rainfall which is consistent with these recent observations of large precipitation events.

For instance, projections of city rainfall by the New York City Panel on Climate Change, which scale from high-estimate range to middle and low-estimate ranges, show an overall increase in more extreme rainfall events in the coming decades.in more extreme rainfall events in the coming decades.

VULNERABILITY

Vulnerability to flooding varies across the city. Different neighborhoods face different risks. Risks are primarily determined by flood type, who and what are exposed to flooding, and the degree of that exposure and how well the "who" and "what" can withstand damage. Flooding's immediate and long-term impacts can include:

- Loss of life, injury, and illness
- Aggravation of existing health conditions
- Psychological effects such as depression and anxiety
- Disruption of critical infrastructure systems, including transportation, energy, telecommunications, and wastewater treatment plants
- Water pollution and release of other contaminants
- Loss of income for individuals and of revenue for businesses
- Disruption of communities and social networks
- Degradation or loss of natural resources

A Stronger, More Resilient New York and other publications listed in "Resources" section present vivid accounts of the damage done by Hurricane Sandy in 2012. Here we identify a number of vulnerabilities.

Neighborhoods at risk

For coastal flooding, proximity to the coastline and elevation are primary indicators of risk. As stated, FEMA's Preliminary Flood Insurance Rate Maps show that approximately 400,000 people currently live in the 1 percent annual chance floodplain shown and are vulnerable to storm surge flooding. Properties located within the FEMA V zones may be more at risk for structural damage due to wave forces, whereas properties in the A zones, and to a lesser degree, the shaded X zones, are more likely to experience flood water inundation, but have a lower risk of structural damage.

Physical factors such as surface permeability, soil type, vegetation, and topographical relief affect the severity of flooding, too. Differing conditions along the coast and along rivers and streams affect levels of protection against storm surge and floodwaters.

For inland flooding, there is no single primary indicator for vulnerability. Communities in low-lying areas with limited drainage capacity tend to experience sewer backups and street flooding that can expose them to contaminated stormwater and wastewater. Exposure to contaminated water can have both short and long-term public health effects.

Individuals at risk

Socioeconomic and demographic characteristics can influence an individual's capacity to adopt preventive measures that would reduce flood risk and to quickly recover from flood impacts. People with little income and few resources will have a harder time rebounding from a flood that interrupts their income than people who are affluent. If a neighborhood must be evacuated, people whose mobility is limited and who have no transportation options could be at risk. They could also be less able to access emergency assistance in the aftermath of a flood. The City issues emergency alerts in many languages and employs many forms of media to communicate about help available from government agencies and community organizations. But people not reached by that news are at greater risk, and may recover more slowly from a severe flood.

If flooding causes power outages, a cascade of secondary impacts can occur. For example, if elevators cannot operate, people with limited mobility can become stranded. People who depend on electricity for motorized wheelchairs, oxygen tanks, and refrigeration for medications are at risk. Heat and cooling systems, essential services in New York City's cold winters and humid summers, may be disrupted, putting vulnerable groups at greater risk.

Homeownership is a factor in recovery from severe flooding. Property owners who reside in their homes are more likely to invest in structural flood-resistant improvements. But many New Yorkers are renters and cannot control such investments. Landlords confronting steep economic challenges related to property value and the cost of uninsured losses may not be easily able to make repairs. This can cause temporarily displacement for tenants– or, if they cannot find affordable alternative housing, they may have to remain in homes that are damaged and perhaps subject to the growth of toxic mold.

Property at risk

Geography, land use, and the density of built assets exposed to risk affect the vulnerability of property. Dense commercial and residential areas line the Hudson and East Rivers. Industrial districts line the Long Island Sound and New York Harbor. Residential neighborhoods abut oceanfront beaches. Different areas have different building types. Each type faces some unique risks. Variables include building height, construction type, construction materials, and age.

An estimated 71,500 buildings are in the 1 percent annual chance floodplain, based on FEMA's Preliminary Flood Insurance Rate Maps. In general, low-rise buildings (one to two stories) are more vulnerable to structural damage than mid-rise

UNDERSTANDING FEMA'S FLOOD ZONES

FEMA's Flood Insurance Rate Maps define different zones of vulnerability within the 1 percent annual chance floodplain, including areas that are at higher risk of destructive wave action and that generally require protective design and construction standards to minimize flood damage.

The zones range from high- to- moderate-risk areas:

V Zones are high-risk coastal areas in the 1 percent annual chance floodplain where wave heights can reach 3 feet or higher.

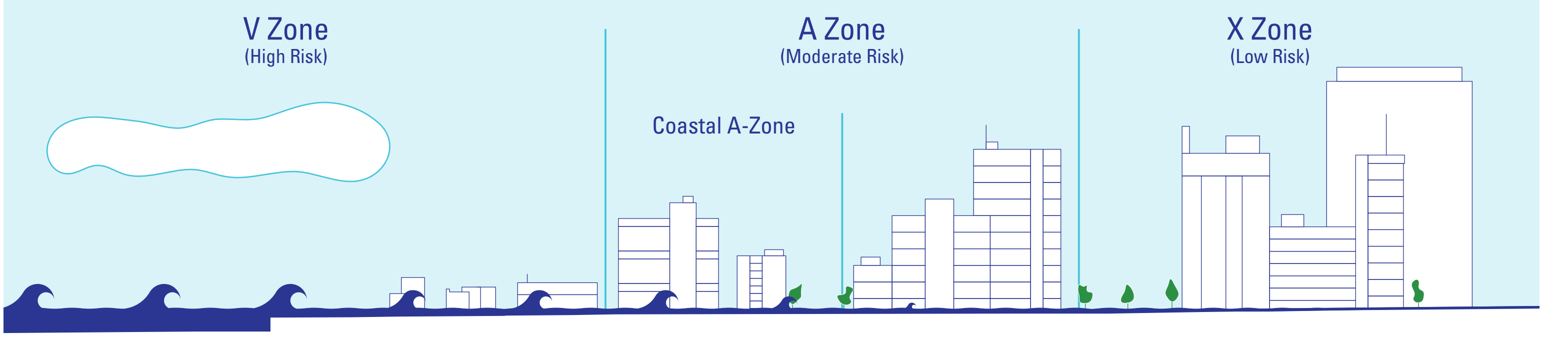
A Zones are high-risk areas in the 1 percent annual chance floodplain with a lower risk for wave action (waves less than 1.5 feet).

AO Zone are areas inundated by 1 percent annual chance flooding where flood depths range from 1 to 3 feet.

Coastal A Zones are portions of the A zone where base flood wave heights are expected to be between 1.5 and 3 feet high. This zone is indicated by the Limit of Moderate Wave Action Line on the latest FEMA flood maps.

Shaded X Zones, the 500-year floodplain, are areas with moderate flood risk.

Local building codes must comply with FEMA standards for the 1 percent annual chance floodplain to maintain eligibility for National Flood Insurance Program coverage. Owners of structures in the 1 percent annual chance floodplain who hold federally backed or federally regulated mortgages are required to carry flood insurance. Flood insurance is not mandatory for property in the .2 percent chance floodplain, also called the 500-year floodplain, but homeowners and businesses can elect to buy it at lower rates.



SOURCE: FEMA

(three to six stories) and high-rise (seven stories or higher) buildings. Moreover, in low-rise buildings, occupants tend to house their primary activities on the ground floor, putting themselves at greater risk.

Low-rise buildings also tend to be constructed with lighter, wood-stud frames, which are more prone to structural damage – and to fire from electrical shorts that can be caused by flooding – than are the steel, masonry, or concrete frames characteristic of larger, more recent building types. Although wood buildings are less expensive to repair, reconstruct, and elevate than masonry buildings, new wood-frame housing is generally not permitted in New York City.

Infrastructure at risk

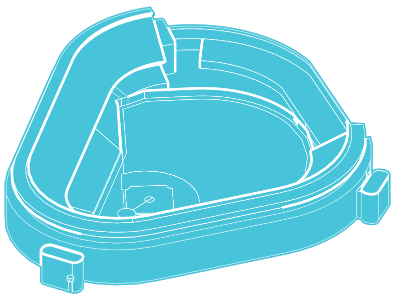
Parts of our critical infrastructure are vulnerable to flooding.

The underground and low-lying portions of our vast, complex, and aging transportation infrastructure – roads, bridges, tunnels, subways, railways, and ferries are at risk. During Hurricane Sandy, the MTA's subway and rail systems, the Staten Island Ferry, and some of the city's tunnels were forced to shut down entirely. Much of our transportation infrastructure is in the 1 percent annual chance floodplain out of operational necessity, including 12 percent of our

IN 2050, THE 1 PERCENT ANNUAL CHANCE FLOODPLAIN IS PROJECTED TO BE ALMOST 32 SQUARE MILES; THAT IS EQUIVALENT TO...

2,300

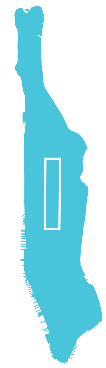
×



2,300 Yankee Stadiums

1.5

×



Almost 1.5 times the entire island of Manhattan

roadways, major arteries such as the Belt Parkway and FDR Drive; three major tunnels; three heliports; commuter rail yards; and dozens of subway entrances and ventilation structures. Many bridges are at risk if fast-moving floodwaters cause "scour": erosion of the bridge foundation or the sediments into which it is anchored. Scour could undermine the structure.

Our two major airports face significant risk: LaGuardia is next to the East River, JFK is next to Jamaica Bay, and both are constructed primarily on landfill in low-lying areas prone to flooding. All of LaGuardia Airport is within the current 1 percent annual chance floodplain. The area along its waterfront is particularly vulnerable to storm-related wave action. JFK is at lower risk today, but with sea level rise, it is projected to be in the 1 percent annual chance floodplain in the 2020s. At LaGuardia, sea level rise could diminish the effectiveness of existing levees, even for less-severe storms.

Both airports were forced to close during and after Sandy. Their terminals were spared serious damage, but flooding damaged airport infrastructure including runways. It took 3 days to bring both airports back into operation. More than 6,000 flights were cancelled, affecting roughly 1 million passengers. The Port of New York and New Jersey, which has waterfront shipping facilities in both New York and New Jersey, is also at risk of flooding and during Sandy was shut down for several days.

Our electricity, steam, telecommunication, and fuel supply systems, and wastewater treatment plants are vulnerable to flooding. The power plants that produce just over half of the city's electricity-generation capacity are within the 1 percent annual chance floodplain, as is 88 percent of our steam generating capacity. Hurricane Sandy severely flooded telecommunications equipment in Lower Manhattan. Flooding is a great risk for our liquid fuel supply (gasoline and diesel fuel): nearly all of our metro area's 39 fuel terminals are within the 1 percent annual chance floodplain.

INSURANCE RESEARCH AND CONSUMER EDUCATION

Consumers must be aware of the risks they face and exactly what coverage their insurance policies include and exclude.

New York City's Office of Recovery and Resiliency will conduct two studies to better understand the impact that rising flood insurance costs and an expanded floodplain will have on New Yorkers, with the aim of helping to keep flood insurance affordable.

The Office of Recovery and Resiliency will also conduct a consumer education campaign to build consumer awareness of issues related to changing flood insurance conditions. The campaign will stress that standard homeowners insurance and small business property policies do not cover damages caused by flooding.

PEOPLE AND ASSETS IN THE 1 PERCENT ANNUAL CHANCE FLOODPLAIN

	2013 PFIRMs
Residents	400,000
Buildings	71,500
1-4 Family	57,400
Floor Area (Sq Ft.)	532M

Of our 14 wastewater treatment plants, 10 were inoperable during Sandy. All 14 plants will be at least partially below FEMA's Base Flood Elevation (the anticipated rise in floodwater during the base flood, or the 1 percent annual chance storm) by the 2020s. Department of Environmental Protection has investigated a wide range of resiliency strategies and is taking steps to protect facilities as outlined in the New York City Wastewater Resiliency Plan.

The city's vital healthcare facilities and networks are vulnerable to flooding. Of the more than 300 healthcare facilities in New York City – including hospitals, nursing homes, hospices, and adult health care centers – over 10 percent are in the 1 percent annual chance floodplain. Beyond direct impacts (Sandy forced some hospital evacuations), storm victims can place additional strains on healthcare facilities. During Sandy, hospitals incurred emergency response costs estimated at over $1 billion.

Our city's food supply system is complex and heavily dependent on other networks, such as power, transportation, liquid fuels, and to a lesser degree, telecommunications. Approximately 95 percent of the city's food travels here by truck, which makes our system reliant on liquid fuels. Electricity is essential for the refrigeration required to protect perishable foods as they travel through the food distribution system. Telecommunications and the Internet link the supply chain's partners and facilitate electronic payments.

The bulk of our city's key food distribution facilities, including the Hunts Point Food Distribution Center as well as a host of other wholesale warehouses, public markets, and private food and drink distribution buildings, are located in the Hunt's Point neighborhood in the South Bronx. Daily, nearly 13,000 trucks travel to and from the Center. Because it is located on a peninsula, with the East River on two sides and the Bronx River on the third, nearly 30 percent of the site lies in the 1 percent annual chance floodplain and is at risk of flood damage.

A major flood that disrupted New York City's critical infrastructure systems and services could have serious effects not only citywide but regionally, and beyond.

The environment at risk

Floods can damage the city's natural resources extensively. Coastal storms can submerge wetlands for prolonged periods of time and cause barrier islands to narrow or split. Wave action and storm surge can flood inland vegetation with salt water, erode the shoreline edge, and damage non-salt tolerant trees and shrubs that can act as a buffer for inland parks and neighborhoods.

Heavy rainfall can harm inland parks, natural areas, and preserves by releasing contaminants and pollutants. Rainfall runoff can impact planted areas that lack adequate drainage, damaging vegetation and saturating porous soils that could otherwise help slow the release of water and reduce the impact of inland floods on adjacent areas.

HOW DO WE MANAGE THE RISK?

An integrated approach to managing flood risk begins with the recognition that flooding is a natural process that cannot be altogether prevented.

The approach focuses on increasing public awareness of risks, particularly among people living in flood zones, and reducing the vulnerability of risk-prone individuals and communities, creating multiple lines of defense to protect buildings and infrastructure, and employing the collaboration of many parties, from both the public and private sectors to strengthen the city's overall capacity to cope with and recover from periodic flooding.

Recognizing the complex and varied nature of flood risk in New York City, in the aftermath of Hurricane Sandy the City developed a comprehensive coastal protection plan that explores strategies ranging from short term to long term, from "hard" to "soft," and from brick-and-mortar to policy and created the Mayor's Office of Recovery and Resiliency to implement the plan. Taken together, these strategies – regulatory controls, land use management policies, surface and groundwater management measures, protections for buildings and infrastructure, and environmental controls – add up to a broad but deliberate, multidimensional approach to promoting flood-risk resiliency in New York City.

For detailed information on these strategies, please see "Resources" section, particularly *A Stronger, More Resilient New York*, *Urban Waterfront Adaptive Strategies*, and Design Manual studies. What is presented here is a sampling of key strategies.

REGULATORY CONTROLS

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

Federal controls: the National Flood Insurance Program (NFIP)

FEMA's NFIP provides flood insurance for property owners in the FEMA-designated 1 percent annual chance floodplain. In order to participate and maintain eligibility for the NFIP, the city must 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.

FEMA is implementing reforms to the NFIP that are mandated by the Homeowner Flood Insurance Affordablity Act of 2014. The reforms repeal and modify certain provisions of the Biggert-Waters Flood Insurance Reform Act of 2012 that mandated insurance premium increases for many policyholders to more accurately reflect flood risk. Many older buildings constructed before FEMA's initial flood maps were issued are located in high-risk flood zones and are covered by flood insurance policies with federally subsidized rates. Most subsidies remain but will be phased out over time, with the rate of phaseout varying by type of structure insured.

New York City's controls

- **The Construction Code**. The New York City Department of Buildings is designated as the City's Floodplain Administrator and is tasked with enforcing Appendix G of the NYC Building Code, which prescribes standards for flood-resistant construction in accordance with federal mandates.

GUIDELINES FOR DESIGN AND CONSTRUCTION OF STORMWATER MANAGEMENT SYSTEMS

New York City's Department of Environmental Protection is responsible for providing adequate drainage services to the city. The Department also governs the construction of private sewers and drains to ensure compliance and adequate drainage capabilities. The Department is pioneering a number of sustainable stormwater management strategies, including Bluebelts and green infrastructure.

The Department's comprehensive *NYC Wastewater Resiliency Plan* details cost-effective strategies for reducing flood damage to wastewater infrastructure and safeguarding public health and the environment. It examines 96 pumping stations and 14 wastewater treatment plants, identifying and prioritizing those most at risk of flood damage and presenting resiliency recommendations for them.

New and substantially improved structures located in the A-zones within the 1 percent annual chance floodplain must meet the following standards:

- Lowest occupied floor constructed above the base flood elevation (BFE)
- If there is an enclosed space below the BFE, it can only be used for parking, storage and building access
- Utilities must be elevated above BFE or designed to prevent water from entering and accumulating

New and substantially improved structures located in the V-zones within the 1 percent annual chance floodplain cannot have enclosed space below the base flood elevation. The structure must either be on piles or an open foundation.

Basements are not allowed in either zone.

In January 2013, the City's Construction Codes were amended to require that buildings in the 1 percent annual chance floodplain be elevated beyond what's required by the NFIP. "Freeboard" is the term used to refer to this additional height. The City's requirement applies to new construction and buildings undergoing substantial renovation.

One- and two- family homes are now required to provide 2 feet of freeboard extra protection above flood elevation, and most other buildings are required to provide 1 foot.

The added height provides an added margin of safety that allows for the uncertainties inherent in flood modeling and FIRMs, which are based on historical data. Because sea level elevations shown on those maps do not include projected sea level rise, the allowance for freeboard can help keep structures above floodwaters as storm surge elevations increase.

Recognizing that freeboard reduces flood risk, FEMA provides substantial reductions in flood insurance premiums for structures incorporating freeboard.

- **Land use management and zoning law**. Municipal governments use zoning to shape the way land is used. Zoning determines the size and use of buildings, where they are located, and, in large measure the density of neighborhood. In New York City, the Department of City Planning administers zoning law. Policy tools for managing flood risk can be applied at scales that range from site-specific to local to regional.

  Amendments to zoning law can facilitate investment in flood-resil¬ient buildings by removing disincentives or restrictions to meeting or exceed¬ing flood-proofing standards in Building Codes. For example, in the flood zones, building height limitations established by the zoning law were a disincentive for property owners to elevate their structures to reduce flood risks. The zoning law was amended to remedy this.

- **New zoning text**. The 2013 Flood Resilience Zoning Text Amendment encourages flood-resilient building construction throughout FEMA-designated flood zones. It removes regulatory barriers that would hinder or prevent the reconstruction of storm-damaged properties. It also makes it possible for new and existing buildings to comply with new, higher building flood elevations required by FEMA, and with new requirements in the

City's Building Codes. The Department of City Planning is currently in the process or refining and making this text amendment permanent. In addition, the Department is looking at specific neighborhoods within the flood zone and working with communities to identify changes to zoning to enable a more resilient building form.

MANAGING SURFACE AND GROUNDWATER

Excess rainwater and flash flooding can be managed by improving drainage systems, employing green infrastructure, providing floodwater storage, and managing surface water run-off. In New York City, the Department of Environmental Protection works with the Departments of Transportation, Sanitation, and Parks and Recreation to advance these measures.

Sewers, drainage, and green infrastructure

New York City's stormwater management improvements focus on investments in sewer infrastructure upgrades that expand capacity by adding high-level storm sewers, upgrading stormwater and sewage pumps and backflow valves, and better maintaining catch basins and storm drains in City parks and neighborhoods.

"Green infrastructure" expands the water infiltration and storage properties of urban drainage systems. It can help reduce sewer overflow and in some instances it may help minimize flooding. By enhancing vegetation in densely developed areas and on rooftops, it can also lower the amount of energy needed to cool buildings, lowering energy costs.

- **Green/natural drainage** uses natural features of the landscape for infiltration and storage. Natural drainage corridors – including streams, ponds, wetland areas, parks, and open spaces – help convey, store, and filter stormwater. For example, the Staten Island Bluebelt, an award winning wetland preservation program that 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.

RETROFITTING BUILDINGS FOR FLOOD RISK IN NEW YORK CITY

The Department of City Planning's *Retrofitting Buildings for Flood Risk Design Manual* analyzes and illustrates retrofit design options for ten real-world examples representing New York City's vulnerable building typologies. It is intended as a resource for a variety of public and private-sector parties, including policy makers, architects, engineers, builders, developers, and property owners.

By offering practical solutions for retrofitting properties in the flood zone, the manual advances the City's climate adaptation goals.

- **Green roofs** consist of vegetation that grows in an engineered soil that sits on top of a drainage layer. Green roofs divert the water they absorb, and rain barrels on roofs divert the rainwater they capture, thus helping to reduce the volume of water that enters city sewers.

- **Temporary flood storage** of rainwater can help alleviate floods, especially flash floods that occur when the rainfall rate exceeds the ground's capacity to absorb the rain. These features, such as retention ponds and reservoirs, divert water away from vulnerable structures or infrastructure, allowing it to drain more easily.

- **Roadside drainage** includes natural or semi-natural features – such as the ground right next to tree trunks and street-side swales, and porous pavement that divert water away from the street – to drain more easily.

PROTECTING BUILDINGS

Strategies employed in New York City to make buildings more flood resistant include these:

- **Dry floodproofing** involves the use of watertight construction methods, such as the installation of temporary shields or barriers that keep water out of a building. Site protection can also be accomplished with deployable or permanent floodwalls, or a berm (an earthen mound) outside a building or around the site perimeter.

- **Wet floodproofing** involves constructing or retrofitting buildings with materials that resist flood damage and allow water to freely flow in and out without causing significant damage.

- **Elevation** involves raising a building so that the lowest floor is above the design flood elevation, which is equal to the height of a 100-year flood at a given location plus a safety margin for freeboard.

- **Elevation of mechanical equipment** above the design flood elevation involves either moving such equipment to higher floors, placing it on a raised platform, or suspending it from an overhead structure. High-rise buildings can employ a system that prevents elevators from descending into floodwaters.

- **Elevation of land and streets** is a strategy that works best on large development sites or at a neighborhood scale, where both lots and streets can be raised in a coordinated manner. In New York City, Arverne By The Sea, a 117-acre development on the Rockaway Peninsula, was elevated approximately 5 feet prior to construction, and for the most part experienced significantly less flooding during Hurricane Sandy than surrounding areas did.

PROTECTING INFRASTRUCTURE

This major objective can be served by many measures, including:

- **Protection of critical infrastructure** iis needed for assets such as subway entrances and tunnels, electricity generation and distribution systems, water supply systems, wastewater treatment plants, healthcare facilities, and other facilities housing vulnerable populations. Strategies vary widely depending on the type of infrastructure, and range from floodproofing or elevating individual facilities and equipment to larger operational and design changes. Among many examples:

    - Elevating air vent gratings over subways, so floodwaters cannot enter the system

    - Improving pumping capacity in subway, commuter train, and passenger car tunnels

    - Raising or dry floodproofing track switches and electrical equipmen

    - Elevating electrical equipment and ensuring emergency backup power in hospitals

    - Improving redundancy in the power supply by increasing the number of power supply feeders, installing additional distribution transformers, and building new substations outside of flood-prone locations

Projects to protect New York City's critical infrastructure systems from flooding are being undertaken by many agencies (the Department of Environmental Protection, the Department of Transportation, the Health and Hospitals Corporation, the Metropolitan Transportation Authority, and the Port Authority of New York and New Jersey, to name just a few) and utility providers (Con Edison and PSEG). These efforts have increased markedly since Hurricane Sandy.

COASTAL DEFENSES

Well before Hurricane Sandy, structural measures to protect properties prone to flooding were being implemented. Post-Sandy, these efforts have expanded to include integrated flood protection systems, increased coastal edge elevation, and protection of infrastructure and critical services. They also include studies, funded with federal and state recovery funds, to evaluate what coastal protection measures are best suited to the unique vulnerabilities of specific sites and neighborhoods.

Many coastal protection structures are built by the U.S. Army Corps of Engineers, with the involvement of other agencies based on project scope and location. Such structures include the following:

- **Bulkheads**, usually made of stone or concrete, hold soil in place and stabilize the shoreline to help resist erosion. They are not typically designed to prevent flooding from storm surge from a coastal storm, but rather are designed to work with everyday tidal fluctuations, currents, and wakes. Many stretches of the Upper Bay and Hudson shoreline have been bulkheaded since the early 20th century. Today, bulkheads are located along the city's waterfront industrial areas, commercial and residential areas, and parkland. Approximately 25 percent of New York City's shoreline is protected by bulkheads.

- **Surge barriers**, typically used in combination with larger flood protection systems that include levees, floodwalls, and pumps, provide a high level of protection from storm surge. Under normal conditions, surge barriers remain open and allow water and vessels to pass, but can be closed when water levees rise due to storm surge. All surge barriers require extensive maintenance and monitoring.

  While surge barriers can be found across the East Coast, none currently exist in New York City. However, in the aftermath of Hurricane Sandy areas such as Gowanus, Newtown Creek and Coney Island have taken steps to explore its feasibility.

- **Levees** (also called dikes) are earthen embankments built at the shoreline that provide protection from flooding. Levees are commonly used throughout the country along riverbanks. In the Netherlands, multipurpose levees – levees that combine other functions such as transit, highways, buildings, and parks, on top of or within a levee structure – are used in combination with surge barriers along the coastline.

  In New York City, the U.S. Army Corps of Engineers constructed a levee in Staten Island at Oakwood Beach in 2000.

- **Floodwalls** are permanent or deployable vertical structures anchored in the ground at the shoreline or upland to prevent flooding from rivers or storm surge. Permanent floodwalls are sometimes used on top of, or as an extension of, a levee,

IN A FUTURE THAT BRINGS HIGHER SEA LEVELS, MIGHT NEW YORK CITY ADOPT STRUCTURES THAT FLOAT?

Structures that float at all times and are designed to move vertically with tidal fluctuations and storm surge. Unlike houseboats, they have no motoring or steering capabilities and can't move through water on their own. Utility connections are flexible, allowing the structure to move naturally with the water. Floating structures are rare in New York, and effectively prohibited here, but they exist in Sausalito, California; Portland, Oregon; and Seattle, Washington, as well as in the Netherlands, Germany, and Australia.

Amphibious structures are built on dry land but can float if the site is flooded because they have buoyant foundations and pile supports. A few amphibious homes have been constructed in Louisiana and the Netherlands.

such as in New Orleans, to add protection or provide protection where there is not enough land for a levee. Some floodwalls have gates to allow access for a roadway or other right-of-way; can be closed in advance of a flood.

Deployable floodwalls are installed in preparation for a flood event. They can be inserted into permanent ground fixtures or vertical posts. Most deployable floodwalls require human intervention to install, but some designs automatically rise in response to flood conditions.

The New York University Langone Medical Center, a key emergency facility along the East River that was severely damage by Hurricane Sandy and forced to partially close for nearly two months, is rebuilding with significant investment in floodwall protection as well as elevating critical equipment to higher floors.

- **Breakwaters** are offshore structures parallel to the shoreline that are typically made of rock or other robust materials. They can reduce coastal flooding and wave forces by breaking waves before they reach the shoreline and adjacent neighborhoods. The South Shore in Staten Island is a potential site for future breakwater investments.

ENVIRONMENTAL CONTROLS

City agencies that lead this work include the Departments of Parks and Recreation, City Planning, and Environmental Protection. Post-Hurricane Sandy, the City has made significant efforts to improve coastal design and governance; for example, by studying how natural areas and open space can be used to protect adjacent neighborhoods.

Natural protective features such as wetlands, dunes, and vegetation naturally absorb energy from storm surge and waves and provide varying degrees of protection for structures behind them:

- **Living shorelines** are engineered natural buffers. This bank stabilization technique combines plants, sand and/or soil, and minimal hard infrastructure to protect the shoreline, helping to reduce erosion and maintain valuable intertidal habitats and coastal vegetation.

- **Wetlands** use plants and soils to retain and filter water while creating wildlife habitat. Large wetlands may help slow the rate of storm surge through friction, and in some cases may reduce flood heights, depending on the storm's speed and intensity as well as the size of the wetland. Flooding can even enhance the functionality of wetlands. In New York City, the numerous co-benefits of wetlands have prompted the development of constructed wetlands where hard infrastructure protections can be combined with ecological enhancements.

- **Beaches, beach nourishment and dunes** are natural protective features that function as sandy buffers: they help protect the shoreline from waves and flooding. They're sometimes reinforced with vegetation, geo-textile tubes, or a rocky core. Beach nourishment is the process of replenishing sand or depositing it on beaches to increase the elevation and distance between upland areas and the shoreline. The dunes collectively act as a buffer that dissipates storm wave energy and blocks rising water from inundating lower-elevation areas.

After the flood waters recede and the period of recovery following a flood begins, mold can be a problem. Information on removing mold is available from FEMA, U.S. Environmental Protection Agency, the Centers for Disease Control, and other sources.

SOURCE: NYC DCP

CASE STUDY: BROOKLYN BRIDGE PARK

This park is one New York's newest waterfront parks as well as one of the most resilient to flooding. Because the site is low-lying and located on a formerly industrial waterfront, Michael Van Valkenburg Associates, the parks landscape architects, knew that resiliency had to be incorporated into every aspect of design, so that the park could withstand storm impacts and flooding.

Features such as the park's elevation, newly installed riprap shoreline and saltwater wetland, pier stabilization, and the use of salt-tolerant vegetation and soil were all carefully selected to increase the park's resiliency to the changing coastal environment.

STRONG WINDSTORMS
CHAPTER 4.4

Windstorms are a common occurrence in New York City. Any variety of windstorms can occur with little warning, damaging property and infrastructure, disrupting transportation, downing trees and power lines, and causing serious injury. New York City's dense high-rise environment, older building stock, and open construction sites heighten its vulnerability to dangerous winds.

WHAT IS THE HAZARD?

Windstorms produce winds at speeds that typically exceed 34 miles per hour (mph), with winds blowing faster at higher elevations. A variety of windstorms can occur in New York City: straight-line storms that blow in one direction, thunderstorms, microbursts, and tornadoes. High-wind events are often associated with other storms, such as hurricanes or nor'easters, but may occur independently.

Windstorms may or may not be accompanied by precipitation. They vary in intensity, duration, and geographical extent. For example, they can range from short bursts of high-speed winds, as during a severe thunderstorm, to longer periods of stronger sustained winds. They typically have a few hours of lead time and can last for hours, or for up to several days if they result from a large-scale weather system.

TORNADOES

A tornado is a violently rotating column of air with winds ranging from 65 mph to more than 300 mph. These short-lived storms generally appear as funnel-shaped clouds extending toward the ground from the base of a thundercloud. Initially they are transparent — a danger because they cannot be easily seen. As they pick up debris and dust, they acquire their grayish coloration. That gray color can also be caused by a cloud, because water vapor condenses in the funnel due to its low pressure.

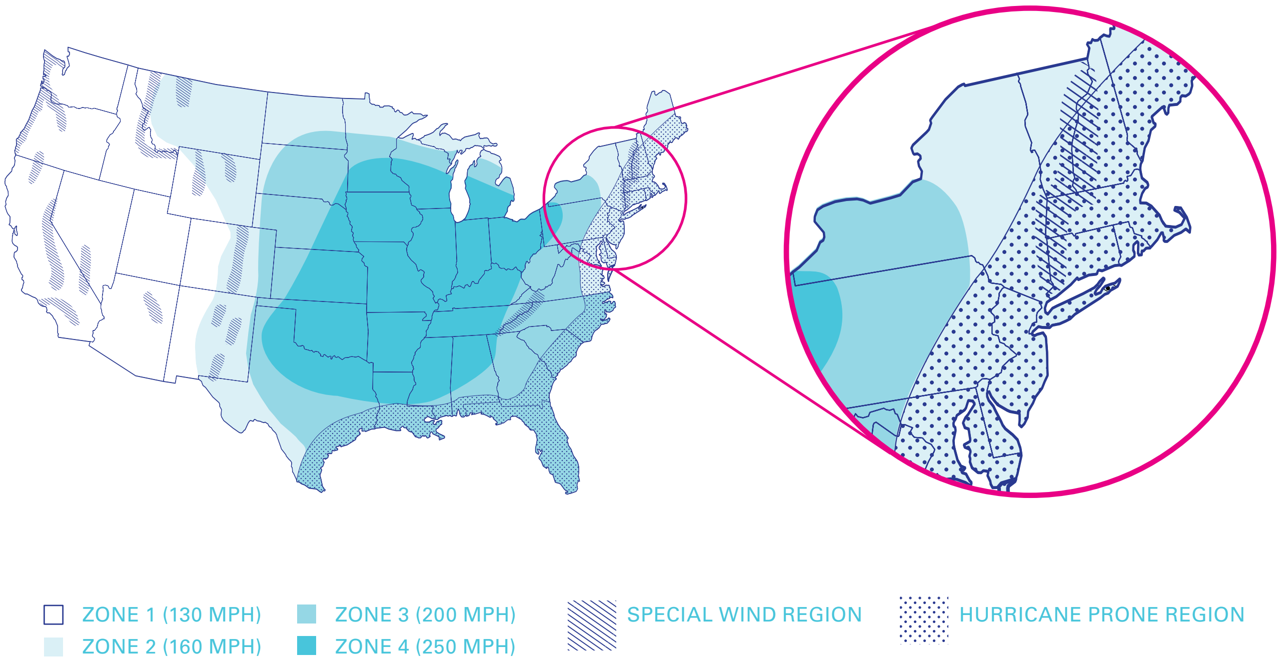
Most tornadoes advance west-to-east, but tornadoes can often move southwest to northeast, at an average speed of 30 mph. They are most frequent east of the Rocky Mountains during spring and summer, between 3 PM and 9 PM. They may accompany hurricanes.

Tornadoes are the most violent atmospheric phenomenon that occurs over land, and, over a small area, the most destructive. They are rarely predictable in advance and can uproot trees, demolish buildings, and turn harmless objects into deadly missiles in a matter of seconds. The path of destruction can exceed one mile in width and 50 miles in length. Each year an average of 1,200 tornadoes strike nationwide. Tornadoes cause on average 60 to 65 fatalities and 1,500 injuries per year.

BEAUFORT WIND SCALE TABLE
Source: NOAA

FORCE	WIND SPEED (MPH)	NAME	DAMAGE
0	< 1	Calm	Calm, smoke rises vertically
1	1 – 3	Light Air	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	13 - 18	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	19 - 24	Fresh Breeze	Small trees in leaf begin to sway
6	25–31	Strong breeze	Large branches in motion; whistling in telephone wires; umbrellas used with difficulty
7	32–38	Near gale	Whole trees in motion; resistance felt while walking against the wind
8	39–46	Gale	Twigs break off trees; wind impedes walking
9	47–54	Strong gale	Slight structural damage to chimneys and slate roofs
10	55–63	Storm	Seldom felt inland; trees uprooted; considerable structural damage
11	64–72	Violent storm	Very rarely experienced; widespread structural damage; roofing peels off buildings; windows broken; mobile homes overturned
12	72-83	Hurricane	Widespread structural damage; roofs torn off homes; weak buildings and mobile homes destroyed; large trees uprooted

U.S. WIND ZONES
Source: FEMA



WHAT IS THE RISK?

WINDSTORMS

Gale-force windstorms are common here and a highly probable hazard in the future. From 1996 to 2013, at least 31 documented windstorms with gusts above 40 mph occurred in the city. During this same period, 14 major windstorms with gusts ranging from 50 to 80 mph occurred. For example, on February 12, 2009, wind gusts reached up to 50 to 60 mph, killing a construction worker in Staten Island, injuring several people in Brooklyn.

Windstorm speeds can range from 34 mph to more than 75 mph. One of the earliest scales for measuring wind speeds and associated damage is the Beaufort Wind Scale, developed in 1805 and still in use.

New York City is located in a hurricane prone area and exposed to hurricane winds that can potentially reach much higher speeds than windstorms as shown in the Wind Zones in the United States map put out by FEMA. The NYC Building Code requires that city buildings be designed to resist high winds and hurricanes. The difference between these two events is that windstorms occur more frequently than hurricanes. The result is that buildings are designed at a much higher level due to concerns of high hurricane winds.

Areas with large concentrations of high-rise buildings are subject to higher wind loads because of the "urban canyon effect." This occurs in areas where narrow streets cut through dense blocks of tall buildings such as Midtown Manhattan, the Financial District in Lower Manhattan, and Downtown Brooklyn.

TORNADOES

A common misconception is that tornadoes do not occur in dense urban areas like New York. But over the past 40 years, 12 tornadoes have hit our city. At least one has occurred in each of the five boroughs.

The standard measurement for rating the strength of a tornado used to be the Fujita Scale (F-Scale). The National Weather Service previously used this scale and an analysis of damage done by a tornado to estimate wind speed. In 2007, the National Weather Service transitioned from the F-Scale to the Enhanced Fujita Scale (EF-Scale).

HISTORICAL TORNADOES (1950 - 2014)

SOURCE: NOAA NATIONAL CLIMATIC DATA CENTER

*8/31/1995 NEW YORK COUNTY (MANHATTAN) TORNADO IS NOT DISPLAYED ON THE MAP. NO ACCURATE COORDINATES ARE AVAILABLE FOR THIS EVENT.

WIND EVENT TYPE

- TORNADO
- THUNDERSTORM WIND (MACROBURST)
- TORNADO TRACK

The EF-Scale is more complex and enables surveyors to assess tornado strength with greater precision. It is now the standard for determining tornado strength. But the EF-scale references to the old F-scale are needed for historical purposes.

Reported tornadoes have increased over the years. Seven tornadoes have been reported in New York City from 2007-2014, in comparison to only six over the previous 33 years. (The first reported tornado was in 1974.) This increase in reported occurrences may be due to the greater precision of the Enhanced Fujita Scale.

One of the strongest tornadoes, rated an EF2, hit Brooklyn in 2007, damaging 16 homes, tearing the roof off a car dealership, and destroying trees. This was a presidentially declared disaster in which FEMA provided more than $5.1 million in Individual and Household Program funding to property owners. On September 16, 2010, an EF0 tornado in Brooklyn caused significant tree damage and an estimated $8.5 million in total damages. The same day an EF1 tornado in Queens killed one person and severely damaged residential buildings, causing an estimated $17.2 million in damages. In addition, some tornadoes have occurred during major coastal storms, include Tropical Storm Irene, which had two confirmed tornadoes: one EF0 in Cunningham Park and one on Long Island.

Climate change is projected to bring warmer weather and moister air. This could create conditions that generate severe weather. But these same conditions have been shown to reduce the wind shear necessary for tornadoes to get a full lift. At this point it is unclear how the long-term effects of climate change will impact the strength and frequency of tornadoes. What is clear is that windstorms and tornadoes will continue to be a risk.

VULNERABILITY

Tornadoes and other windstorms can cause many kinds of damage, of greatly varying severity. Besides the impacts on people and buildings, these storms can disrupt transportation, and down trees, phone lines, and power lines, causing outages and in some instances fires. In turn, power outages trigger their own cascade of effects. Heavy branches torn from trees and falling trees can damage cars and houses. Storms can damage the natural environment, by destroying historic trees and degrading the beauty of our parks and open spaces.

COMMON TYPES OF WINDSTORMS

Straight-line: These storms, the most common, blow in one direction at speeds varying from low to very high. They're associated with intense low atmospheric pressure. They can last for up to a day.

Thunderstorm: These storms can produce high wind speeds, heavy rain, hail, or sometimes a tornado.

Microburst: Associated with a thunderstorm, this is a powerful downdraft that can cause severe, localized damage.

Tornado: A violent, rotating column of air with wind speeds ranging from 65 to 300 mph.

Hurricanes/nor'easters: These storms are featured in the Major Coastal Storms section of this chapter.

People at risk

In extreme cases, tornadoes and windstorms can cause injuries and fatalities. Flying debris can injure or kill people. So can falling trees and heavy branches. Since 1996, at least 12 people have been killed by downed trees in New York City during severe weather events:

- February 25, 1996 – 1 fatality during a high-wind event
- October 19, 1996 – 3 fatalities during a high-wind event
- March 6, 1997 – 4 fatalities during a high-wind event
- December 23, 2004 – 1 fatality during a high-wind event
- September 16, 2010 – 1 fatality during a tornado
- October 29, 2012 – 2 fatalities caused by downed trees during Hurricane Sandy

TAKE COVER!

Windstorms allow six to eight hours of lead time. By contrast, tornadoes are rarely predictable, and in most instances, people will have only about a 30-minute warning.

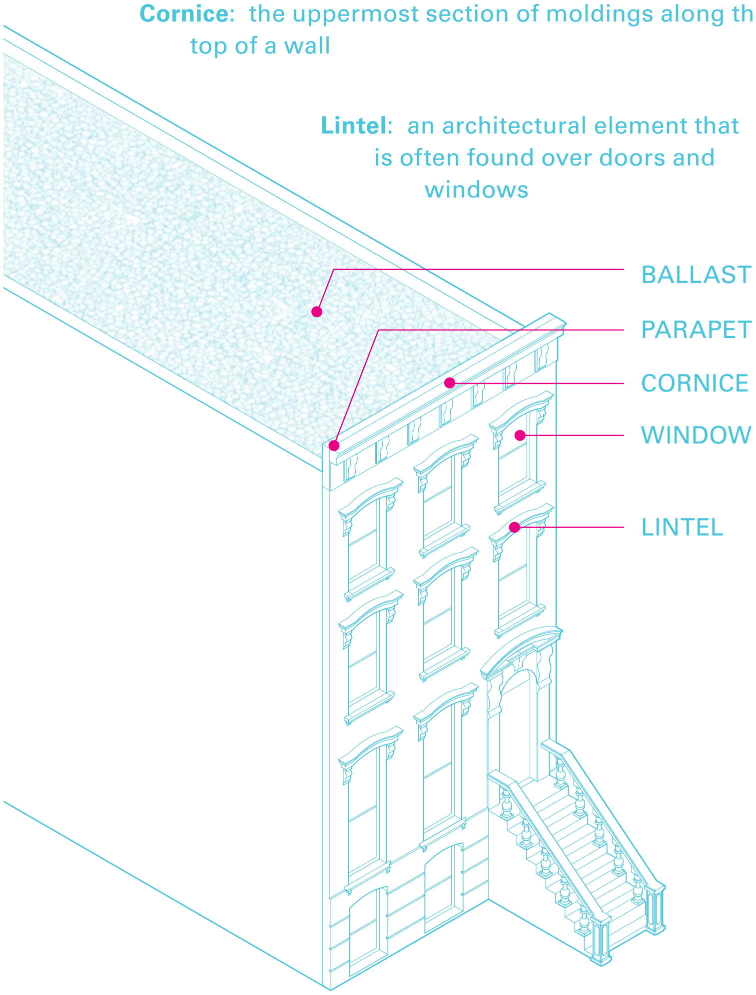
In a building that cannot withstand high winds well, occupants' best strategy is to take cover in the most secure area of the building.

Ballast: designed to anchor roofing materials to the structure by sheer weight. Materials commonly used include pea gravel or stones

Parapet: a low protective wall around the edge of a roof or balcony

Cornice: the uppermost section of moldings along the top of a wall

Lintel: an architectural element that is often found over doors and windows



Buildings at risk

New York City's dense urban environment, concentration of high-rise buildings, older building stock, and construction sites amplify risk.

Although the 1938 Building Code addressed wind loads for skyscrapers and multi-family buildings, the requirements were not as stringent as current building codes. Approximately two-thirds of all buildings in our city were built before this code was adopted. In particular, the glass and metal envelopes of some commercial high-rise buildings constructed under this code could be vulnerable to high wind events. The Urban Green Council say approximately 60 of these buildings still stand in our city today.

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. And although buildings constructed after the 1968 code (and some before) are designed to withstand windstorms, there is no clear engineering method to design for tornadoes.

Flying debris can damage structures. And because wind pressures are higher at greater heights, some older tall buildings with aging exteriors are more easily damaged: they can withstand strong winds, but cladding that is not securely attached and components such as glass windows and parapets, cornices, lintels, and roof coverings pose potentially fatal threats to pedestrians on sidewalks below.

On historic buildings, parapets can crack or collapse when exposed to wind, rain, snow, and heat for a long time. In particular, poorly maintained masonry parapets and cornices on six-story structures may be vulnerable to wind events. In addition, street facades on a typical brownstone are also vulnerable, because they are often poorly attached to the party walls and are vulnerable to collapse during a high wind event.

Some buildings built in the 1960s that feature cavity wall construction (two masonry walls separated

ENHANCED FUJITA SCALE
Source: NOAA

F-Scale	3 -sec. gust speed (mph)	EF-Scale	3 -sec. gust speed (mph)	Typical Damage
F0	45-78	EF0	65-85	**Light damage**. Some damage to chimneys. Branches broken off trees. Shallow-rooted trees pushed over, signboards damaged.
F1	79-117	EF1	86-109	**Moderate damage**. Peels surface off roofs. Mobile homes pushed off foundations or overturned. Moving autos blown off roads.
F2	118-161	EF2	110-137	**Considerable damage**. Roofs torn off frame houses. Mobile homes demolished. Boxcars overturned. Large trees snapped or uprooted. Light-object missiles generated. Cars lifted off ground.
F3	162-209	EF3	138-167	**Severe damage**. Roofs and some walls from off well-constructed houses. Trains overturned. Most trees in forest uprooted. Heavy cars lifted off the ground and thrown.
F4	210-261	EF4	168-199	**Devastating damage**. Well-constructed houses leveled. Structures with weak foundations blown away some distance. Cars thrown and large missiles generated.
F5	262-317	EF5	200-234	**Incredible damage**. Strong frame houses leveled off foundations and swept away. Automobile-sized missiles fly through the air in excess of 100 meters (109 yards). Trees debarked. Incredible phenomena will occur.

by a cavity of 2 to 4 ½ inches) may be vulnerable, too, because this construction type was still in the early stages of development and the need to anchor walls to back-up blocks was not fully understood.

Some older buildings use loose stone, aggregate, or gravel as roof covering. Small fragments of such materials can become dangerous projectiles during a high wind event, injuring people and damaging surrounding buildings.

Structural vulnerability is also related to building construction type and age. Wood-frame structures are more susceptible to high winds; steel and concrete are more resistant. In New York City, 50 percent of all buildings are wood-frame structures. Staten Island has the highest percentage, where 92 percent of its structures are made of wood, increasing that borough's vulnerability to windstorms and tornadoes.

Even if a building remains structurally sound, broken glass from windows can cause injuries inside and outside the building and badly damage building contents. Failures of windows and doors can greatly increase storm damage. Wind entering the building changes the pressure differential between the building's interior and exterior, causing more windows to break.

If wind-driven rain and water reach the interior, materials can be damaged or ruined. Wet materials can promote the growth of mold, and even materials that do not appear damaged can harbor enough moisture to contribute to mold growth later on.

Construction sites are especially vulnerable to high winds because they are so exposed to the elements. Tools, construction materials, cranes, scaffolding, derricks, concrete formwork, sidewalk bridges, and other items may loosen in high winds. Partially completed buildings are also vulnerable if their components have not yet been fully connected, or if structural features intended to withstand strong winds have not yet been completed.

HOW DO WE MANAGE RISK?

Many strategies can be employed to protect people, property, infrastructure, and the environment from the impacts of strong windstorms. What follows is a sampling and a few examples of their application in New York City. Because our city's immense and dense building stock constitutes such a significant risk exposure, we begin with measures to strengthen buildings.

REGULATORY CONTROLS TO STRENGTHEN BUILDINGS

Our Construction Codes specify design standards for winds probable in the dense, high-rise environment of New York City. New buildings and older buildings undergoing major renovations must meet those standards.

New buildings

Design strategies:

- Ensuring that structural components are connected in such a way as to form a reliable load path for wind forces.
- Incorporating lateral bracing to resist movement caused by windstorms.
- Installing dampers to increase comfort for building occupants by counteracting the movement of the building.

Structural engineers use highly refined methods to analyze how a building responds to wind loads and the response of structures. Most of the wind loads on high rises in NYC are evaluated using wind tunnels (small-scale models of the built environment and of wind conditions). The structures are designed with highly sophisticated computer programs that assure not only building resistance but also the comfort of occupants during high wind events.

Retrofitting existing buildings

Older buildings can be retrofitted to withstand high wind loads. Measures include these:

- Strengthening the connections of a building's structural components, by anchoring wooden buildings to their foundations and anchoring the roof frame to load-bearing walls.
- Replacing unreinforced brick masonry parapets with reinforced masonry parapets securely anchored to the rest of the building.
- Replacing roof covering with larger pavers to meet code standards, to reduce the risk of their being blown off.
- Installing impact-resistant windows.
- Installing window shutters.
- Reinforcing and securing rooftop equipment, such as heating, ventilation, and air conditioning units.

MAINTENANCE AND REPAIRS

Protecting our existing building stock requires inspection, maintenance, and repair of structural weaknesses.

For buildings that predate the 1968 building code, maintenance is particularly important to lowering the risk from high winds. Measures include these:

- Keeping roofs tight and in good condition.
- Regularly inspecting wood for rot.
- Securing cornices.
- Repointing mortar regularly and fixing cracks.
- Replacing glass that is not rated for New York winds. (The standard is 30 pounds per square foot for buildings under 100 feet high).

The Department of Buildings Façade Safety Inspection Program requires 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 Department. This program helps identify the need for repairs and reduces risk.

Research

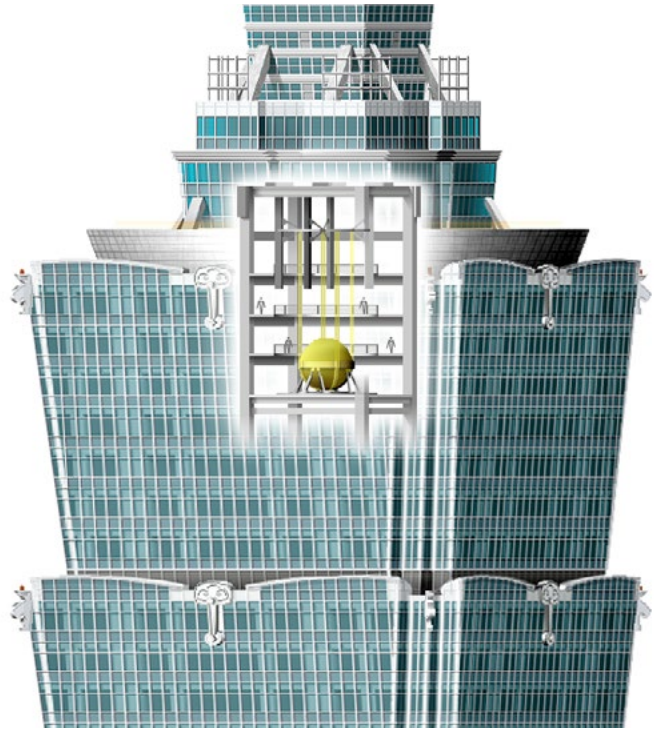
What is learned from research can help inform future revisions to our Construction Codes. Subjects for investigation include how high winds impact different building types; how windstorms impact partially completed buildings and construction sites; and how building age, construction, materials, and height affect vulnerability to structural damage.

Local Law 81 of 2013 requires the Mayor's Office of Long-Term Planning and Sustainability in consultation with the Department of Buildings to complete a report that analyzes the impact of heavy winds on certain at-risk buildings. The analysis will identify the types of existing buildings that are vulnerable to falling debris, based age, construction type, construction materials, height, and occupancy. In addition, the study will focus on buildings that are raised and buildings that are under construction in the city.

ENVIRONMENTAL CONTROLS

As stressed above, trees are exceptionally vulnerable during high winds and can themselves become a hazard. Tree pruning and tree maintenance strategies can help lower that risk.

Con Edison's vegetation maintenance program trims branches and removes damaged or unhealthy trees and vegetation near power lines along right of ways, to create minimum distances between power lines and surrounding trees. Every three years Con Edison returns to trim back growth, to reestablish the minimum clearance.



MASS DAMPER IN TAIPEI 101

MASS DAMPERS

Mass dampers are sometimes used in tall buildings to limit wind vibrations, which increase the comfort of building occupants during a high wind event. Dampers can be made of different masses such as water or steel plates.

"Tuned mass dampers" move in a way that counteracts the movement of the building caused by heavy winds.

The Citicorp Building, completed in 1977 in midtown Manhattan, was one of the first buildings in the world to feature a tuned mass damper. Taipei 101, a high-rise in Taipei, the capital of Taiwan, contains a 728-ton tuned mass damper on the upper levels of the building in full view of the building's occupants.

TORNADO DAMAGE

The Department of Parks' Central Forestry Division oversees block pruning and commitment-pruning programs. Every seven or eight years on each city block, contractors prune all street trees. Commitment pruning deals with emergency situations such as tree limbs obscuring traffic signals. The Division also prunes trees in parks.

PROMOTING PREPAREDNESS

Because windstorms and tornadoes can arrive suddenly, the public needs to know beforehand how to respond to a warning of a severe storm. Communication strategies include:

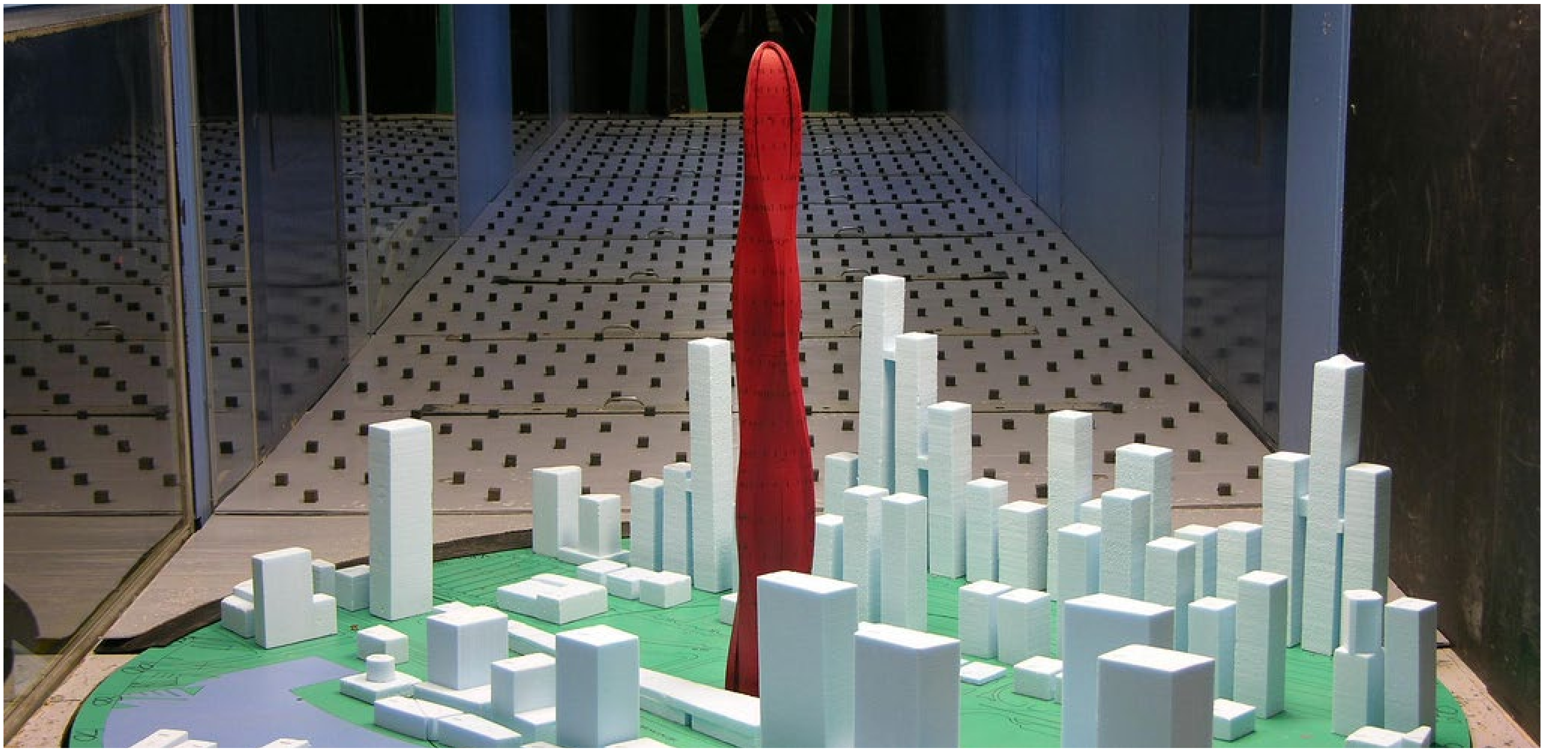
- Sending emergency alerts that a high wind event is forecast, using text messaging, email, local radio and TV stations, and social media.
- Targeting vulnerable and special needs populations.
- Ensuring that communication is multi-lingual.

Notify NYC is the City's official source of information about emergency situations and is used prior and during strong windstorm events. NYC Emergency Management sends these notifications and alerts swiftly to more than a quarter million subscribers.

Another important communication strategy is to send weather advisory notifications to property owners, contractors, and developers, and alerting them to preventive actions they can quickly take like removing loose construction materials and securing loose items.

The Department of Buildings offers an emergency warning system that building owners can sign up for. It also issues Inclement Weather Advisories to property owners, builders, and contractors, advising them to take precautionary steps to prepare for high winds. The Department's *Extreme Weather Guide* provides more-detailed instructions for securing buildings and sites prior to a windstorm. Violation notices are issued as enforcement actions when construction sites are not safely secured.

Longer-term education efforts can help the public learn how to prepare for and respond to strong windstorms. Messaging stresses points like these:



WIND TUNNEL

- People in buildings not built to modern standards should know beforehand the safest place to take cover inside the building.

- Furniture on balconies and other loose items should immediately be secured.

- Building owners and residents should have emergency action plans that define procedures to be implemented in the event of a building-related incident or emergency.

NYC Emergency Management's *Ready New York Household Preparedness Guide* provides information on how households can prepare for severe weather events like strong windstorms.

The *Ready New York Reduce Your Risk Guide* explains to New Yorkers, and in particular to homeowners, how to reduce risks posed by tornadoes and other strong windstorms. Measures include performing routine building maintenance, inspecting buildings for structural weaknesses, and making needed repairs.

EXTREME HEAT

CHAPTER 4.5

Extreme heat causes more fatalities annually than any other extreme weather event in the United States. New York City is particularly susceptible to this hazard due to its dense urban environment, which absorbs and traps the heat. Prolonged periods of this heat accompanied by high humidity create a dangerous situation for vulnerable populations while straining the city's utilities and infrastructure. Climate scientists expect extreme heat events to worsen as a result of climate change.

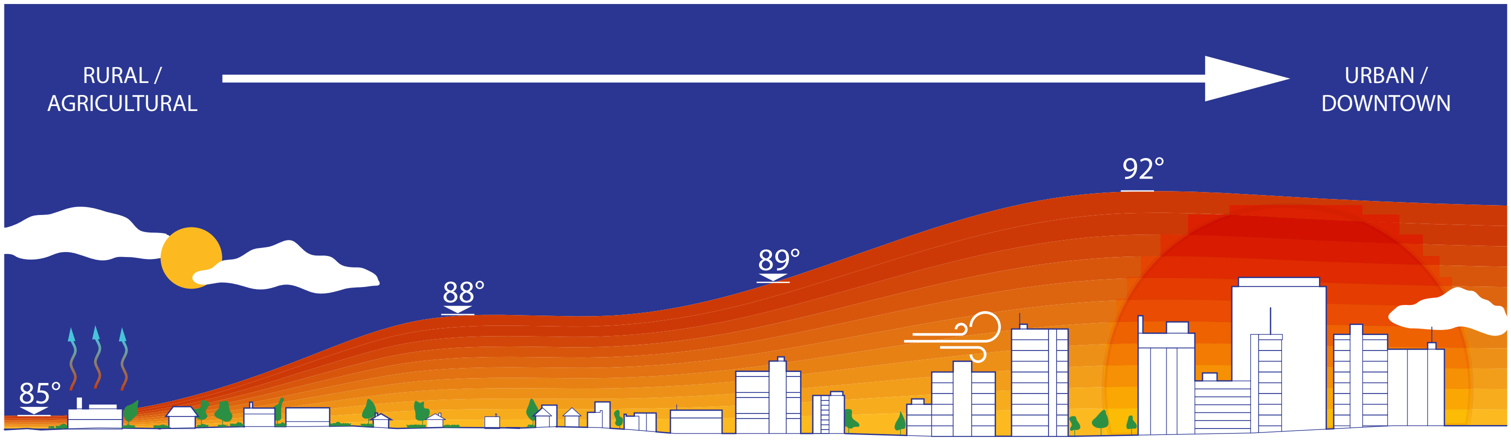
WHAT IS THE HAZARD?

During the summer, New York City usually experiences one or more periods of extreme heat. Heat is not just uncomfortable; it can be dangerous – causing dehydration, heat exhaustion, heat stroke, and in extreme cases, death. It can also cause power outages that produce a cascade of impacts throughout the city.

Extreme heat events are most likely to occur between June and August, but they may also occur in May or September. Between 1971 and 2000, Central Park averaged 18 days a year with temperatures of 90°F or higher.

The effects of extreme heat are worsened by high levels of humidity – the amount of moisture in the air. The higher the temperature, the more moisture the air can hold. High humidity impairs the body's ability to cool itself and can make the temperature feel hotter than it actually is. The combined effect of temperature and humidity – what the temperature "feels like" – is known as the heat index. Another effect of extreme heat is poor air quality, which can occur in New York City during summer months, when stagnant atmospheric conditions trap humid air and pollutants, such as ozone, near the ground.

In New York City, extreme heat events are defined as periods when the heat index is 100°F or higher for one or more days, or when the heat index is 95°F or higher for two or more consecutive days. The longer a heat wave lasts and the hotter the temperature is, the greater the risk of adverse impacts on human health and the city's infrastructure. Climate change is likely to bring us hotter temperatures, more hot days, and more frequent and longer heat waves.



URBAN HEAT ISLAND TRANSECT

KEY HEAT FACTS

Heat causes more fatalities annually than any other extreme weather event.

In New York City, most people who die from heat stress are exposed in homes without air conditioning.

An estimated one in four New Yorkers (25 percent of our population) either do not have or use air conditioning regularly during hot weather.

EXCESS 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 recognized 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 expected compared with normal summer conditions.

WHAT IS THE RISK?

THE ROLE OF THE URBAN ENVIRONMENT

Our city's massive, dense, built environment creates a phenomenon known as the "urban heat island effect." Heat islands develop in urban areas where natural surfaces that were once permeable are paved with asphalt or covered by buildings and other structures. Incoming radiation from the sun is absorbed by these surfaces during the day and re-radiated at night, raising ambient temperatures. Waste heat from air conditioners, vehicles, and other equipment also contributes to the urban heat island effect. The effect is most pronounced during summer nights, when New York City is, on average, about 7°F warmer than surrounding suburban areas. Under certain nighttime conditions, the city can be as much as 10-20°F warmer than its surroundings.

The severity of an extreme heat event is typically measured by how the temperature and humidity affect people's health. To describe health effects, the National Weather Service developed the heat index chart. The National Weather Service also issues heat advisories, watches, and warnings for New York City. These advisories are based on analyses of the relationship between weather conditions and mortality, conducted by the New York City Department of Health and Mental Hygiene (DOHMH).

While extreme heat affects all of our city, the air temperature varies from location to location within the city. For example, areas with high concentrations of heat-trapping materials and less vegetative cover can be warmer than areas with more vegetative cover, or areas cooled by ocean breezes. Across the city, surface temperatures (the temperature of the ground and of surfaces in the built environment) are typically even more variable than air temperatures on hot days.

Since the late 19th century, the number of days with temperatures of 90 F or higher has been on the rise. Climate scientists predict that by the 2050s the city could have as many 90 F days as Birmingham, Alabama does today - more than triple the 18 days we have now.

PEOPLE AT RISK

Extreme heat can be lethal. Prolonged exposure to extreme heat can take a serious toll on the body and lead to dehydration and heat exhaustion. In extreme cases, heat stroke may occur when the body is no longer able to regulate its internal temperature, causing permanent damage to the brain and other vital organs, and, if not treated immediately, death. Heat exposure can also exacerbate chronic health problems such as heart and respiratory conditions.

In New York City, most deaths and serious illnesses from extreme heat occur from exposure in homes without air conditioning. Most at risk are people who fall into one or more of these categories:

Are aged 65 years or older

- Have chronic health conditions (e.g. heart disease or diabetes)
- Have dementia or serious mental illness that impairs their judgment
- Take certain medications
- Abuse drugs or alcohol
- Are obese
- Are socially isolated or homebound and unable to care for themselves

People who work outdoors or otherwise engage in vigorous outdoor activities are also at risk.

Between 2001 and 2011, an annual average of 450 emergency department visits and 150 hospital admissions due to heat-related illness were reported in New York City, along with an annual average of 13 heat stroke deaths.

In addition to directly causing deaths, heat can produce an excess of natural-cause deaths. This occurs when chronic conditions are exacerbated by heat and result in death, but heat is not recognized as a contributing cause of death on the death certificate. DOHMH estimates that between 1997 and 2013, an average of approximately 100 excess natural-cause deaths per year were associated with heat waves in New York City.

As our population ages and climate change brings more extreme heat events, rates of heat-related impairments and deaths may rise. A 2013 study based in Manhattan projects that the number of heat-related deaths will increase sharply throughout the 21st Century.

CONSEQUENCES FOR THE BUILT ENVIRONMENT

Buildings – internal temperatures

During an extreme heat event, the temperature can rise rapidly in buildings that lack air conditioning, or in which air conditioners are not working properly. A building's age and construction materials can affect internal temperatures, because older buildings were not built to Construction Code standards that require better-insulated windows and walls.

Factors that most affect internal temperature in hot weather are the type of windows and their size, the amount of air that escapes from the building through cracks and leaks in walls, and the amount of insulation in walls and roofs.

Windows matter for the same reason that greenhouses are made of glass: glass transmits heat far more readily than materials like brick, masonry, and wood. Thus, on a hot day, windows cause an internal greenhouse effect. During an extreme heat event, single-family homes that are exposed on all four sides and all-glass buildings tend to heat up the most, while row houses that share

Heat Index (Apparent Temperature)

AIR TEMPERATURE (F°)

RELATIVE HUMIDITY (PERCENT)

0	70	75	80	85	90	95	100	105	110	115	120	125	130	135	
5	64	69	73	78	83	87	91	95	99	103	107	111	117	120	125
10	64	69	74	79	84	88	93	97	102	107	111	116	122	128	
15	65	70	75	80	85	90	95	100	105	111	116	123	131		
20	65	71	76	81	86	91	97	102	108	115	123	131			
25	66	72	77	82	87	93	99	105	112	120	130	141			
30	66	72	77	83	88	94	101	109	117	127	139				
35	67	73	78	84	90	96	104	113	123	135	148				
40	67	73	79	85	91	98	107	118	130	143					
45	68	74	79	86	93	101	110	123	137	151					
50	68	74	80	87	95	104	115	129	143						
55	69	75	81	88	96	107	120	135	150						
60	69	75	81	89	98	110	126	142							
65	70	76	82	90	100	114	132	149							
70	70	76	83	91	102	119	138								
75	70	77	85	93	106	124	144								
80	70	77	86	95	109	130									
85	71	78	86	97	113	136									
90	71	78	87	99	117										
95	71	79	88	102	122										
100	71	79	89	105											
	72	80	91	108											

FATIGUE POSSIBLE WITH PROLONGED EXPOSURE AND/OR PHYSICAL ACTIVITY.

SUNSTROKE, HEAT CRAMPS AND HEAT EXHAUSTION POSSIBLE WITH PROLONGED EXPOSURE AND/OR PHYSICAL ACTIVITY.

SUNSTROKE, HEAT CRAMPS OR HEAT EXHAUSTION LIKELY, AND HEATSTROKE POSSIBLE WITH PROLONGED EXPOSURE AND/OR PHYSICAL ACTIVITY.

HEAT/SUNSTROKE HIGHLY LIKELY WITH CONTINUED EXPOSURE.

National Weather Service Heat-Related Products

Heat Advisory   Issued within 24 hours prior to onset of any of the following conditions:

- Heat index of 100°F-104°F for any period
- Heat index of 95°F-99°F or greater for two consecutive days

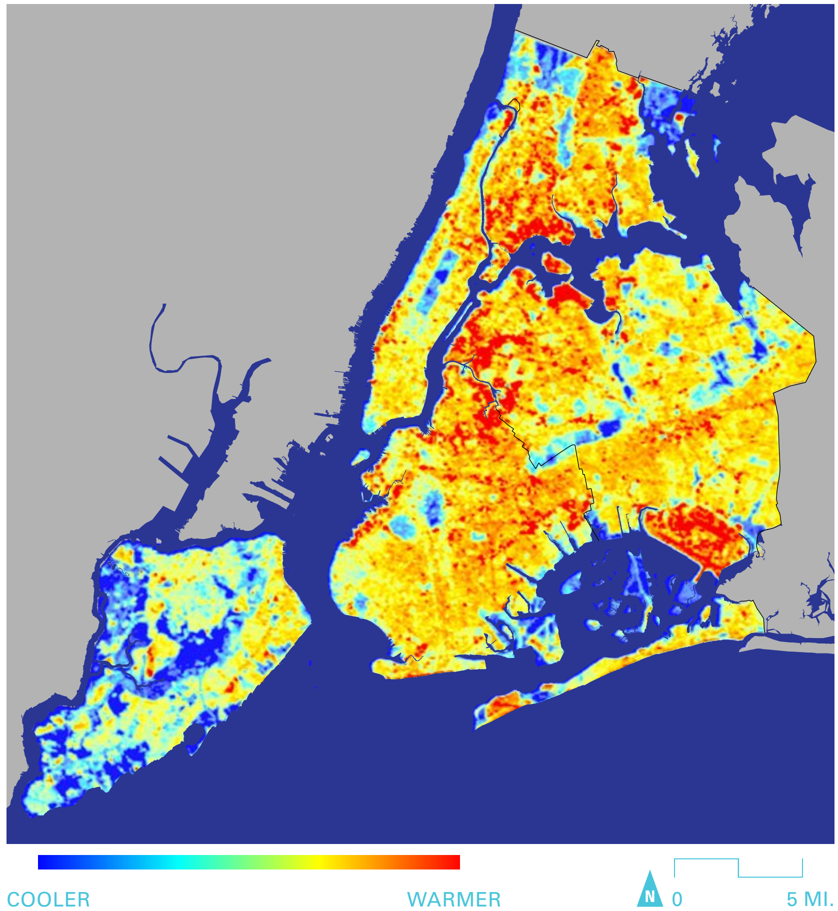
Excessive Heat Watch   Issued 24-48 hours prior to onset of the following condition:

- Heat index of at least 105°F for at least two consecutive hours

Excessive Heat Warning   Issued within 24 hours of onset of the following condition:

- Heat index of at least 105°F for at least two consecutive hours

SOURCE: NATIONAL WEATHER SERVICE, 2013



THERMAL IMAGERY

SOURCE: LANDSAT THERMAL DATA 08/18/09. NYC DOHMH

walls with their neighbors and masonry buildings with thicker walls are typically at an advantage.

The grid – power outages

Extreme heat drives the use of air conditioning, and thus demand for electricity. When demand threatens to outstrip the grid's capacity to supply electricity, utility providers must take precautions to reduce strain on the system. When capacity is exceeded, blackouts may occur.

Heat can also damage the electric system physically, stressing electrical generation, transmission, and distribution infrastructure. Power lines can overheat and short circuit, in some cases causing power outages. These systems are also affected when more electricity flows through them to meet higher demand, stressing electrical generation, transmission, and distribution infrastructure, which increases the likelihood of failure. The heat can also cause overhead electric and telecommunications lines to sag. If they sag onto trees, they may short circuit and cause an outage.

Outages can have pervasive and severe impacts on people and the built environment. They can shut down air conditioning, fans, elevators, electric pumps that distribute water to the upper floors of high-rise buildings, refrigerators, freezers, computers, and everything else that is plugged into the grid and lacks a source of backup power, including life-sustaining medical equipment. Impacts are greatest on vulnerable populations such as people dependent on oxygen concentrators, motorized wheel chairs that must be recharged, and medications that must be refrigerated.

A citywide power outage that occurred in August 2003 on a normal summer day - not during a heat wave - produced approximately 90 excess deaths. A widespread outage during a heat wave could cause even more deaths.

Power outages can also have significant consequences on communication. If the power is out, cell phones cannot be recharged and internet connections may be lost, and with them access to vital information or assistance in the case of an emergency.

Among other services that are potentially vulnerable in the case of a power outage are healthcare, our food supply system, and wastewater treatment.

Transportation

Extreme heat poses a risk to ground transportation infrastructure. For instance, high temperatures can cause railroad tracks and wires, and pavement and joints on roads and bridges to crack, buckle, or sag, resulting in service disruptions, potentially hazardous travel conditions, and the need for costly repairs. Along with this come problems with the opening and closing of movable bridges and the softening of asphalt roads. Power outages can also disable rail operations that are dependent on electricity.

THE SUMMER 2006 HEAT WAVES AND LONG ISLAND CITY NETWORK POWER OUTAGE

The summer of 2006 featured two severe heat waves. The first lasted from July 16 through July 18; the second from July 27 through August 5. Combined, the two directly caused 46 heat stroke deaths, most of which occurred during the second heat wave. The second heat wave also contributed to an estimated 100 excess deaths from natural causes. The majority of fatalities were among seniors and people with preexisting medical conditions.

While the first heat wave was shorter and caused far fewer fatalities, record power usage during its first 2 days resulted in a major power outage in northwestern Queens that started on July 17 and lasted for 9 straight days. This unprecedented event was the longest single power outage in New York City's history.

Equipment failures in Con Edison's Long Island City network exacerbated the outage, which affected 174,000 residents in the Queens neighborhoods of Astoria, Long Island City, Sunnyside, and Woodside. Local businesses lost an estimated $111 million in revenue and inventory such as spoiled food. The outage also caused traffic congestion: traffic lights didn't work, and police officers had to direct traffic. Total outage-related costs were estimated at $188 million.

The extensive impacts of the outage drove home dramatically the need to protect electric utility networks from extreme heat events. Con Edison subsequently increased its operational capacity, strengthened its communication procedures, and improved its ability to track customer outages. These measures now help limit service disruptions.

CONSEQUENCES FOR THE NATURAL ENVIRONMENT

Poor air quality can occur during a heat wave, when stagnant atmospheric conditions trap pollutants in urban areas. Ozone, a major component of smog, is created in the presence of sunlight by reactions of chemicals in gasoline vapors from vehicles and industrial smoke stacks. Hot weather can increase ozone levels. High ozone levels often cause or worsen respiratory problems.

The U.S. Environmental Protection Agency monitors ozone levels and issues daily air quality forecasts. Its Air Quality Index (AQI) was created to correlate levels of different pollutants to one scale. The higher the AQI value, the greater the health concern. When levels of ozone and/or fine particles are expected to exceed an AQI value of 100, an Air Quality Health Advisory is issued alerting sensitive groups to take necessary precautions. When ozone levels in the unhealthy range are expected, people are advised to limit vigorous outdoor physical activity during the afternoon and early evening hours.

HOW DO WE MANAGE THE RISK?

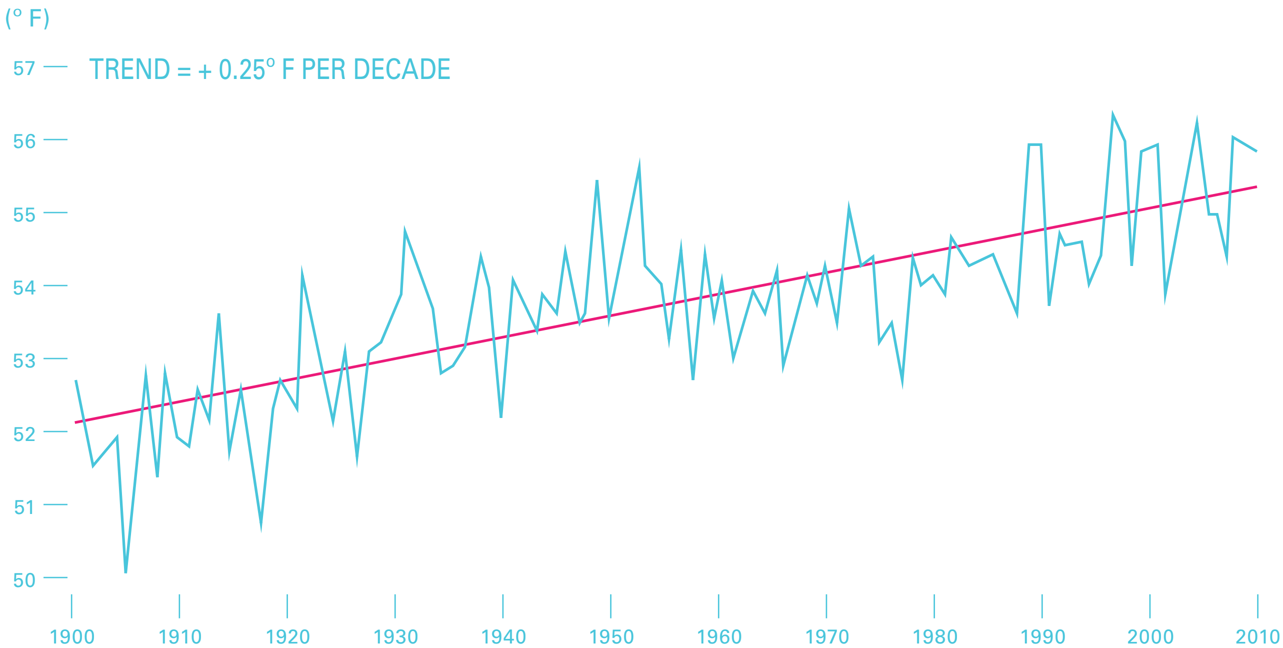
Extreme heat can have significant consequences for vulnerable populations and infrastructure, and the fact that these events are becoming more frequent and severe calls for more comprehensive risk management strategies. Those strategies begin with efforts to inform vulnerable populations about health risks and include measures to protect infrastructure, keep internal building temperatures cool, and reduce the urban heat island effect. What follows is a sampling of strategies.

EDUCATION, COMMUNICATION, AND OUTREACH

Before a heat wave strikes, the public – especially vulnerable populations – must understand the dangers posed by extreme heat, who is most at risk and why, and what practical measures they can take to protect themselves.

- **Education**: OEM's brochure "Beat the Heat" delivers important safety tips and information online and in print. DOHMH offers information about the health impacts of heat and heat illness prevention.

OBSERVED ANNUAL TEMPERATURE IN CENTRAL PARK (1900 - 2011)
Source: NPCC, 2013



- NYC Emergency Management closely monitors National Weather Service heat advisories, and excessive heat watches and warnings. When conditions warrant, OEM activates the City's Heat Emergency Plan, which it developed jointly with the National Weather Service, DOHMH, and many other partners.

- **Public alerts** offer safety tips during heat advisories through Notify NYC and organizations serving vulnerable populations through the Advanced Warning System. Alerts are also given to health care providers through the Health Alert Network and other DOHMH outreach.

- **Cooling centers** are opened at designated locations such as community centers, senior centers, and public libraries, to offer air conditioning to the public. Studies show that spending as few as 2 hours a day in air-conditioned spaces can significantly reduce the risk of heat-related illnesses. During the summer of 2014, the City had over 500 air-conditioned spaces available.

- **Outreach** to the homeless is extended when the heat index reaches 90°F or higher, especially during the sun's peak hours: between 11:00 a.m. and 5:00 p.m. Agencies in regular contact with vulnerable populations, including the homeless, can determine whether individuals may need further protection.

- The "Be a Buddy" campaign describes DOHMH's outreach to the general public advising them to check on neighbors, family, and friends who may be vulnerable during a heat wave. DOHMH includes these messages in all public communications including press releases and heat-health guidance.

PROTECTING INFRASTRUCTURE

Government agencies and private sector parties pursue many strategies to manage risks related to infrastructure. Some are short-term; some are long-term. Some long-term measures deliver the short-term benefit of reducing demand on the grid and thus the risk of power outages.

MAJOR HEAT WAVES THAT INFORMED OUTREACH STRATEGIES

Two of the most significant heat waves in recent memory occurred in Chicago in 1995 and across much of Europe in 2003. The Chicago heat wave lasted for 2 weeks during July. The heat index peaked at nearly 120°F, claiming over 700 lives. The European heat wave was even more dramatic. It affected France, Portugal, The Netherlands, Spain, Italy, Germany, Switzerland, the United Kingdom, and Ireland, and lasted for most of the summer (with the first half of August being hottest). Estimates of heat-related deaths range from 50,000 to 70,000, with nearly 15,000 of them in France. One reason impacts were so severe is that air conditioning is not widespread in Europe. Should a widespread power outage occur in New York City during an extended, severe heat wave, it could greatly increase the public health threat.

The Chicago and European heat waves exposed the vulnerabilities of certain population groups, particularly the elderly, who made up the majority of the victims, and people without air conditioning.

The 10-day heat wave in 2006 was one of New York City's worst extreme heat events in the past two decades. This event prompted expansions of the City's Heat Emergency Plan to increase outreach to vulnerable populations and to emphasize the importance of air conditioning in preventing heat illnesses.

An important dimension of outreach is the Check on Your Neighbor (DOHMH calls the campaign "Be a Buddy") strategy that asks citizens to share life-saving information about heat risks and safety measures with people they know who may require assistance, particularly those living alone.

Energy systems

Utilities employ "supply-side" strategies to reduce strain on the system and continue operations during extreme heat events:

- **System reinforcements** provide alternate or additional supplies of power to minimize the risk of disruption due to heat – for example, by increasing the number of power supply feeders, installing additional distribution transformers, building new substations, and redistributing electric loads among substations.

- **Improving system reliability** safeguards system components so that they are operational and available for service. This includes inspecting and maintaining equipment, upgrading components, and implementing improvements such as redesigning circuits to minimize the number of customers affected, and installing automated switches.

- **Operational readiness** involves measures to prepare system operations for summer conditions by conducting engineering analyses and studies to assess system conditions, implementing protective steps such as voltage reduction, conducting staff training and exercises on how to handle extreme heat scenarios, and confirming that power generators have adequate capacity.

- **Increased system redundancy** provides alternate power supplies if the main supply is disrupted due to heat.

The city's primary utility providers, Con Edison and PSEG, are strengthening their power sources and energy infrastructure by making utility systems more flexible and by diversifying energy sources to minimize impacts of extreme weather events.

- **Utility demand response programs** are short-term strategies that offer financial incentives to customers to avoid blackouts when demand for electricity soars. Con Edison runs aggressive demand-response programs in which commercial, industrial, and residential customers can enroll voluntarily. When demand for electricity soars, Con Edison pays those customers who *temporarily* reduce their consumption of electricity upon request.

Transportation systems

Transportation systems can be protected with measures such as these:

- Equipment upgrades to rail systems involve replacing or retrofitting trains, track signals and switches.

- Retrofits to roads and bridges employ heat-resistant materials to prevent cracking and buckling from thermal expansion.

The MTA has invested in measures to protect its systems and equipment from heat-related damage, such as new redundancy measures and structural improvements to trains, railroad tracks, and buses. The City's Department of Transportation is studying the use of permeable pavements in roads and bridges. While such pavements would primarily reduce impacts from heavy precipitation and snowmelt, it may also reduce impacts from extreme heat: this type of roadway surface would not get as hot as a typical roadway surface.

PROTECTING BUILDINGS

Long-term strategies aim at increasing energy efficiency and lowering indoor air temperatures. Reducing energy consumption over the long-term helps reduce the need for short-term strategies such as utility demand-response programs, and it reduces the risk of power outages.

As building codes have grown stricter over time, they have required better-insulated windows and walls. Many buildings are now being built to performance standards that are even higher than the minimum required in our Construction Codes. High-performance buildings use advanced design and materials such as windows that keep cool air from escaping during

BIOSWALE IN QUEENS BY NYC GREENSTREETS

summer, rigorous air sealing, and extensive insulation. The internal temperatures inside these high-performance buildings remain significantly lower.

Existing buildings can benefit from retrofits like these:

- Sealing and insulating buildings properly keeps them cooler by ensuring that cooled air does not leak out. This can be accomplished by caulking and sealing doors and windows that leak air, and caulking and sealing air leaks where plumbing, ducts, or electrical wiring comes through walls, floors, or ceilings. Making sure walls and attics are properly insulated helps, too, as insulation slows the transfer of heat into the building's interior.

- High-performance materials, such as multiple-paned windows with reflective coatings, help insulate buildings from extreme heat and keep cool air from escaping.

- Energy efficiency retrofits such as higher-efficiency mechanical systems and smart sensors can reduce energy demand, decreasing the strain on the electric grid.

NYC GREEN ROOFS
SOURCE: NYC PARKS

- Utility demand reduction programs provide incentives to commercial and industrial building owners to permanently reduce their energy consumption. Con Edison offers a number of energy efficiency tools to encourage residential, small business, multifamily building, and commercial/industrial customers to reduce energy consumption.

The New York City Department of Housing Preservation and Development has developed *New York City Greenhouse*, a program to help building owners retrofit with higher-performance materials and to reduce the amount of energy and water their building operations consume. The program provides tax credits, rebates, and incentives that promote energy efficiency, as well as tips for lowering energy bills.

PlaNYC includes the *Greener Greater Buildings Plan*, a set of regulatory measures aimed at reducing the City's carbon footprint. As of 2013, the city had reduced its overall emissions by 19 percent since benchmarking first took place in 2005. The *New York City Carbon Challenge*, which commenced in 2007, calls specifically on private sector partners – including universities, hospitals, commercial offices, multifamily buildings, and Broadway theatres – to reduce their greenhouse gas emissions 30 percent by 2017.

While greenhouse gas reductions serve the long-term goal of slowing climate change, the gains in energy efficiency directly and immediately serve the near-term goal of avoiding power outages (while also reducing electricity bills).

ENVIRONMENTAL CONTROLS

Certain features of the natural environment can partially offset the impacts of extreme heat. The urban heat island effect is directly tied to the ratio of natural cover (trees and other vegetation) to artificial built surfaces. Trees and vegetation keep the surrounding environment cooler by releasing moisture into the air, while many built surfaces trap heat and keep the surrounding environment warmer. Risk management strategies focus on increasing vegetative cover to help lower air temperatures and reduce the urban heat island effect:

- Light surfaces reflect more light and heat than dark surfaces, which absorb and retain heat and worsen the urban heat island effect. Converting dark surfaces such as asphalt and blacktop to lighter materials can reduce local temperatures by several degrees. Replacing roofs with lighter materials ("cool roofs") can help lower a building's internal temperature, in addition to reducing surface and surrounding air temperatures.

NYC COOL ROOFS PROGRAM
SOURCE: DOB-SAMANTHA MODELL

- Planting trees and vegetation along streets and in open spaces – "ecological infrastructure" – can significantly reduce local air temperatures. Trees naturally cool the surrounding air by releasing moisture and absorbing carbon dioxide from the atmosphere. Replacing concrete, asphalt, or even grassy surfaces with trees can help reduce the air temperature by several degrees. Green roofs – roofs with vegetation planted on them – can reduce both outdoor and indoor air temperatures.

Through the NYC Cool Roofs Program – a collaboration between NYC Service (New York City's regional volunteer center) and the Department of Buildings – nearly 6 million square feet of roofs have been re-coated with lighter-colored materials, both reducing internal building temperatures and the local urban heat island effect.

The Department of Transportation has also begun to explore the use of lighter-colored pavement and to incorporate it into street resurfacing and reconstruction.

MillionTreesNYC is a public-private initiative which was launched in 2007 by New York Restoration Project and the Department of Parks and Recreation. It aims to plant and care for one million new trees citywide by 2015. The City will plant 70 percent of these trees in parks, along streets, and in other public spaces. The remainder will be planted by homeowners, businesses, and community organizations. Over 870,000 trees had been planted as of July 2014.

The City's *Green Infrastructure Program*, led by the Department of Environmental Protection, promotes a variety of sustainable green infrastructure practices such as green roofs, rain gardens, and right-of-way bioswales on City-owned property such as streets, sidewalks, schools, and public housing. While the program is primarily aimed at reducing the impacts of stormwater runoff and combined sewer overflows, several strategies, such as expanding the number of green roofs, help reduce urban heat island effects as well.

In the summer of 2013, the Mayor's Office of Long-term Planning and Sustainability formed an Urban Heat Island Working Group to explore further means of reducing heat-island effects. It includes policymakers, scientists, and subject matter experts from across the city and from leading academic institutions.

WINTER WEATHER
CHAPTER 4.6

The winter months in New York City can be brutal. They are often characterized by periods of extremely cold temperatures and by storms that haul in large amounts of snow, ice, sleet, and freezing rain in addition to strong winds. The number of storms per season, the amount of snow from each storm, and prolonged periods of extreme cold can take a toll on people, buildings, infrastructure, and the economy. Hazardous wintry conditions also induce dangers like traffic accidents, power outages, and hypothermia and frostbite.

WHAT IS THE HAZARD?

SNOW AND ICE

The term heavy snow generally means snowfall accumulating to a depth of four inches or more within 12 hours or less, or six inches or more within 24 hours. Sleet is pellets of ice composed of frozen or mostly frozen raindrops, or refrozen partially melted snowflakes. Freezing rain is precipitation that falls as rain, but freezes on contact with a surface, forming a glaze of ice.

The severity of a winter storm depends on temperature, wind speed, type of precipitation, accumulation rate, and timing. A storm that occurs during early winter, when trees still have leaves, may result in more downed trees and power lines due to the additional weight of snow and ice.

Our city can experience a variety of winter storms:

Snow showers are brief, intense periods of snowfall resulting in accumulations of one inch or less.

A **blizzard** is a severe snowstorm with winds of 35 mph or greater and snow and blowing snow that reduce visibility to less than one-quarter mile for three hours or longer.

A **snowsquall** is moderate to heavy snowfall accompanied by strong, gusty winds and, sometimes, lightning.

Thundersnow events are snow accompanied by thunder and lightning.

Ice storms occur when freezing rain results in dangerous accumulations of ice, usually one-quarter inch or more.

The intensity of a winter storm can be classified by meteorological measurements and societal impacts. The Northeast Snowfall Impact Scale (NESIS) characterizes and ranks high-impact Northeast snowstorms – those with large areas of snowfall accumulations of 10 inches and greater. The National Climatic Data Center developed this scale because the transportation and economic impacts of Northeast snowstorms can significantly affect the rest of the country. The index uses population data and meteorological measurements to gauge a storm's impacts on society.

NESIS SCALE

Notable	Signficant	Major	Crippling	Extreme
1	2	3	4	5

WINTER WEATHER EXTREMES IN NEW YORK CITY

The largest snowstorm to hit New York City occurred on February 11-12, 2006, bringing in a total of 27 inches of snow.

The month with the most snowfall is February 2010: 37 inches fell.

One of the worst winters for snow was 1996-1997, when snowfall totaled 76 inches.

The coldest day of the year was recorded on February 9, 1934, with temperatures dipping 15 degrees below zero.

The coldest month was recorded in February 1934, with an average temperature of 20°F.

TOP FIVE SNOWSTORMS IN NEW YORK CITY FOR SNOW ACCUMULATION

DATE	INCHES OF SNOW	NESIS RATING
February 11 to 12, 2006	27 inches	3
December 26 to 27, 1947	26 inches	2
March 12 to 14, 1888	21 inches	4
February 25 to 26, 2010	21 inches	3
December 26 to 27, 2010	20 inches	3

SOURCE: WEATHER 2000/FORECAST RESEARCH

Winter storms are frequent here. Since 1798, New York City has experienced 19 snowstorms with snowfall totaling 16 inches or more. One was Extreme, five were Crippling, five were major, one was significant, and one was notable. The remaining six historical snowstorms did not qualify for a NEIS rank.

EXTREME COLD

While snow and ice are the defining features of winter storms, wind gusts and frigid temperatures can accompany these weather events. Extreme cold can occur independent of storms.

Extended periods of subfreezing temperatures are most common here between December and March. An extreme cold event typically involves an extended period with temperatures at or below 32°F. As the temperature drops and wind speed increases, heat drains from our bodies more rapidly. This “wind-chill effect” can make a person feel even colder.

In general, New York City experiences less severe cold due to the urban heat island effect (explained in the “Extreme Heat” profile) and proximity to the ocean. Areas right next to the shoreline are often slightly warmer during colder months, but wind-chill temperatures along the shore may be lower than temperatures several miles inland, due to stronger winds near the water, even if the actual air temperature is higher. Neighborhoods with lower population density, greater natural cover, and less heat-absorbing asphalt may be a few degrees cooler, though this effect is less pronounced during colder months.

A National Weather Service (NWS) wind-chill chart reports the temperature felt on exposed skin due to the combination of air temperature and wind speed. When conditions warrant, the NWS issues wind-chill advisories or wind-chill warnings for the New York City region. An advisory is issued when wind-chill values are expected to fall to between 24°F and minus 15°F. A warning is issued when values are expected to fall to minus 25°F or below.

According to the New York City Panel on Climate Change, the city experiences an average of 72 days per year with temperatures at or below 32°F. This annual average is projected to decrease by the 2020s to 52 to 58 days and by the 2050s to 42 to 48 days.

WIND CHILL CHART (Source: NWS)

Temperature (°F)

Wind (mph)

Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
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 (°F) V= Wind Speed (mph)

Wind Chill (°F) = 35.74 + 0.6215T - 35.75(V0.16) + 0.4275T(V0.16)

WHAT IS THE RISK?

Accumulations of snow and ice, as well as cold temperatures, can impact public health, public safety, buildings, infrastructure, and the economy in ways that range from inconvenient to grave.

PEOPLE AT RISK: HEALTH AND PERSONAL SAFETY

Power outages caused by winter storms – typically, when trees topple onto power lines or the weight of ice brings power lines down – can trigger a cascade of problems. For example, during power outages, people living without backup power are at increased risk. If a winter storm interrupts the supply of fuel oil, natural gas, steam, or electricity to building heating systems, the drop in building temperatures can put occupants' health at risk.

One risk is hypothermia. When exposed to cold temperatures for an extended period, our bodies lose heat faster than we can generate it, causing our internal temperature to drop. Symptoms include shivering, fatigue, loss of coordination, blue skin, dilated pupils, slow pulse and breathing, and loss of consciousness. Death can result.

The NYC Department of Health and Mental Hygiene (DOHMH) reports nearly 200 hypothermia-related hospital admissions and emergency department visits on average each year from 2005 to 2010.

Another serious condition brought on by extreme cold is frostbite: a freezing of the body's outer tissue, most commonly the nose, ears, cheeks, chin, fingers, and toes. Symptoms include numbness, tingling or stinging, aching, and skin discoloration. Frostbite can cause permanent damage to body tissue and in severe cases may result in the need for amputation.

Exposure to cold can also exacerbate chronic illnesses, such as asthma and other respiratory diseases.

Another threat is carbon monoxide poisoning. Home appliances, notably gas kitchen ranges and space heaters emit carbon monoxide if not properly ventilated. While carbon monoxide poisoning can happen any time of the year, the danger is greater during winter.

Icy conditions may contribute to falls and other injuries for people who venture outdoors. Snow and ice storms can be especially hazardous for people who work outdoors, those who are homeless, and other vulnerable populations.

Falling icicles from buildings can be dangerous in a dense city such as New York. In the winter of 2013-14, icicles formed on 1 World Trade Center, and some fell, from great heights. As a safety measure, officials closed portions of the Westside Highway, the PATH train station next to 1 WTC, several side streets, and nearby sidewalks.

PEOPLE AT RISK: PUBLIC SAFETY

The downing of trees and power lines can put people at risk. Icicles falling from buildings can injure pedestrians, damage vehicles, and disrupt transportation if streets must be closed for safety reasons. When heavy snow and ice disrupt the city's infrastructure and services, commuters and travelers can be stranded, the flow of essential supplies (including food and medicines) can be interrupted, and emergency and medical services can be constrained.

All types of wintry precipitation contribute to hazardous travel conditions. Freezing rain is the most treacherous. The greatest danger during winter storms in New York City is the risk of traffic accidents. Even small accumulations of ice on roadways can cause accidents, resulting in injuries or fatalities of motorists, bicyclists, and pedestrians.

BUILDINGS THAT PUT PEOPLE AT RISK

Winter storms can disrupt utility services. Some building types handle temperature drops better than others. Three factors affect this: the type and size of windows, the amount of air escaping through cracks and leaks in the walls, and the amount of insulation in the walls and roof. Older buildings constructed to less-stringent building code standards are vulnerable to drafts due to leaks in the walls, windows, and doors. Buildings constructed to later standards have better thermal protections.

The Urban Green Council created computer models of representative buildings to determine indoor temperatures during a utility disruption and found that many older New York City buildings would drop below 40°F in three to five days. This same study also looked at how building typology influences the ability of a building to retain heat during a power outage. Their study found that:

- the temperature inside a single-family detached home would fall below freezing four days after an outage.
- a row house apartment, brick low- and high-rise apartments, and an all-glass high-rise apartment could fall below freezing one week after an outage occurred.

Residents' long-term exposures to low temperatures could cause significant health problems.

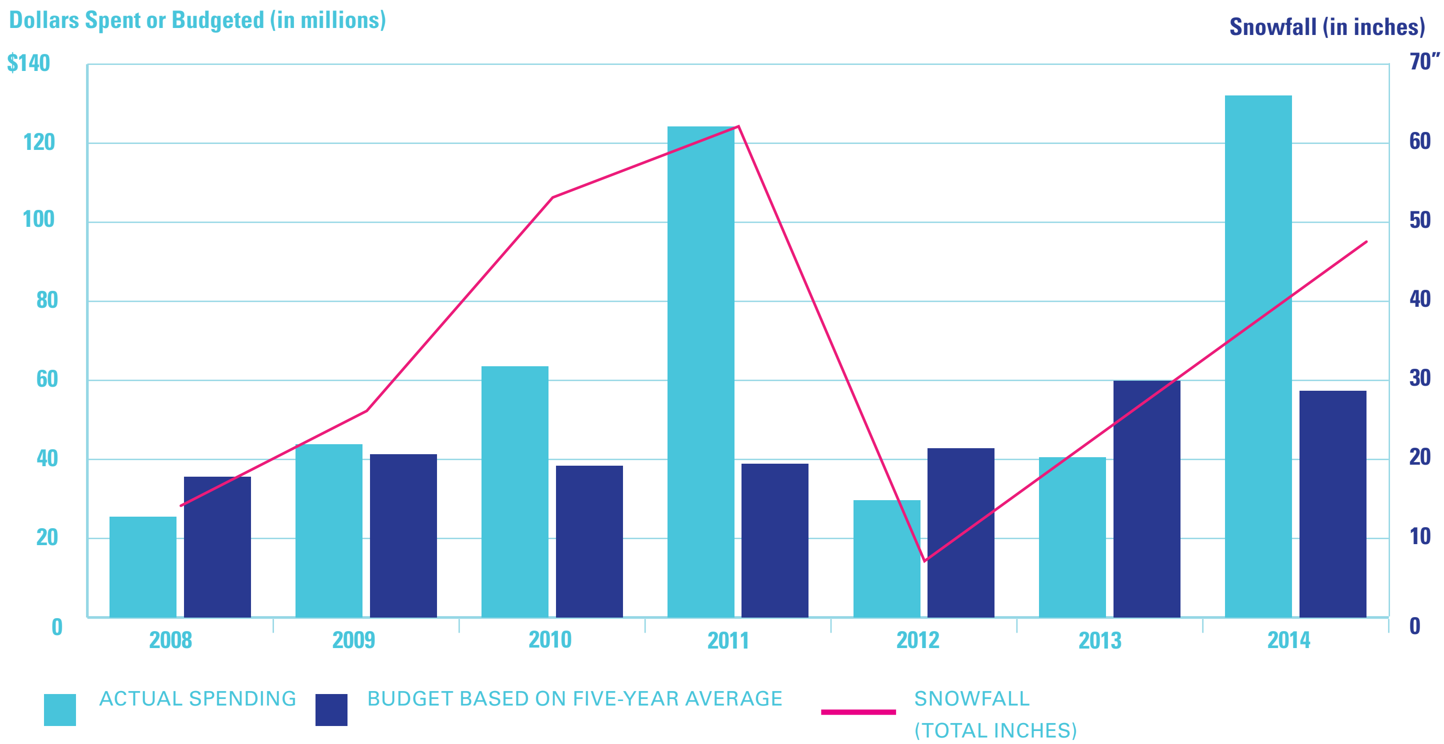
Structural damage or building collapses because of snow and ice are rare here. If the roof structure is poorly maintained, snow accumulation can cause damage, may cause leaks, and in the worst cases would result in roof collapse. Decaying wood or brick masonry can also worsen winter weather impacts. However, poorly maintained vacant buildings, which constitute a small portion of our total building stock, are most at risk to this type of damage.

INFRASTRUCTURE AT RISK

Winter storms can affect infrastructure dramatically, with follow-on effects. Streets covered with snow can cause traffic accidents and impede emergency access. Fire hydrants buried in snow may slow Fire Department response times. Ice accumulations can affect roads, rail beds, and mass transit rail switch systems, making travel dangerous. Bridges and overpasses are particularly dangerous because they freeze before other surfaces.

Retaining walls that are not well maintained may be structurally compromised if saturated with snow and ice.

HOW MUCH HAS SNOW REMOVAL COST THE CITY IN RECENT YEARS? (Source: NYC Independent Budget Office)



Ice storms can have a greater impact than heavy snowfalls because ice adds significant weight to tree limbs and overhead lines. While power lines can withstand one-quarter inch of ice accumulation, surrounding tree limbs can fail, especially under windy conditions, knocking out power and phone lines.

During winter months, freezing temperatures and repeated freeze-thaw cycles can cause potholes, which may damage vehicles and cause traffic accidents as vehicles swerve to avoid them.

The thaw phase of freeze-thaw cycles can dissolve rock salt that the Department of Sanitation spreads on roadways to melt snow and ice. That salty water can then seep into manholes, corroding and short-circuiting underground electric cables, in some cases interrupting service, in some cases causing fires in manholes and, in rare cases, causing explosions in them.

Frozen pipes, a common occurrence during cold spells, may interrupt water and gas supplies, and damage drainage systems.

Heavy snowfall and ice can overwhelm the capacity of the City's wastewater treatment plants, because, when snow and ice melt, the runoff flows into the city's sewer system, and if the combined volume of runoff and wastewater exceeds what treatment plants can handle, untreated sewage is discharged into local waterways.

ECONOMIC AND FINANCIAL RISKS

During and after major winter storms, businesses and government may see short-term revenue and productivity losses. And because New York is a global travel hub, winter storms that cause flight delays and cancellations can disrupt travel on a global scale, with resulting economic consequences.

The Departments of Sanitation, Transportation, and Parks and Recreation may bear additional costs related to snow and ice removal and pothole repair. The City's budget for snow removal is based on a rolling five-year average of actual expenditures. Fluctuations in annual snowfall make budgeting for snow removal challenging. For example, the City fell short by $87 million for the 2010/2011 winter season because average annual snowfall for the previous five years was less than the snowfall during that season.

The blizzard in late December 2010 is estimated to have cost the region over $68 million. This includes the $30M for that the Metropolitan Transportation Authority paid in overtime expenses and lost ridership revenue. Total costs to City government were reported to exceed $38.8 million – the entire City's snow budget for the year. A majority of the costs were due to overtime pay for Department of Sanitation workers.

HOW DO WE MANAGE RISK?

Strategies for managing winter-weather risks include regulatory controls on building design, as well as building maintenance routines and retrofits; infrastructure protections; environmental controls; and efforts to help New Yorkers prepare for and respond to severe weather events.

REGULATORY CONTROLS

Engineering standards

Regulatory controls take the form of provisions in our City's Construction Codes that require that new buildings and existing buildings that are undergoing major renovations be designed to withstand winter storms and extreme cold. Relevant Code provisions include the following:

- Roofs must be able to withstand snow-load (the weight of snow on the roof) and snowdrifts caused by parapets on adjacent buildings.
- Windows must provide thermal protection and buildings must be insulated against extreme cold.

Snow load is of moderate concern in New York City. Building Codes as early as 1899,specified minimum design loads (the weight a roof can hold), load combinations, and procedures for determining snow loads. The Department of Buildings bases snow loads on regional climate values for ground snow load and incorporates thermal factors for heated and unheated buildings. In July 2009, the Department adopted the latest national standards for determining snow load, snowdrift loads, and sliding snow loads when it adopted the International Code Council family of codes.

As stated above, the City's construction codes apply to newer buildings and to older buildings when substantial changes are being made to them. The Department of Buildings aims to adopt a code specific to existing buildings based on the International Existing Building Code. This will simplify the regulation of building upgrades and streamline permitting for resiliency improvements.

Building maintenance

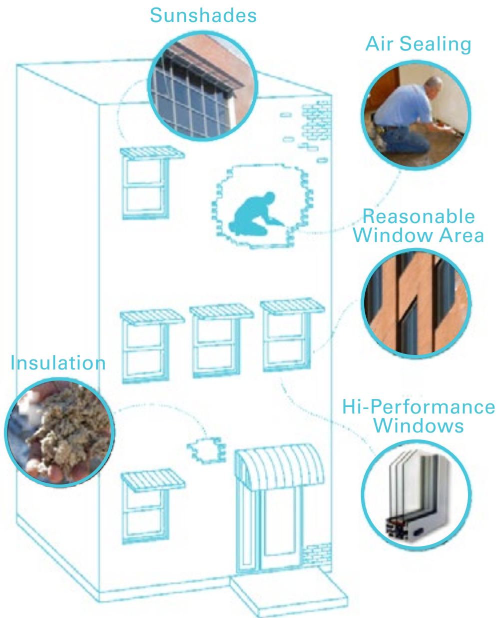
To protect buildings from extreme cold and heavy snowfall, regular maintenance and repairs are essential. The Department of Buildings encourages that buildings be periodically inspected to identify the need for repairs.

Maintenance measures include the following:

- Regularly inspect building elements including parapets, cornices, window lintels, exterior walls, and roofs.
- Clear roofs and overhangs of snow and ice, and clean gutters and roof drains before and after a snow or ice storm.
- Inspect and repair all wood that has rot (especially when rot is close to outside walls).
- Regularly inspect roof structure for wood rot.
- Repair sagging ceilings, to better withstand snow load.
- Replace all damaged roof joists.

Building retrofits and upgrades

Retrofits and upgrades to higher-performing building materials help buildings retain heat and better withstand severe winter weather in other ways, too. Measures include:



SOURCE: URBAN GREEN COUNCIL

HOW HIGH-PERFORMANCE OUT-PERFORMS

A high-performance building can retain heat longer than other building types during a power outage.

The Urban Green Council found that, during a weeklong power outage, the temperature differential inside a typical building and a high-performance building of the same type was 18°F to 27°F. And, the high-performance building retained heat longer, with temperatures above 54°F.

- Air-seal doors and windows by caulking them.
- Install insulation and high-performance windows: multi-paned windows with reflective coatings that lower winter heat loss and heating costs.
- Be aware that glass can never retain building heat as well as an insulated wall.
- Protect internal building infrastructure by fitting exposed pipes with insulation sleeves or otherwise wrapping them, to slow heat transfer.
- Seal cracks and holes in outside walls and foundations near water pipes with caulking.
- Add insulation indoors or as a new exterior layer.
- Eliminate drafts in air ventilation systems by caulking and sealing.

For old and new buildings, a backup generator is good insurance against possible power outages caused by winter storms.

PROTECTING INFRASTRUCTURE AND EQUIPMENT

One promising strategy is the use of alternative materials for streets and sidewalks that accelerate snowmelt and reduce reliance on the salt, snowplows, and chains on vehicle tires that damage city streets. The ability to clear paved areas more quickly reduces traffic accidents and improves emergency access, too.

The City's Department of Transportation is planning demonstration projects to monitor how well permeable pavement materials accelerate snow and ice melt at three locations. The projects are required by Local Law 80 (enacted in 2013), which directs the Departments of Transportation and Environmental Protection to study alternative roadway and sidewalk materials. Their study will examine the following:

- various types of permeable materials
- expected costs
- ease of installation
- how well materials perform
- how much stormwater they can absorb, and long-term maintenance requirements

One recent study suggests that permeable pavements noticeably improve snow and ice melt, reducing the need for plowing.

Another strategy complements investments in traditional “gray” infrastructure by relying on green infrastructure – such as bioswales and green roofs – to capture ice and snowmelt that might otherwise overwhelm wastewater treatment plants, causing the combined sewer overflows that discharge raw sewage directly into water bodies. The Department of Environmental Protection’s *NYC Green Infrastructure Plan* employs such measures, which will help the City achieve compliance with federal water quality regulations.

A very simple measure for protecting infrastructure is one taken by the MTA. To protect its trains, the MTA stores them underground when forecasts predict temperatures 10°F below zero, ice storms, icing conditions, or more than five inches of snow.

ENVIRONMENTAL CONTROLS

Because the weight of snow and ice can break tree branches and take down power lines, tree pruning and tree maintenance strategies lower risk.

The Parks Department’s Forestry Division oversees block pruning. Performed by contractors on a seven to eight year schedule, it requires pruning all street trees on a block. This Division also performs in-park pruning of trees.

Toward the goal of reliable service, the city’s major utility, Con Edison, manages a tree maintenance program that trims branches along right of ways, so trees do not encroach on power lines.

PROMOTING PREPAREDNESS

Helping the public understand how to prepare for and respond to winter weather events is a major priority. Strategies range from communicating with the public immediately before and during a winter weather event, to longer-term educational measures aimed at households and property owners.

Short-term communication strategies include these:

- Sending emergency alerts prior to severe winter weather events, taking care to target populations with special needs, ensuring that communication is multi-lingual, and reaching out to populations who are homeless.
- Sending weather notifications to property owners, contractors, and developers, advising them of measures they can quickly take to prepare for a winter storm, such as clearing gutters and removing snow or ice from roofs.
- For major storms or prolonged periods of extreme cold, coordinating with multiple City agencies to communicate a consistent message about weather conditions and steps New Yorkers can take to prepare. Severe weather events may require mayoral press conferences.
- Communicating via as many media as possible: social media, press releases, notifications to elected officials, and alert systems. For social media platforms, providing real-time updates as conditions worsen or improve.

DOHMH declares a Cold Weather Alert whenever the temperature falls below 32°F between 4 PM and 8 AM. This temperature threshold may be affected by wind chill and other meteorological factors. During extreme cold events, the City increases outreach to the homeless population. The New York City Police Department monitors the city for homeless individuals and transports them to shelters run by the Department of Homeless Services or City hospitals. The Metropolitan Transportation Authority also monitors the transit system for individuals in need of sheltering and notifies appropriate responding agency.

NYC Emergency Management’s Special Needs Advance Warning System reaches populations with access and functional needs through agencies and organizations that serve them as clients and are trusted by them. By means of email, conference calls, and a website, NYC Emergency Management delivers information targeted to individuals with special needs that can be relayed to them if they are at risk because of an impending hazard event.

The system is often used when winter storms or extended periods of extreme cold temperatures are forecast.

Notify NYC is the City's official source of information about emergency situations, including severe winter weather events. NYC Emergency Management sends notifications to a quarter million subscribers and Twitter followers.

Long-term strategies aim for these objectives:

- Help the public learn how to prepare for severe winter weather events.
- Help homeowners learn how to maintain buildings to reduce heat loss, roof leaks, and roof collapses.
- Help households understand the potentially lethal dangers of carbon monoxide poisoning that can be caused by gas appliances in their homes.

New York City Emergency Management's *Ready New York: Preparing for Emergencies in New York City* steps households can take to prepare for prolonged cold weather and winter storms. It includes guidance on safety precautions related to home heating equipment. The *Ready New York Reduce Your Risk Guide* explains how New Yorkers, and in particular homeowners, can reduce risks related to winter weather.

The Department of Buildings issues Inclement Weather Advisories that advise property owners, builders, and contractors to take precautionary steps to prepare for winter storms, such as clearing roofs, overhangs, and gutters of snow and ice; tying down and securing material and loose debris at construction sites; covering electrical equipment from exposure to the weather; and securing netting, scaffolding and sidewalk sheds.

DOHMH's website presents information about carbon monoxide poisoning that covers causes, symptoms, and preventive measures. A brochure developed jointly by the DOHMH, NYC Health and Hospitals Corporation, and NYC Poison Control Center explains how to prevent carbon monoxide poisoning. In addition, DOHMH provides general preparedness information about preventative measures to take to lessen the impact of cold weather.

WATER SHORTAGE

CHAPTER 4.7

The City's complex water supply system is a remarkable feat of engineering. It originates in upstate reservoirs and extends over 125 miles to supply New Yorkers with high-quality water. Water shortages are possible due to a failure of a major component of the water system's infrastructure due to age or other factors. A water shortage can also be caused by an upstate drought, which can affect reservoir water levels. Droughts have occurred in the past and may occur again – in a future that is being shaped by climate change.

WHAT IS THE HAZARD?

The City's Department of Environmental Protection (DEP) manages our water supply system, ensuring the steady flow of water from large upstate watersheds through a complex network of reservoirs, aqueducts, tunnels, and neighborhood water mains.

Each day, more than one billion gallons of water is delivered to New York City, almost all by simple gravity. We use water daily for our basic needs – drinking, bathing, cooking, and laundry. Therefore it comes as no surprise that residential buildings (that is, not mixed-use, commercial/residential buildings) are our largest water consumers, accounting for 62 percent of total water usage. Water is also used for institutional, commercial, and manufacturing purposes. For example, hospitals use water in the form of steam to sanitize medical equipment and water is also used in some manufacturing processes, including bottling plants in New York City.

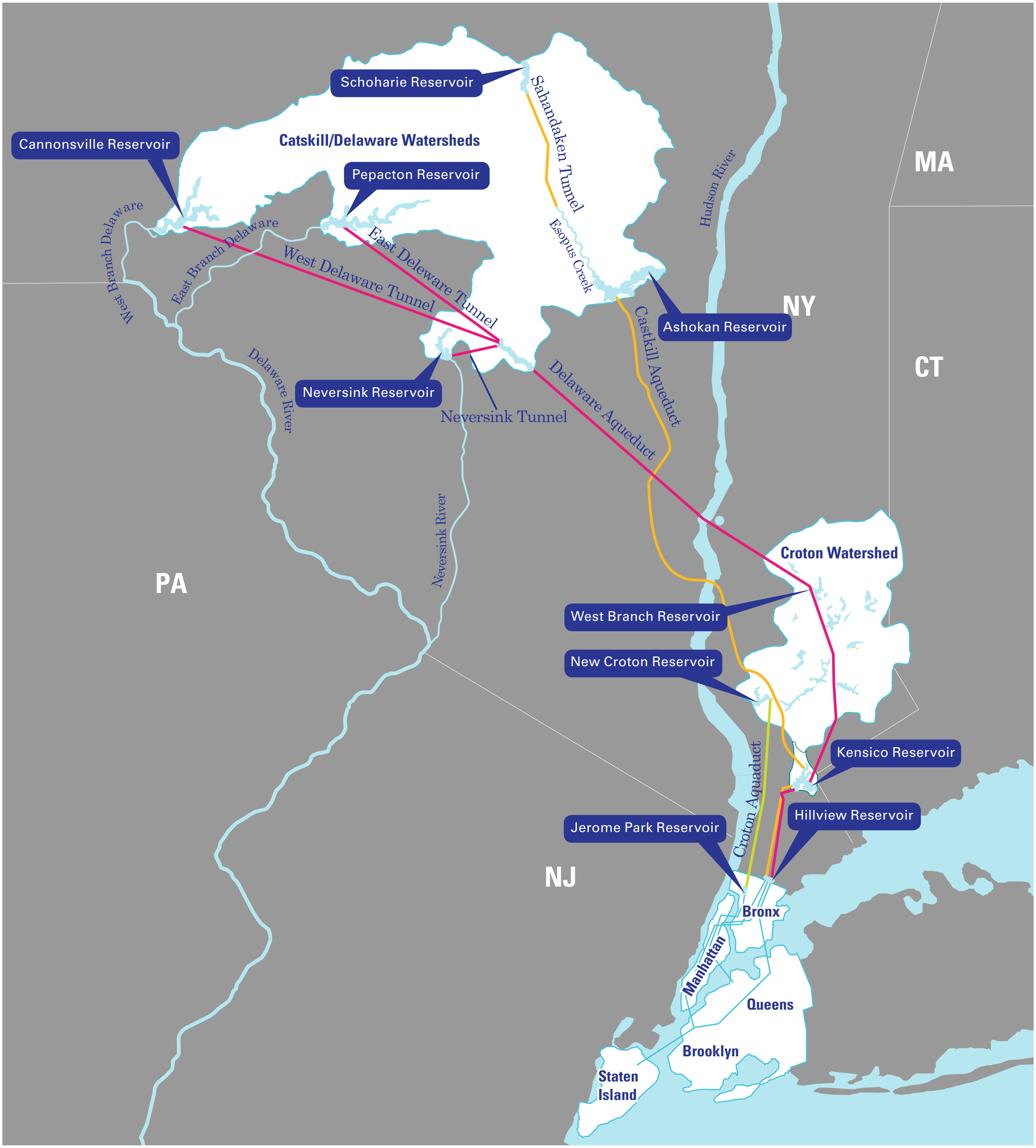
Water shortages could be caused by drought or failures in our water-supply infrastructure. Water contamination is beyond the scope of this brief profile, which focuses on drought and infrastructure. For information about it, see DEP's web site.

WATER SHORTAGE CAUSED BY DROUGHT

Occasional drought is a normal feature of many climates in the United States. It results from climate conditions that can develop over several months or years. A drought can last briefly, or for a long time. A brief drought's impacts can be worsened by extreme heat and/or wind.

Water shortages due to a drought affect New York City on a citywide basis. Because the reservoirs that supply our water are upstate, rainfall in that region, not within our city, is what determines how adequate our water supply is.

New York State has a generally temperate, moist climate. Average precipitation in New York City's watershed is approximately 45 inches per year, but normal fluctuations in regional weather patterns can lead to periods of dry weather. Since 1939, New York City has experienced nine periods of drought. The last severe drought in New York State occurred from 1962-1965. At least five less-severe drought emergencies have occurred since the 1960s.



WATER DELIVERY SYSTEM (SOURCE: NYC DEP, 2011)

PHOTO OF CANNONSVILLE RESERVOIR: PHOTOS ARE FROM SAME VIEW; LEFT PHOTO IS RESERVOIR AT 6.5% CAPACITY Y (DEC. 20, 2001). SOURCE: NYSDEC AND NYC DEP

The most recent period of dryer weather occurred in December 2001, when DEP issued a Drought Watch because reservoir water-storage levels were at 44 percent. A month later DEP issued a Drought Warning; a Drought Emergency was issued in April 2002. Over the next eight months, increased precipitation and reduced water consumption alleviated drought conditions. Normal conditions were restored on January 2, 2003 ending a 14 month drought event.

The New York City Panel on Climate Change projects future disruptions in precipitation patterns and rising temperatures for New York City. While annual rainfall is predicted to increase here, along with the intensity of severe storms, it is more likely than not that more late-summer, short-duration droughts will occur. It is unclear whether longer duration droughts will increase.

A 2011 study by the Lamont-Doherty Earth Observatory predicts that a severe drought similar to the one that occurred in the 1960s could easily return to the greater Catskills region without warning, and that its duration cannot be forecast. That is, the wetter conditions that have prevailed since the 1970s may not persist in the future.

WATER SHORTAGE CAUSED BY INFRASTRUCTURE FAILURES

New York City's water supply system dates back to the 1840s, when the Croton Aqueduct in Westchester County opened. Water travels daily through a complex system of reservoirs, aqueducts, tunnels, and water mains to New York City as well as many upstate communities. Due to the system's age, size, and extent, parts of it may be subject to failure.

A water shortage can occur from a failure at any point in the water systems infrastructure. Depending on its location and scale, a failure can have varying degrees of impact. For example, a water main break may only impact a specific area of the city, while a dam failure or a collapse of tunnels or aqueducts could impact the distribution of water to all of New York City.

Of particular concern now is the Delaware Aqueduct, which delivers approximately half of the city's drinking water – 500 million gallons per day. It is leaking as much as 35 million gallons per day. New technologies have permitted DEP to perform inspections of it, and a major project to repair it is under way.

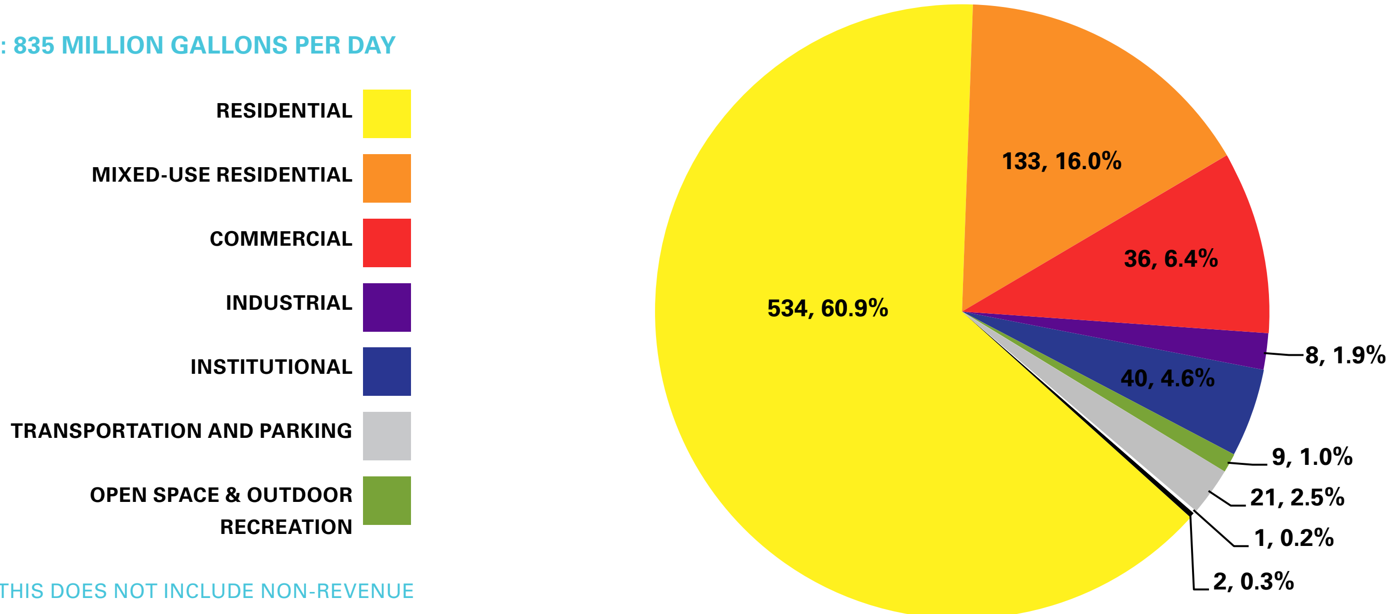
Among other portions of the system that may need maintenance or repair, most notable are City Water Tunnel No. 1, completed in 1917, and City Water Tunnel No. 2, completed in 1936. They have been delivering water to our homes, businesses, and institutions continuously since they were placed in service. Because of concerns that a reduction in water pressure might damage part of the system, neither tunnel has ever been shut down for inspections and repairs.

Water main breaks occur frequently. Some of the causes include the age of the mains and pipe material. For instance, 46 percent of the City's 6,785 miles of water main were built before 1941. The majority of mains are composed of unlined cast iron or cement-lined cast iron, which is susceptible to internal corrosion and leaks.

WATER USAGE BY LAND USE IN MILLIONS OF GALLONS

(SOURCE: NYC DEP, 2011)

TOTAL: 835 MILLION GALLONS PER DAY



*THIS DOES NOT INCLUDE NON-REVENUE WATER, WHICH IS APPROXIMATELY 21 PERCENT OF TOTAL WATER USAGE

DEP's decades-long, intensive efforts and multi-billion-dollar investments in maintaining and repairing our water supply system are discussed on the following pages, in "How Do We Manage the Risk?"

Water shortages may also occur as a result of planned outages for system repair.

WHAT IS THE RISK?

VULNERABILITY

A water shortage, caused by drought or an infrastructure failure has the potential to be severe. Because New York City is embedded in a regional economy and is a global financial center, severe impacts could reverberate far beyond its borders. What follows is a brief sampling of vulnerabilities and consequences.

People at risk

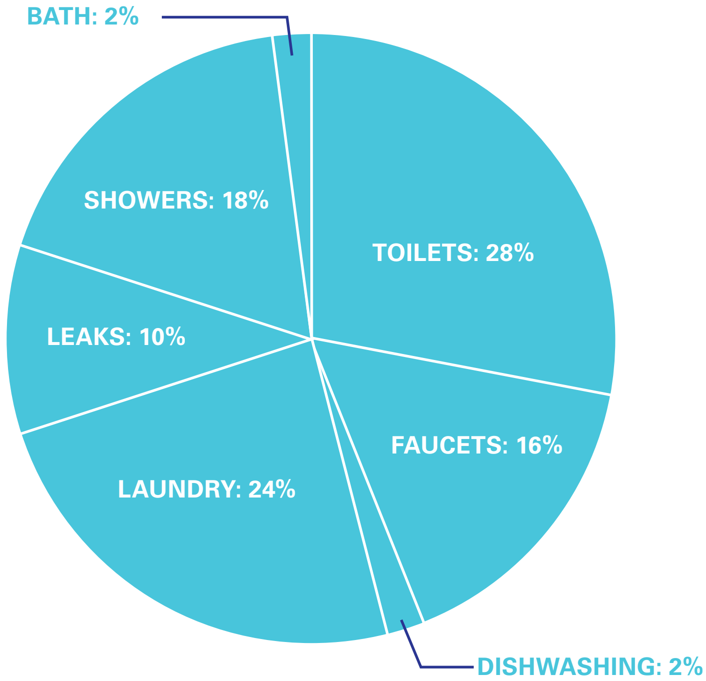
A water shortage could affect public health broadly, with effects most pronounced among people with pre-existing health conditions that make them more susceptible to illness and the spread of disease. During prolonged droughts, some indirect health effects might not be readily identifiable, making it difficult if not impossible to prevent and monitor them.

Dehydration is a major risk. With water in short supply, people may wash their hands less frequently and thoroughly and otherwise not maintain good personal hygiene. They may wash fruits and vegetables less thoroughly. Compromised sanitation and hygiene may raise rates of illness.

Even air quality can be affected during periods of drought. The Centers for Disease Control caution that when air laden with particulate matter from dust is not washed clean by rainfall, poor air quality can increase chronic respiratory illnesses such as asthma, as well as the risk of acute respiratory infection.

Localized disruptions in the distribution system such as a water main break or illegally opened fire hydrants may also impact water pressure.

INDOOR WATER USE IN A TYPICAL SINGLE FAMILY HOME (SOURCE: NYC DEP, 2011)



The food supply system

Within our tri-state region, severe drought would harm the hundreds of farms that supply food to us, limiting growing seasons and suppressing crop yields, with consequences for the many farmers markets that operate within the city, and the many Community Assisted Agricultures that transport farm goods to us from tri-state area farms.

It should be noted that, because New York City imports most of its food, a prolonged severe drought in any region of the world that supplies a significant quantity of our food supply could produce some shortages and higher prices. Higher prices may create further hardships for low-income households and strain the budgets of commercial and institutional kitchens.

Economy at risk

According to the National Weather Service, droughts are among the costliest weather-related events. Obviously vulnerable are businesses that use water heavily. Such businesses may be forced to suspend some or all of their operations if the City curtails water usage.

Recreational activities could decline as a result of a water shortage. Certainly, a prolonged severe drought would curtail tourism, a significant sector of New York City's economy.

Buildings and infrastructure at risk

In general, a water shortage does not cause structural damage to buildings, highways, and bridges. But it does pose a risk, albeit very low, of aggravating "soil shrinkage," the reduction in soil volume that occurs as soil loses moisture. The condition can compromise the foundations on which infrastructure stands, including retaining walls and bulkheads, affecting their stability.

The ability to cool equipment and buildings that use water-dependent cooling systems may be disrupted during a water shortage.

Our city's energy and steam supply systems could be affected by a water shortage. A number of power-generation plants rely on our water supply to produce power. Water-use restrictions during a prolonged severe drought would disrupt or reduce that power supply. This includes the city's steam system, which relies heavily on water during

NEW YORK CITY WATER TUNNEL NO. 3
SOURCE: NYC DEP

DEP's largest and longest-running project – one of the country's largest infrastructure projects – is City Water Tunnel No. 3. Initiated in 1970, it is scheduled for completion in 2018, at an estimated total cost of $5 billion. The tunnel is a critical piece of infrastructure. When it is completed, it will add capacity to the system, deliver water to customers, and allow DEP to inspect and repair as needed City Water Tunnels No. 1 and 2.

Tunnel No. 3 is being constructed in stages. Stage 1 was put into service in 1998. Stage 2 was put into service in October 2013. Manhattan and the Bronx are served by the first two sections. Stage 3 will connect Brooklyn and Queens to the upgraded system. `

winter months, when it consumes a peak of 1.6 million gallons of water per hour to heat homes and buildings in parts of Manhattan. Hospitals also rely on steam to sterilize medical equipment.

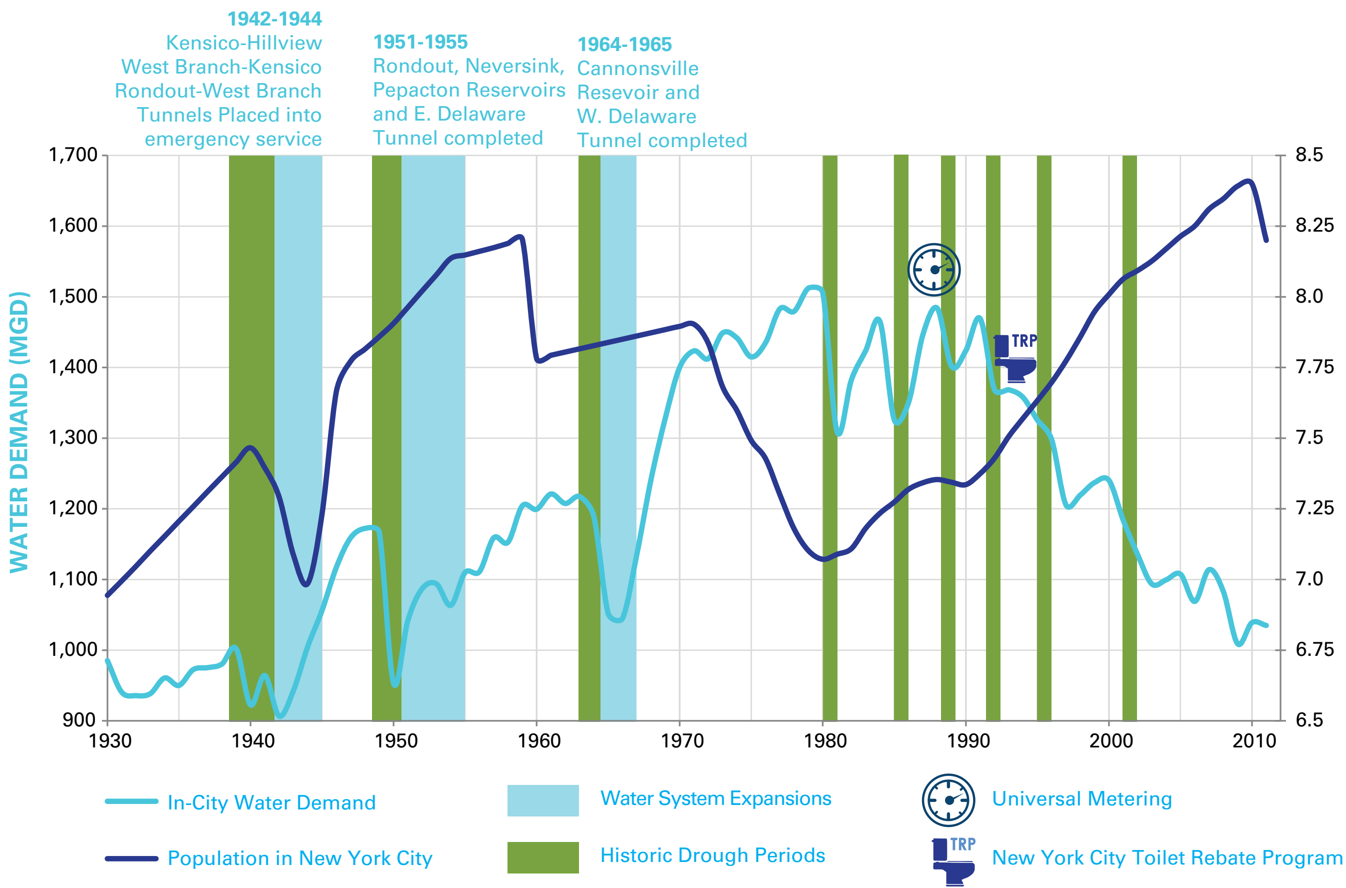
Environment at risk

The impacts of a water shortage are greater on the natural environment than on the built environment.

Green infrastructure can be affected by drought within the city or by limited water supply to the city. All vegetation in the city helps purify air and reduce heat. For example, the vegetation on green roofs provides insulation, offsets some of the urban heat island effect, and improves air quality.

A water shortage would affect the nearly 500 community gardens in our city. Like green roofs, they help reduce air pollution and offset the urban heat island effect. They also increase access to fresh produce.

TIMELINE SHOWING NYC WATER DEMAND COMPARED WITH POPULATION GROWTH (SOURCE: NYC DEP, 2011)



A prolonged drought may affect wetlands, plant species, and biodiversity. Our wetlands range from approximately 5,600 acres to just over 10,000 acres, in Jamaica Bay, on Staten Island, and along the Long Island Sound. They protect wildlife and improve water quality. Jamaica Bay Park alone is home to 325 species of birds, 50 species of butterflies, and 100 species of finfish.

HOW DO WE MANAGE RISK?

Strategies for managing the risk of water shortage include measures to protect infrastructure; regulatory controls and programs to promote and incentivize long-term water conservation; robust protocols for monitoring reservoir water levels; contingency planning for drought conditions; and communication efforts designed to inform water users of water shortage conditions and actively enlist them in water conservation efforts.

PROTECTING INFRASTRUCTURE

Maintaining our water supply system, repairing leaks and cracks, and creating redundancy are crucial to ensuring the system's continued performance under normal conditions, and to reducing the impacts of any water shortages.

DEP's Water for the Future program addresses the leak in the Delaware Aqueduct. In 2013, DEP began building a three mile tunnel, the Delaware Bypass Tunnel, to bypass the section of the aqueduct that is leaking in Orange County. To connect this tunnel, the Aqueduct will be shut down for six to eight months in 2022, during which time DEP will augment available supply and minimize demand.

DEP is also working on a number of projects that will increase the capacity of the Catskill and Croton Water Systems. Some of these infrastructure improvements will enable the Catskill Aqueduct to provide up to 60 million gallons of water per day of additional flow from the Catskill watershed.

Because of factors related to the surrounding area and water quality, the Croton water supply has been taken offline since 2008 so that DEP can construct a water filtration plant to reduce the risk of water contamination. This new facility will help increase the capacity of water supply to New York City.

DEP's Water Distribution System Optimization program targets local water main leaks, implements system repairs, and upgrades water distribution infrastructure.

The Department of Buildings' Retaining Wall Rule regulates inspections and filing requirements for retaining walls to determine safety and maintenance conditions. The rule requires regular inspections of retaining walls that are 10 feet or higher and that face a public right-of-way (sidewalk or entrance).

REDUCING DEMAND THROUGH REGULATORY CONTROLS AND PROGRAMS

Long-term water conservation strategies help reduce water demand and thus extend how long water remains available during a prolonged water shortage. They also help to meet the demands of a growing population. They take the form of regulatory controls and programs that encourage conservation.

Both building design and the equipment used in buildings can reduce water use, with bathrooms a key target. The Department of Buildings Construction Codes encourages water conservation strategies in new buildings as part of an approved water conservation plan.

During the 1980s and 1990s, DEP instituted a number of programs to incentivize water efficiency and reduce water demand by 30 percent. Even during the droughts of 1989, 1991, and 1995, water demand decreased when restrictions were put in place despite population increases during this period. The timeline shows that as New Yorkers began to use water more efficiently, water demand was reduced as the population grew – demonstrating the success of regulatory controls and programs that incentivize water conservation.

DEP's water conservation programs now include these:

- Toilet Replacement Program. Because residential buildings account for the largest share of water use, DEP has identified opportunities to conserve water in these building types. Older toilets can use 3.5 to 5.0 gallons of water per flush; high-efficiency models consume as little as 1.28 gallons per flush. From 1994-1997, DEP ran a Toilet Rebate Program that successfully reduced water demand. In 2013, DEP launched a Toilet Replacement Program. The program provides discounts for owners of residential and multi-family buildings who replace old toilets with high-efficiency models.

- The Municipal Water Efficiency Program is retrofitting City-owned properties, with savings estimated at up to nine million gallons of water a day.

- The Residential Water Efficiency Program offers building owners free surveys that identify opportunities for water savings, including leak detection.

- The Non-Residential Water Efficiency Program encourages major water users such as hospitals, hotels, universities, and restaurants to implement water-efficiency measures.

- DEP's website enables customers to see how their behavior is affecting their water use and helps them identify leaks by providing daily and sometimes hourly information. DEP is conducting a pilot program to help customers evaluate monthly billing, so that by better understanding their usage patterns they can reduce their demand.

RESERVOIR MONITORING, BACKUP SUPPLIES, AND WATER SHORTAGE PROTOCOLS

Monitoring

DEP closely measures and monitors reservoir levels. Its Operations Support Tool is a predictive modeling tool that helps the agency monitor and predict water supply reliability. It uses ensemble streamflow forecasts from the National Weather Service to assist with making these predictions. DEP also closely monitors the condition of our in-city water distribution system.

Alternative water supplies

The City has alternative drinking water sources, and while their capacity falls far short of the more than 1 billion gallons of water we consume each day, they could make a difference in water shortage situations:

- DEP's groundwater supply system in southeast Queens County consists of 68 wells. It has a State Department of Environmental Conservation permitted capacity of 68 million gallons per day on an annual basis.
- Several interconnections between private utilities in Nassau County are available during an emergency.
- The Chelsea Pump Station in Dutchess County near Poughkeepsie can tap water from the Hudson River. This could augment the city's water supply by 100 million gallons per day under emergency conditions. This pumping station was used during the droughts of 1985 and 1989.

Water shortage protocols

During a planned or unplanned water shortage, reducing the amount of water we consume is imperative. DEP's Water Shortage and Contingency Plan – to be released in the spring of 2015 as an update to the current Drought Management Plan – defines formal operational phases (Watch, Warning, and Emergency) for managing a water shortage and actions for each phase.

Actions in the Drought Management Plan address all water system customers, including City agencies, the private sector, and households. Action items will change with each phase as water shortage conditions progress. Some of the actions include reducing water usage, communication with customers, enforcement of emergency rules, and implementation of alternative water sources. DEP also evaluates the option of raising water rates to encourage water conservation and increase revenues to maintain operations, for each water shortage phase. The plan will be expanded to address issues related to infrastructure failure and planned system repairs.

One of the city's main utility providers, Con Edison, supplies steam to customers in Manhattan. It implements protocols during water shortages to prioritize all water leaks requiring urgent repairs, to modify operations to conserve water, and to encourage steam customers to reduce steam usage.

COMMUNICATION

As a water shortage initially develops, clear communication with water users is essential. They must be informed about the potential seriousness of the situation and about steps they can take to curtail their water use.

Since water shortages can vary in duration, location, and severity messaging may have to be tailored. For situations where the water shortage is localized such as a water main break, messaging is targeted to the affected customers.

During a drought, DEP employs many strategies to inform customers of water supply status, water restriction rules, and steps for conserving water. Additionally, DEP works with other City agencies and the Mayor's office to ensure that messaging is clear, concise, accurate, and reaches a broad audience. The agency develops messages intended for residents, community groups, and elected officials using many communication tools: media announcements, social and digital media posts, notifications to elected officials, direct community outreach (including meetings), direct mail, phone calls, and emergency alerts.

Notify NYC and the Advanced Warning System would be used to inform the public of emergency conditions. The City would use social media, notifications, alerts, and targeted outreach tools to communicate updates on water shortage conditions and practical information on how the public can conserve water.

EARTHQUAKES
CHAPTER 4.8

Although New York City does not sit on a seismically active fault line, earthquakes are a possibility. While the probability of a strong earthquake occurring is moderate, the risk is heightened by our population density, the scale of our built environment, the interdependencies of critical infrastructure systems, the age of much of our infrastructure, and the fact that much of our building stock was constructed before New York City adopted seismic design provisions for buildings in 1995.

WHAT IS THE HAZARD?

An earthquake is a sudden, rapid shaking of the ground caused when two blocks of earth slip past each other beneath the surface. Most earthquakes originate from pre-existing faults or from new breaks in the rocks that make up the earth's crust, along which rocks on either side move past each other. As the rock is strained, potential energy builds up. Eventually, it becomes so great that it is abruptly released in the form of seismic waves. These waves travel away from the earthquake's deep-underground source – the focus – causing shaking at the earth's surface that geologists and engineers call ground acceleration. The point on the earth's surface directly above the focus is called the epicenter.

How intensely the ground shakes depends on factors that include the amount of energy released, the depth of the earthquake focus beneath ground surface, how far from the epicenter the shaking is experienced, and the underlying soil type and bedrock. How intensely structures shake depends also on their height, weight, and design.

The strength of earthquakes can be expressed by the Moment Magnitude, which expresses the energy released at the source of the earthquake through recorded data. The Moment Magnitude scale replaced the Richter scale as a more accurate measure of the strength of an earthquake since the 1970s. The scale is logarithmic, which means that each one-point increase in the scale represents a 32 times larger energy release.

Earthquakes can trigger landslides and liquefaction of soils. Liquefaction occurs when loose, water-saturated soils become almost liquid due to intense seismic shaking and vibration during an earthquake.

Earthquakes and their aftermath can cause great destruction, trigger fires, damage buildings and infrastructure, interrupt community functions, and cause injuries and loss of life.

Aftershocks are earthquakes that follow the largest shock in an earthquake sequence. They are typically less intense than the main shock and can continue over weeks, months, or years after the initial earthquake is felt.

WHAT IS THE RISK?

The U.S. Geological Survey studies seismic conditions nationally and periodically produces maps to indicate where future earthquakes are likely to occur, the frequency of occurrence, and how hard the ground may shake. The latest maps, released in July 2014, show that on the East Coast, larger, more damaging earthquakes are possible than previous maps had shown.

Although strong earthquakes are uncommon in New York City, moderate magnitude earthquakes are possible. The older, harder bedrock found in the northeast generates high-frequency earthquake motions that can travel great distances before they subside. For example, earthquakes in Virginia in 2011 and Canada in 2013 were felt in New York City. The 2011 Virginia earthquake, with 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.

Unique geologic characteristics in our metropolitan area could create significant soil amplification effects. The two main factors of soil amplification are the sharp contrast of softer soils with very hard bedrock, and the bedrock motions, expected to be of relatively short duration and high frequency. Fast-shaking earthquakes are more common in the bedrock of eastern United States. Thus, if a soft soil above the bedrock is at shallow depths (say less than 100 feet), resonance can the fast shaking nature of the earthquake, affecting mostly short (2 to 5 stories) masonry buildings. On the other hand, a high rise building may resonant with deep soil deposits as they both tend to move slowly during an earthquake.

One of the strongest earthquakes to occur near New York City (thought to have originated somewhere between Brooklyn and Sandy Hook, New Jersey) occurred on August 10, 1884. Based on historical reports of the damage it did, it has been estimated to have been a 5.2 magnitude earthquake. Although moderate, it was felt from Virginia to Maine and damaged chimneys and brick buildings in New Jersey and New York City. Considering that the city was less developed then, if the same magnitude earthquake were to occur today, the damages would be far worse.

The historical earthquakes map shows the distribution of earthquake epicenters throughout the tri-state area from 1737 to 2014. Only two damaging earthquakes with a magnitude of 5.0 or greater have occurred in New York State. Many smaller earthquakes have been felt in New York City. For example, on January 18, 2001, a 2.4 magnitude earthquake was felt in Long Island City, Queens, and the Upper East Side of Manhattan near 125th Street. That earthquake affected an area with many unreinforced masonry buildings but caused little to no damage. Several residents mistook the earthquake for a manhole explosion. Engineers consider these events tremors and not strong ground motion earthquakes which are higher in magnitude (more than 4) and can cause structural damage.

In our metro area buildings must be designed to withstand the Maximum Considered Earthquake: that is, one with a two percent chance of happening at any point within a 50-year period. Such an earthquake would likely produce strong to very strong shaking and light to moderate physical damage, and significant interruptions in city functions. Historically, large earthquakes in New York City have had longer "return periods" – that is, they happen less frequently - on average about once in a hundred years.

VULNERABILITY

PEOPLE AT RISK

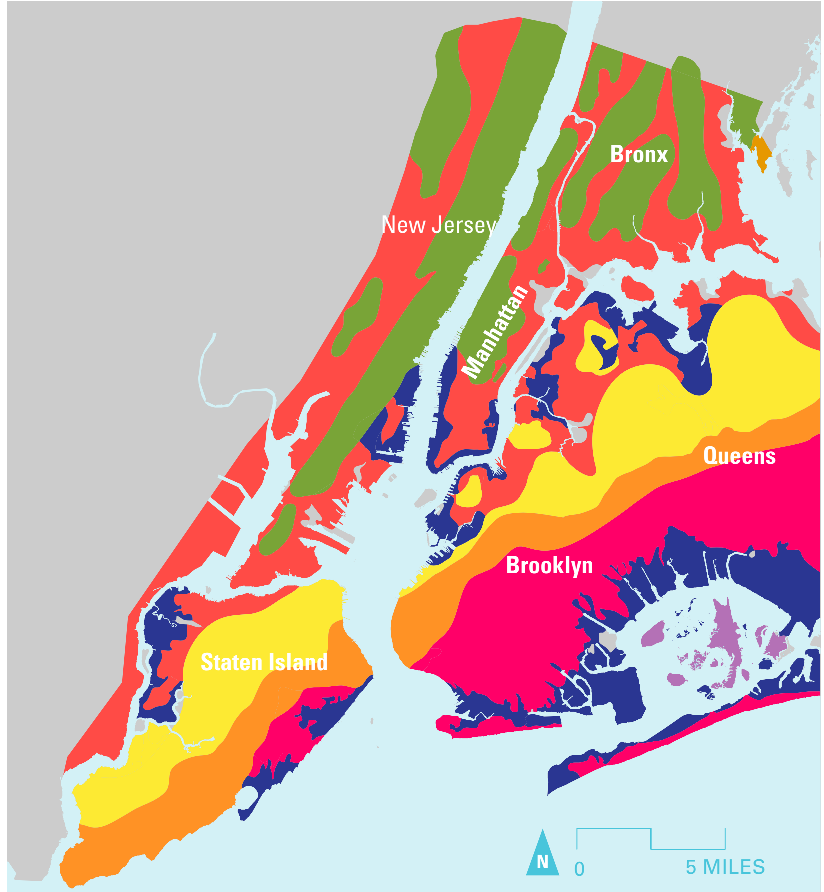
To glance at Chapter Three's survey of features of our city that are vulnerable to hazards is to grasp the extent of the damage that a severe or even moderate earthquake could do to the city.

Public safety is the paramount concern, because earthquakes occur with practically no warning, placing the population at immediate risk. Precisely because earthquakes have not occurred frequently here, the risk to public safety may be higher: the general public may not be as prepared or know how to respond. New York City's dense urban environment, which contains many high-occupancy buildings, amplifies our risk.

NYC AND EASTERN NJ GEOLOGICAL MAP

SOURCE: DEVELOPED BY MUESER RUTLEDGE CONSULTING ENGINEERS BASED ON THE ORIGINAL NYC FOLIO MAP OF 1902 (SEE TAMARO ET AL., 2000 AND MERRILL ET AL., 1902).

- ARTIFICIAL FILL
- ORGANIC SILT AND PEAT DEPOSITS
- GLACIAL OUTWASH DEPOSITS (SAND)
- GLACIAL LAKE DEPOSITS (VARVED SILT, CLAY & FINE SAND)
- TERMINAL MORAINE (SAND, GRAVEL, CLAY, SILT, BOULDERS & COBBLES)
- TILL (SAND, GRAVEL, SILT, CLAY)
- ROCK, WITH THIN TILL OVER ROCK



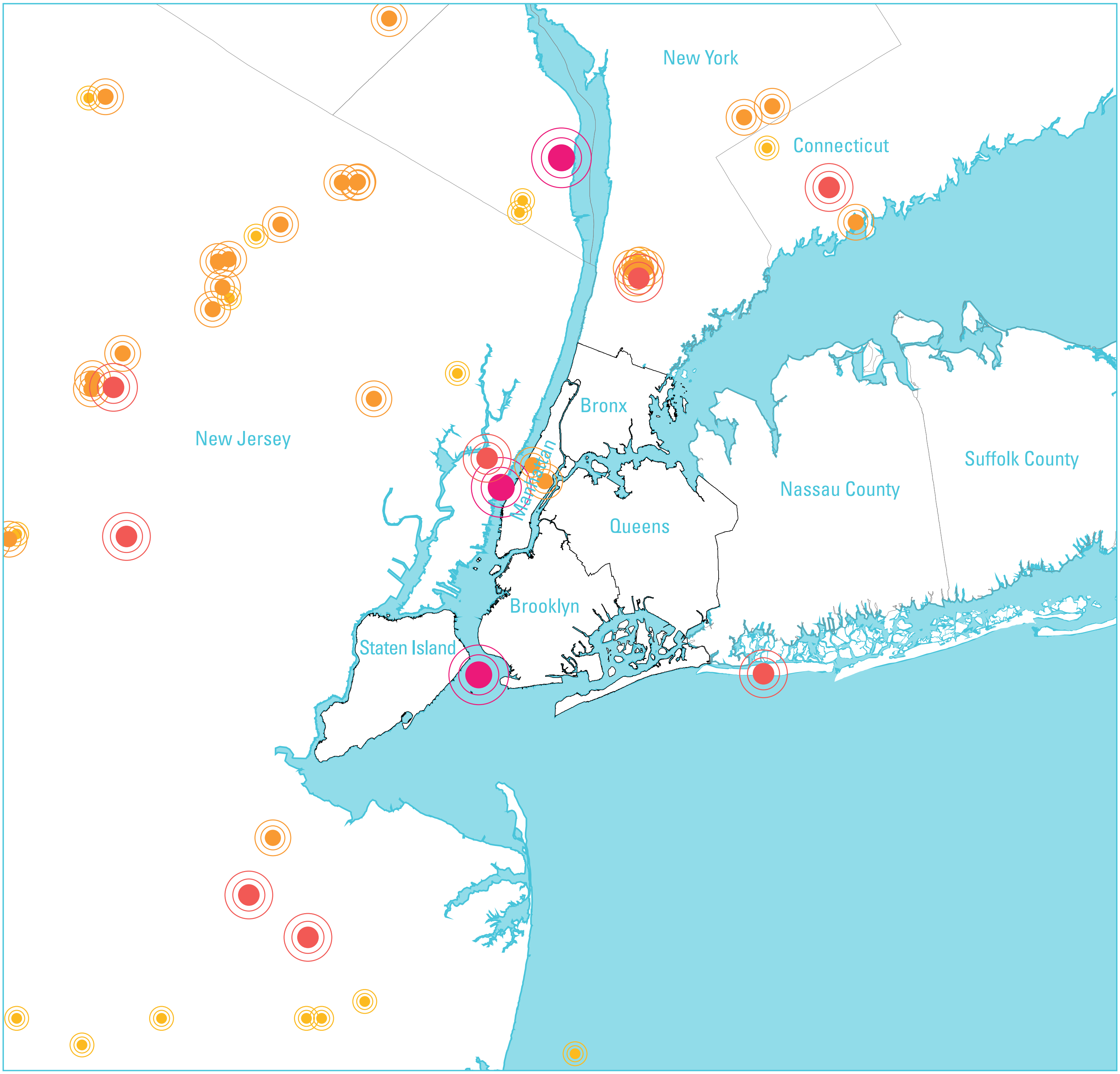
A moderate (magnitude 5.5 to 6) earthquake could cause downtime, injuries, and casualties in New York City. Typically mortality and injury peak within the first 72 hours of an earthquake. The biggest cause of death is building collapse: a study of 1,100 fatal earthquakes found that 75 percent of fatalities were due to this. According to FEMA, non-structural failures account for a vast majority of earthquake damage and can cause serious injuries or fatalities and make a building nonfunctional. Nonstructural components include items that are not part of the building's structural system such as heavy picture frames, mirrors over beds, hanging plants, heavy furniture (bookcases, filing cases, and china cabinets), light fixtures, electrical/mechanical equipment, elevators, and ceiling plasters. During an earthquake, these components may slide, swing or overturn because they are not tightly connected to the structure of the building.

Destruction of roads, bridges, and tunnels can cause injuries and fatalities, and the disruption of infrastructure and critical systems can cause its own cascade of impacts. Earthquakes can also generate fires as a result of seismic shaking, posing significant risk to people. Disruption of transportation can also place individuals dependent on these services at risk by hindering emergency and medical services.

Subsurface conditions, which vary widely in the five boroughs, can affect the amplification of an earthquake's ground motion. Conditions range from sound bedrock at ground surface to artificial fill. To create land that can be developed, large areas of the city have been filled to cover soft sediments and marshes. Examples are Manhattan's present-day Chinatown, which was built on fill that replaced a lake; the World's Fair site in Flushing, Queens; and JFK Airport, which was built on hydraulic sand fill on the south shore of Brooklyn.

The time of day an earthquake occurs can also increase impacts. Mortality rates rise if an earthquake occurs during weekdays between 9 AM and 5 PM, when people are likelier to be at work in large buildings or in school, or during the night, when people are home inside buildings. Other aftermath effects can include health risks from polluted water and spread of disease, and dramatic impact on the city and nation's economy.

Damage to buildings could force thousands of people into interim housing. Some people could require permanent relocation. In the aftermath of an earthquake, long-term mental health risks may include post-traumatic stress, depression, and anxiety.



HISTORICAL EARTHQUAKES (1737 - 2014)

SOURCE: USGS; NYS DHSES

*NOT ALL PRE-1973 EARTHQUAKE EVENTS ARE DISPLAYED ON THE MAP

**EPICENTER LOCATIONS OF PRE-1973 EVENTS ARE APPROXIMATE ONLY

N

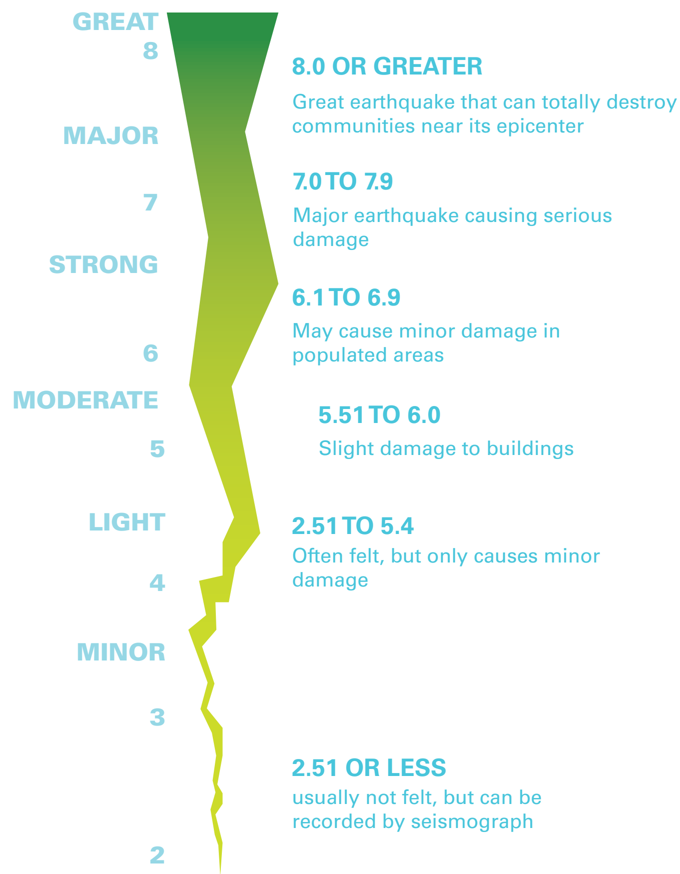
0 10 MILES

MAGNITUDE

0.4 - 1.9 2.0 - 2.9 3.0 - 3.9 4.0 - 5.2

EARTHQUAKE MAGNITUDE SCALE

SOURCE: UPSEIS/MICHIGAN TECH



BUILDINGS AT RISK

Although New York City has a low probability of large-magnitude earthquakes, potential damage could be physically extensive and costly, for reasons that include the following:

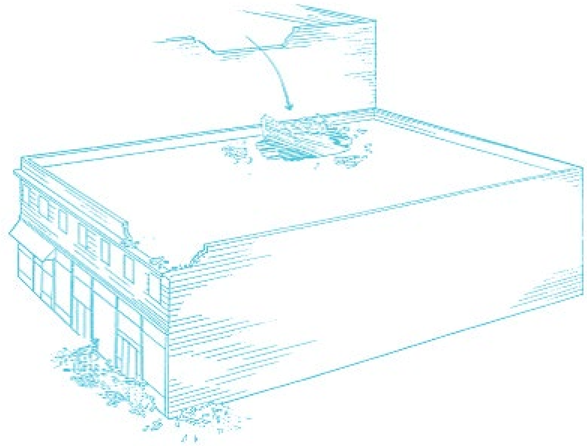
- New York City has nearly one million buildings.
- Dense built environment heightens risk.
- Most buildings were built before the City adopted seismic provisions in its Building Code, in 1995.
- Certain local building construction types are particularly vulnerable.
- Some of our commercial real estate, though built to modern seismic standards, is of such high asset value that damage to it could be costly.
- Interruption of functions (such as Wall Street) could affect not only NYC, but the US and world economies.

A 2008 analysis by FEMA of potential annualized building-related earthquake losses ranks New York State as the fourth most at-risk U.S. state and ranks the New York City-New Jersey-Long Island metro region as the twenty-first most at-risk metro region. Because of our high density of buildings, an earthquake could produce millions of tons of debris and cost billions of dollars' worth of damage to buildings.

Our high-rise buildings are less vulnerable to damage from earthquakes than low-rise buildings. For instance, earthquakes with slow moving waves that tend to damage taller buildings are less likely to occur in New York City. In addition, tall buildings designed to the 1995 Building Code are designed to preserve human life at a minimum in the event of a major earthquake and to preserve general occupancy conditions for less severe earthquakes.

Existing structures not designed for earthquake loads are inherently vulnerable to seismic events. Unreinforced masonry buildings are most at risk because masonry cannot absorb tensile forces during an earthquake: rather than bending or flexing, they break or crumble. We have over 100,000 multi-family, unreinforced brick buildings, most of them between three to seven stories high and built between the mid-1800s and 1930s. Many New York City neighborhoods consist of rows of attached unreinforced masonry buildings. The buildings rely on each other for stability, so those separated by vacant lots are particularly vulnerable. Brooklyn has the largest number of unreinforced masonry buildings followed by Queens and Manhattan.

Even if there is little earthquake damage above ground, buildings may be uninhabitable because their foundations are damaged. Masonry loft buildings are vulnerable due to their lack of interior walls and greater floor-to-ceiling area. Many pre-code emergency response buildings such as fire houses and police stations are housed in unreinforced masonry structures that have not been retrofitted. They could sustain damage that would impede certain emergency services to function post-earthquake.



DANGERS OF UNREINFORCED MASONRY BUILDINGS DURING AN EARTHQUAKE
SOURCE: FEMA

A large portion of New York City's waterfront is built on reclaimed land, which is composed of fill with poor structural properties in the parts built at the colonial times until a few decades ago when controlled fill and construction procedures were applied. Additionally, new guidelines for protecting structures from flooding and increasing resiliency recommend elevating coastal buildings, creating a soft story base that permits floodwaters to pass through – for example, by supporting the first floor on piers. However, during an earthquake, the combination of a soft story base and poor subsurface conditions could shift most of the load to the foundation, concentrating most of the damage on the bottom story.

Over time, our city's stock of seismically vulnerable buildings is being replaced by new structures that conform to current seismic code standards. However, the small percentage of buildings that are historically landmarked will remain vulnerable unless retrofitted.

INFRASTRUCTURE AT RISK

Virtually all of the city's infrastructure – above ground and underground – is vulnerable to earthquakes: bridges, tunnels, the subway, railroads, water tunnels and water mains, utility lines (power cables, communication lines, natural gas lines, steam pipes), and wastewater treatment plants.

Soil liquefaction could result in large-scale ground failure that could damage pavements and building foundations and massively disrupt underground utilities. Structures built on liquefied soils could sink and settle. Damage to underground infrastructure usually occurs in areas where utility transmission lines such as pipes cannot withstand soil movements. Damage to them could trigger secondary impacts like water contamination, fire, and explosions. In addition, critical infrastructure systems have aged and have general maintenance problems that may make them vulnerable.

Our city is vulnerable to earthquakes that occur beyond our borders too. An earthquake that damaged the upstate reservoirs and aqueducts that supply our city's water could have severe consequences including the inability to suppress fires. The Indian Point nuclear power plant is sited 25 miles north of the City near the intersection of two seismic zones that are believed capable of generating a magnitude 6 to 6.5 earthquake.

Large-magnitude earthquakes that occur longer distances away, such as in Canada, can create low-frequency (slow-moving) shaking that can affect tall buildings and tanks.

THE ECONOMY AT RISK

For businesses, damage to buildings and to building contents, including equipment and warehouse and retail inventory, and damage to the infrastructure and critical systems upon which businesses depend, could disrupt operations and revenues, causing significant economic losses. Repairs and equipment and inventory losses not covered by insurance would be a further cost. Low-wage earners, in particular, could be unable to earn income because of downtime.

Damage to infrastructure and critical systems could disrupt government, institutions, healthcare services, and many other functions and facilities, causing economic dislocation not just for the city but the region. Recovery costs could be enormous.

Overall, severe effects on what is a global financial center could ripple through the global economy.

HOW DO WE MANAGE THE RISK?

Although earthquakes can occur suddenly and cannot be prevented, many strategies have been developed to reduce the risks associated with them. The body of knowledge that informs these strategies continues to grow, as seismologists, geologists, engineers, architects, and other professionals continue to pursue research to advance their fields.

The primary strategies involve building code seismic requirements and seismic design requirements for infrastructure. Inspections and maintenance play vital roles, too.

PROTECTING BUILDINGS: REGULATIONS, ENFORCEMENT, AND ENGINEERING STRATEGIES

In New York City, the Department of Buildings develops and updates building codes and enforces them through extensive administrative measures.

Modern building codes require that all new buildings be engineered to provide a minimum of life safety if a very rare, strong earthquake occurs and to ensure general occupancy conditions for less severe earthquakes. In New York City, existing buildings undergoing substantial modifications must meet this standard, too.

The evolution of seismic building code provisions

The first seismic provisions in New York City's Building Code were signed into law in 1995 and took effect in February 1996. The Department of Buildings further addressed structural vulnerability to earthquakes when it adopted the International Code Council's family of codes in 2008, as the New York City Construction Codes.

The 2008 Codes not only make buildings stronger but more flexible and ductile – able to absorb energy without breaking in a brittle manner. The Code's plan for the two-percent chance of a moderate earthquake occurring or being exceeded in a 50-year period. Specific soil type and the building foundation are taken into account, and seismic detailing is required to ensure that joints and structural connections and piping within a building hold up during an earthquake.

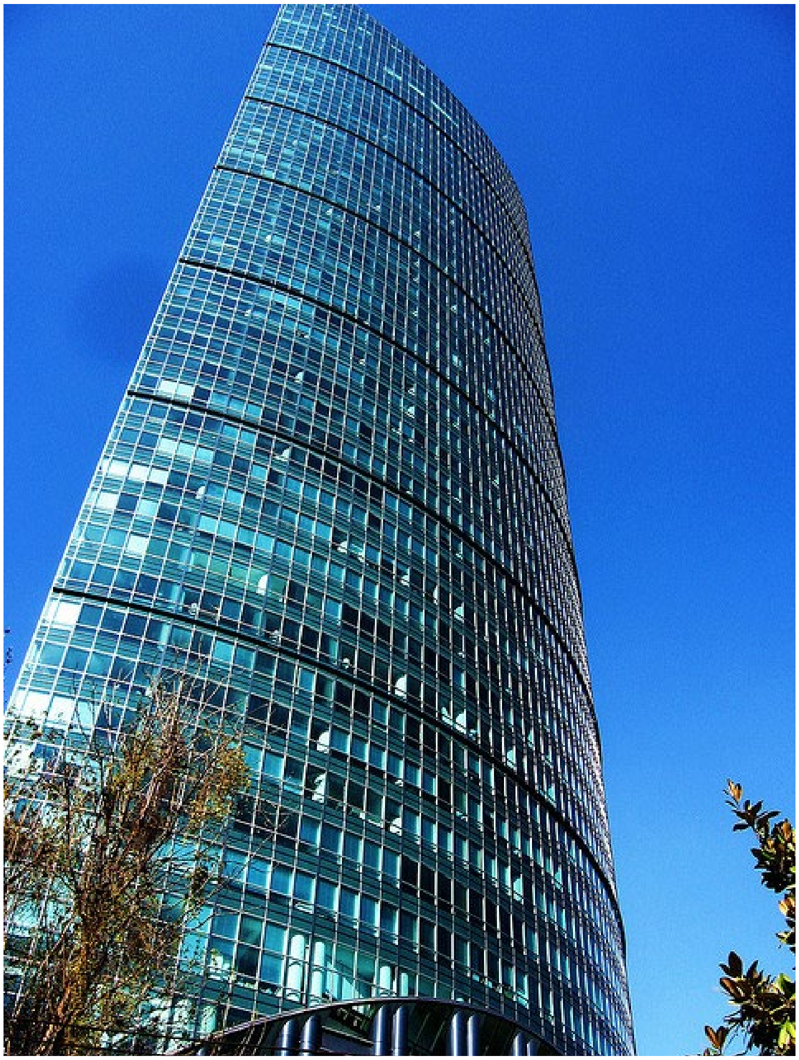
SOFT STORY BASE LOMA PRIETA
SOURCE: CIR ONLINE

Just as under the former City Building Code, under the 2008 Construction Codes critical facilities such as firehouses and hospitals must be designed to not only survive an earthquake but to also remain open and functional afterwards. The code permits unreinforced masonry for new buildings only in rare instances.

In 2014, the Department of Buildings revised the Construction Codes and moved toward a new concept: the risk-based approach, following the model of the American Society of Civil Engineers Standard 7-2010. This means that, instead designing against the probability of an earthquake happening, we are designing against the probability of a new structure collapsing or sustaining significant damage during an earthquake. The update also strengthens design requirements for soil liquefaction and takes into account the city's unique geologic conditions. Design must account for site-specific soil conditions and building foundations. It must ensure that joints and structural connections are flexible. Special detailing for electrical and mechanical systems, and building contents and architectural components is required.

Code enforcement

To ensure that buildings are built to code, new construction and major renovations cannot begin until the Department of Buildings has reviewed plans and issued work permits. The Department inspects properties after the construction



TORRE MAYOR

The Torre Mayor building in Mexico City is one of the strongest buildings in the world in terms of earthquake resistance. It was designed by New York City engineers to withstand 8.5 magnitude earthquakes on a site that has some of the worst soil conditions on earth. Its 96 viscous dampers work like car shock absorbers to block the resonating effects of both the lakebed on which the city sits and the building's own height.

In January 2003, a 7.6 earthquake shook the city. This building survived undamaged, and occupants did not know a tremor had occurred.

process is completed and then issues a final Certificate of Occupancy when the completed work matches plans that the Department has approved for new buildings or major alterations.

Engineering strategies

Architects and engineers employ a variety of methods to design and engineer new buildings and retrofit older ones to meet strict seismic standards. Some engineering strategies include strengthening how building elements are connected to increase flexibility, reducing building mass to reduce seismic forces, and strengthening foundations located in poor soil to ensure stability. Other strategies include incorporating viscous dampers throughout the building to absorb seismic energy or employing techniques that isolates the earthquake movement from the foundation to the structure.

For existing unreinforced-masonry buildings, adding, and in some cases preserving, structural elements that increase the structure's ductility – its ability to absorb energy without failing in a brittle manner – is another strategy. For example, steel reinforcement should be added where possible. Connections between structural elements can be strengthened by anchoring walls to the roof and walls to the foundation. This increases the structure's ability to transfer loads during an earthquake.

Parapets are often the most damaged element of an unreinforced building. Anchoring them with bolt diagonal steel struts and repairing the mortar on parapets can help reduce seismic risk. So can replacing unreinforced masonry parapets with reinforced masonry parapets and anchoring them to the building.

Preserving, rather than demolishing, interior walls in older loft buildings keeps those buildings safer.

Many times, simple, common sense solutions are enough to improve seismic performance and dramatically reduce the seismic risk. For example, to protect a building's contents, furniture can be anchored or bolted to the walls.

Guidelines for protecting coastal buildings from flooding and coastal storms, raise seismic safety issues: attention to the vulnerabilities of elevated buildings. For buildings with a soft story base, one of the easier solutions is to add bracing or shear walls to take the extra load. Another method is to make the columns and piles bigger or stronger.

For all buildings, routine maintenance is essential to reducing earthquake impacts. This means keeping roofs secure and in good condition, securing cornices and aluminum panels, repointing mortar regularly (especially on parapets and chimneys), and fixing all cracks.

Among the initiatives now under way in New York City, the Department of Administrative Services is installing new mechanical equipment to resist seismic forces in 55 City-owned buildings. The Department of Education is conducting a seismic study of its tall buildings and is retrofitting buildings to exceed current Construction Code seismic provisions. The Health and Hospitals Corporation is retrofitting several hospital facilities to meet code seismic standards.

PROTECTING INFRASTRUCTURE: GOVERNMENT GUIDELINES, INSPECTIONS, AND ENGINEERING STRATEGIES

Earthquakes can damage major infrastructure like bridges, tunnels, sewers, water supply systems, and wastewater treatment plants that were not designed to withstand earthquakes. New infrastructure is required to be designed to meet seismic loading, and older infrastructure is required to be retrofitted to meet those standards. Federal, state, and local governments all play roles in managing aspects of seismic safety for infrastructure.

Seismic guidelines for infrastructure govern retrofitting of older bridges and tunnels and other facilities, and the design of new ones to safe standards.

Protecting bridges

After the 1989 Loma Prieta earthquake which caused extensive damage to bridges in Northern California, many states in the central and eastern part of the country began adopting seismic provisions for highway bridges. In New York, many bridge owners hired seismologists to assess the risk of this hazard to our bridges. The Federal Highway Administration administers seismic retrofits of bridges through local authorities, under an inspection and rehab program mandated by Congress in 1991. To this end, the New York City Department of Transportation developed Seismic Criteria Guidelines in 1998 that have been updated since then to include up to date knowledge.

For all buildings, routine maintenance is essential to reducing earthquake impacts.

Since 1985, FEMA has been sponsoring earthquake engineering research by the National Earthquake Hazards Reduction Program (NEHRP). Their latest publication FEMA P-750: NEHRP Recommended Seismic Provisions for New Buildings and Other Structures was released in 2009. These recommended provisions are the primary source of seismic design requirements for new buildings and other structures throughout the nation. The goal of these provisions is to assure that seismic performance will:

- avoid serious injury and loss of life,
- avoid loss of function in critical facilities,
- minimize structural and nonstructural repair costs where practical to do so

Seismic assessment of bridges in the New York City requires evaluating the bridge for performance standards based on whether the bridge is determined critical, essential, or other. Retrofitting older bridges or designing new bridges should be accomplished by designing to the level of damage expected from the earthquake, to allow for the repairs needed after the event. The New York City Department of Transportation, which owns and maintains 789 bridges, is in the process of implementing seismic retrofits of all their critical, essential and other bridges.

SEISMIC ISOLATORS ON THE JFK AIR TRAIN

One of the more common methods of seismic protection in bridges and structures is seismic isolation. It protects bridges or structures by isolating the earthquake movement from the foundation to the structure. This is accomplished by mounting isolators (rubber and steel bearings) between the bridge deck and its piers, or the building and its foundation. The isolators absorb the earthquake energy and minimize the energy transferred to the structure. In New York City, this method has been used in the JFK Light Rail system.

Protecting other infrastructure

The City Department of Environmental Protection is conducting several projects to increase seismic protection of our wastewater treatment system. The agency is retrofitting wastewater treatment facilities and methane gas storage systems to withstand seismic activity, because most of these facilities were designed and built prior to current seismic standards. To reduce the impact of seismic activity on our sewer system, the agency has been inspecting and repairing structural deficiencies in some of its major sewers.

The Department is conducting a study to assess the seismic resiliency of our water supply system (water tunnels, piping, clean water pump stations, dams, shafts, and tanks) and to determine seismic design standards for it. Study findings will help prioritize areas in the distribution system that needs retrofits to meet seismic standards. City Water Tunnel 3 (described in the Water Shortage hazard profile) is designed to strict seismic standards.

Applying the City's seismic guidelines, the MTA, which is administered by New York State, is currently incorporating seismic requirements into its bridge and tunnel restoration projects in New York City.

Entergy Corporation, the operator of the Indian Point nuclear plant, states that the plant was designed to withstand an earthquake greater than the strongest earthquake probable for the area. In 2008, a safety evaluation confirmed that the plant's seismic design was sound and safe.

RESEARCH AND PROFESSIONAL EDUCATION

Collaboration among seismologists, geologists, engineers, architects, and emergency managers is essential to managing earthquake risks. Further research into the potential impacts of earthquakes on our city will expand our knowledge base and help promote awareness. This research may include earthquake impact modeling of New York City's unique built environment, taking into account our large stock of older buildings, soil conditions, and geological characteristics, to estimate potential physical and economic losses. The new seismic hazard maps released in July 2014 by the U.S. Geological Survey will inform future research.

The American Institute for Architects and the New York-Northeast Chapter of the Earthquake Engineering Research Institute held a series of programs ("Consider the Quake: Seismic Design on the Edge") in early 2014 to inform New Yorkers about seismic risk exposure for NYC buildings and how well the city is prepared to deal with earthquakes. The series included workshops on how to design buildings to withstand an earthquake.

The New York City Area Consortium for Earthquake Loss Mitigation, formed in 1998, created an educational guide to create public awareness of seismic risk in New York, New Jersey, and Connecticut. The guide, developed between 1998 and 2003, contains risk and loss estimates for the tri-state area; soil information for use in quantifying seismic hazard; information on Manhattan's building inventory, for estimating local impacts; models of earthquake scenarios and their probable consequences; an assessment of individual essential facilities; and recommendations for how to reduce potential damage and losses.

The Next Generation Attenuation is a multi-disciplinary research project coordinated by the Pacific Earthquake Engineering Research Center. It includes researchers from organizations in academia, industry, and government. They 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.

The Earthquake Engineering Research Institute recently established a New York–Northeast chapter to increase awareness of earthquake risk and to offer educational resources on how to reduce earthquake risk, at all levels of expertise in the fields of engineering, geoscience, architecture, planning, and the social sciences.

The Multidisciplinary Center for Earthquake Engineering, in collaboration with the Structural Engineering Association of New York, initiated studies to better understand the vulnerabilities of unreinforced masonry buildings in New York City. Working with the State University of New York at Buffalo, the Multidisciplinary Center is currently testing the shaking table prototypes of unreinforced masonry structure in order to develop pre-engineered solutions for New York City's building stock.

PUBLIC EDUCATION AND OUTREACH

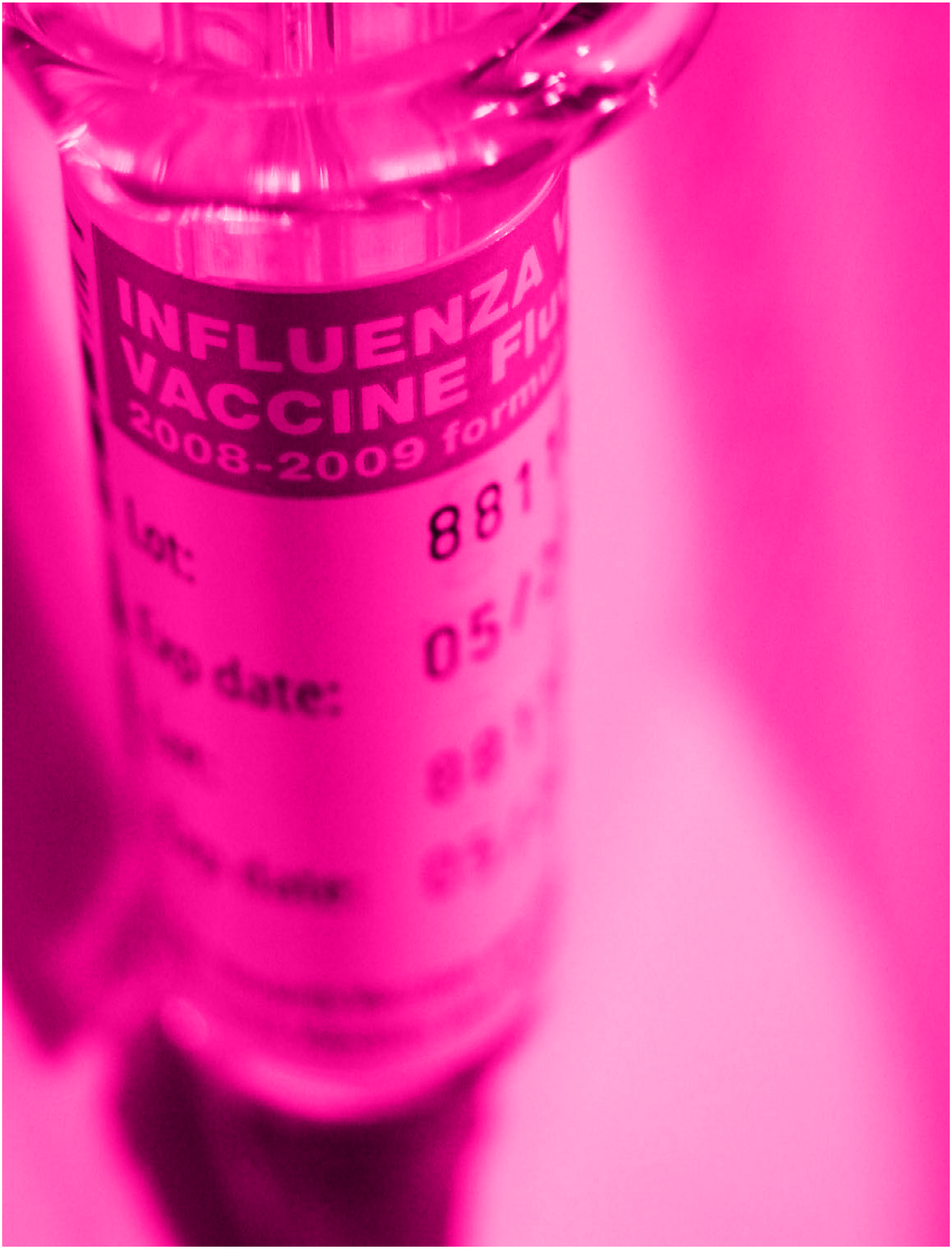
Because many New Yorkers are not aware of the local risk of earthquakes and will not have a warning when one happens, promoting awareness and preparedness is essential.

NYC Emergency Management's Ready New York campaign encourages New Yorkers to be ready for all types of emergencies, to develop a disaster plan, and to keep informed of hazards that may impact the City. Our *Ready New York Earthquake Safety Guide* explains what to do when an earthquake strikes and immediately afterwards.

NYC Emergency Management's *Ready New York Reduce Your Risk Guide* includes longer-term strategies that homeowners and residents can implement to reduce the impacts of an earthquake.

Because earthquakes can inflict not just physical but psychological harm, mental health services are essential to response and recovery. The NYC Department of Health and Mental Hygiene's Mental Health First Aid education program informs the public about mental health problems, warning signs, the forms those problems can take, and the kinds of treatments commonly available.

FEMA and the Northeast States Emergency Consortium organize annual Great Northeast Shakeout drills to encourage organizations, households, and agencies to practice how to be safer during an earthquake. It is also an opportunity for groups to update their preparedness plans, restock supplies, and secure their homes and workplaces to prevent damage and injuries.


INFLUENZA
VACCINE
2008-2009
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881
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PANDEMIC INFLUENZA
CHAPTER 4.9

New York City does not take flu season lightly. The city's high population density, reliance on crowded mass transit systems, and role as an international travel hub amplify the risk of pandemic influenza, a global outbreak of the flu. An outbreak could last many months, return in waves, and cause major daily disruptions and even death.

WHAT IS THE HAZARD?

PANDEMIC AND SEVERE SEASONAL INFLUENZA

Although many disease outbreaks could affect New York City, the one that tends to be the most common is seasonal influenza. Symptoms include fever, achiness, respiratory difficulties, and extreme fatigue for up to two weeks. The disease is spread through human-to-human transmission when people with the flu cough or sneeze, spreading droplets that contain the virus, or when people touch contaminated surfaces and then their nose or mouth.

Typically, five to 20 percent of the population gets seasonal flu each year during flu season in the fall and winter. After getting the flu, some people may develop immunity to them. However, because small changes can occur in seasonal flu strains, getting a new flu vaccination every year is strongly recommended as the best protection against seasonal flu.

Influenza becomes pandemic when a genetic change in a strain of influenza allows the virus to spread quickly across a large segment of population over a large geographic area. Often, this process begins when a strain of animal influenza mutates and becomes infectious to humans and then spread from person-to-person. People are more susceptible to contracting the virus because they are not immune to new strains, and no vaccine for the new strain is readily available.

Even though vaccines might not be ready, antiviral medications can be prescribed by a doctor within 48 hours of symptoms to shorten the time a person is ill. As pandemic outbreaks subside, the once new strain of influenza becomes part of the group of influenza strains responsible for seasonal flu. As vaccinations become available and naturally developed immunization to the strain occurs, the virus loses the impact that makes a pandemic outbreak so concerning.

Influenza pandemics are unpredictable and spread rapidly, possibly reaching global populations within six weeks, making public health response a challenge. Current animal-based (zoonotic) influenza strains are being monitored globally by the World Health Organization, the Centers for Disease Control (CDC), and other national and international public health organizations, for their potential to develop into a pandemic.

PANDEMIC INFLUENZA IMPACT ESTIMATES FOR EACH WAVE IN NYC

	MILD/ MODERATE SCENARIO	SEVERE SCENARIO
Infection rate	5 – 10% of population	20 – 25% of population
Number of people infected	410,000 – 820,000	1,640,000 – 2,050,000
Fatality rate	0.02%	2%
Number of fatalities	80 – 160	33,000 – 41,000

SOURCE: CENTERS FOR DISEASE CONTROL AND PREVENTION. PANDEMIC INFLUENZA (HTTP://WWW.CDC.GOV/FLU/PANDEMIC-RESOURCES/) USING 2010 U.S. CENSUS POPULATION FOR NYC: 8.2 MILLION

WHAT IS THE RISK?

Because New York City is an international air-travel hub and port of entry, it would not take long for a naturally occurring influenza pandemic to reach New York from elsewhere. New York's dense urban environment and the close physical interactions among the general public, especially on public transportation, make its residents exceptionally vulnerable to outbreaks of respiratory illness, including pandemic influenza.

Part of the challenge of responding to this kind of outbreak is predicting when a strain of influenza will become a pandemic and what its impact will be. Historically, pandemic influenza outbreaks have occurred globally every 10 to 60 years. The 20th century saw three outbreaks, with the pandemic of 1918-19 (Spanish Flu) being the most severe. Mild to moderate outbreaks occurred in 1957 to 1958 (Asian Flu) and 1967 to 1968 (Hong Kong Flu). The most recent pandemic was H1N1 in 2009.

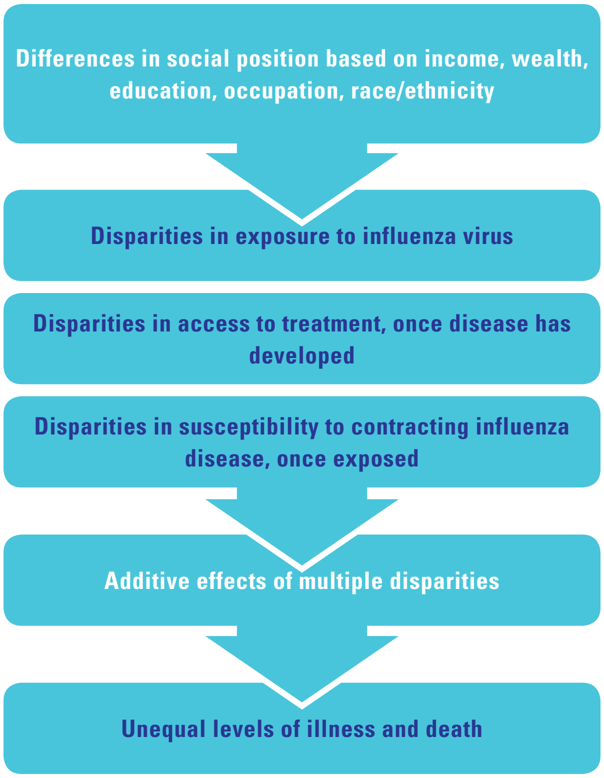
H1N1 was first identified in Mexico in April 2009. The first reported case in the New York City was in Queens that same month, followed by a global pandemic that in New York City lasted through 2010. NYC's Department of Health and Mental Hygiene (DOHMH) estimates that as many as one million New Yorkers were infected. H1N1 continues to infect people to this day, now as the most common seasonal flu strain.

History shows that the number of people infected by pandemic influenza will increase and decrease in waves (two or three 8-12 week periods) separated by many weeks of relative inactivity, over a 12- to 18-month period. Pandemic influenza outbreaks may have mild to moderate impacts that can cause a small number of fatalities. Severe impacts could cause up to 41,000 fatalities for each wave in New York City.

VULNERABILITY

Studies of pandemic influenza outbreaks have shown that some populations are more susceptible to infection or significant illness than others. Infection rates may be highest in school-aged children (as much as 40 percent) who are often the biggest transmitters of influenza viruses in the community. The World Health Organization considers the following populations to be at higher risk for negative medical outcomes (such as significant illness, hospitalizations, or death) from pandemic influenza: pregnant women, children, and seniors (aged 65 years or older), individuals with chronic health conditions, and healthcare workers.

Not only do certain physical and health conditions make some populations more vulnerable to pandemic influenza, societal factors can amplify the risk of disease spread. DOHMH conducted a study to identify areas of clustered population groups most vulnerable to a pandemic in New York City. The study was based on a model of vulnerability that examined how income, race, and other social attributes influence exposure, susceptibility, and access to treatment during an outbreak.



SOURCE: BLUMENSHINE ET AL. 2008.

SOME OTHER DISEASE OUTBREAKS THAT COULD AFFECT NYC:

Coronavirus: An upper-respiratory tract illness that spreads by airborne transmission and ranges from mild to moderate to very serious such as Severe Acute Respiratory Syndrome – coronavirus (SARS-CoV) and Middle East Respiratory Syndrome – coronavirus (MERS-CoV).

Novel Viral Outbreak: Occurs when a previously unknown viral disease is identified. Examples include West Nile Virus, Lyme Disease, and HIV.

Bacterial Outbreaks: Caused by the use of biological agents by terrorists such as aerosolized anthrax or by naturally-occurring outbreaks, such as meningococcal meningitis.

Measles: A highly contagious viral disease that causes fever and a rash. Anyone who is not vaccinated can get measles at any age. It can be spread by contact with an infected person who coughs and sneezes. During the spring of 2014, there were 26 cases in New York City.

Mumps: A viral illness that affects the salivary glands. It is spread by respiratory droplets that are released when an infected person coughs or sneezes.

Here is a sampling of study findings:

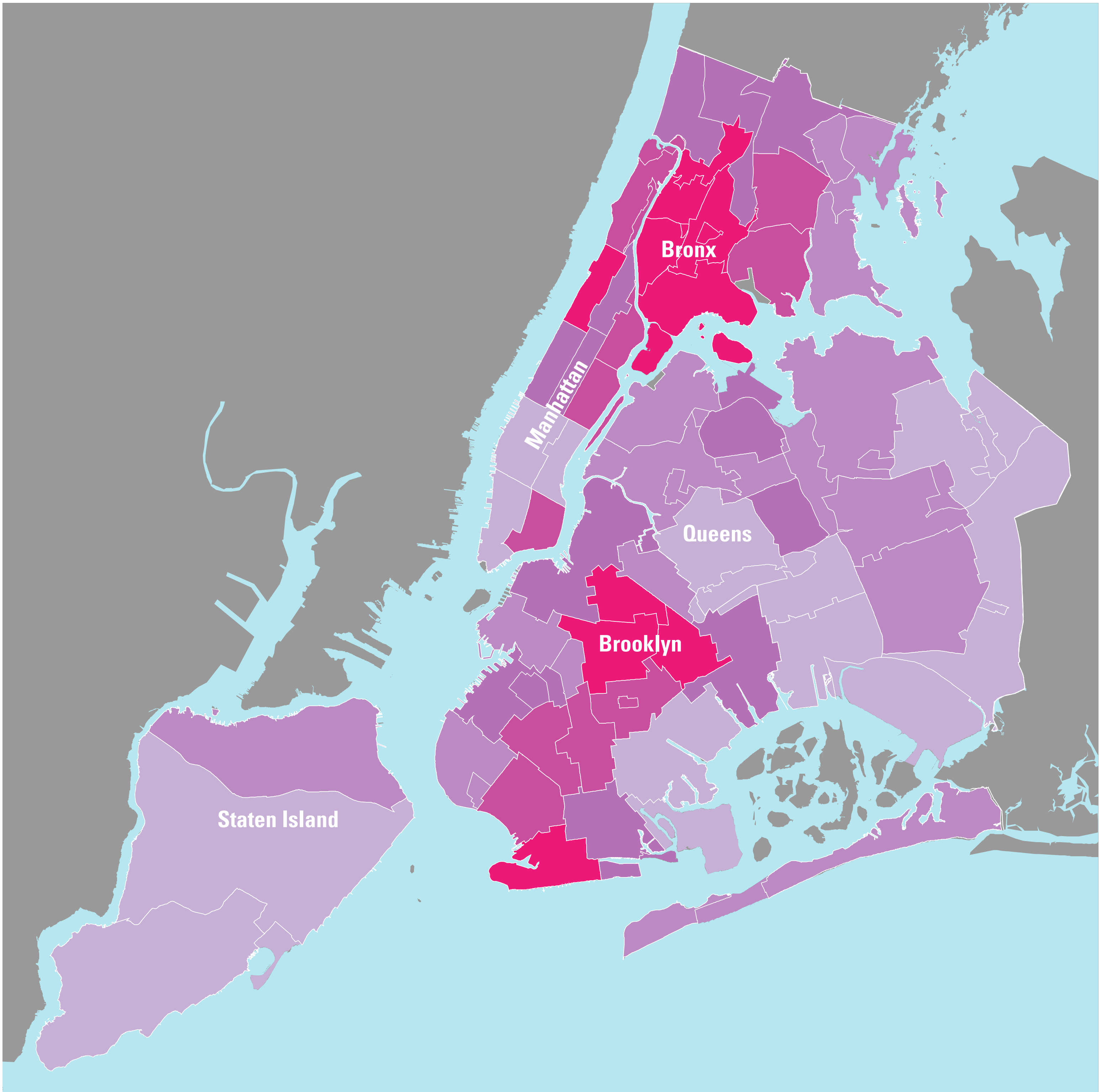
- **Exposure** - Transmission of pandemic influenza is typically airborne, but the flu can also spread through direct and indirect contact. Low-income populations may be more vulnerable to exposure to the virus than other groups because they are more likely to experience crowded living conditions and workplaces and to depend upon public transportation. Because frequent contact with infected populations increases the risk of exposure, healthcare providers, care givers, and first responders are also especially vulnerable.

- **Susceptibility** - The elderly, the very young, and people with pre-existing conditions such as diabetes, cardiovascular disease, or HIV are more susceptible to negative outcomes from an influenza infection. Environmental stressors and social behaviors including high-stress work situations, poor or unsafe housing, or drug addiction and alcoholism can increase the likelihood and severity of infection.

- **Access to treatment** - Lack of access to treatment may also increase vulnerability. In general, uninsured, low-income populations, immigrants, and people with disabilities have less access to care and treatment. People unable or unwilling to get vaccinations or to obtain care if infected may be more vulnerable to severe medical complications.

The ability of healthcare facilities to maintain continuity of care is another important factor. Pandemic influenza outbreaks can disrupt the continuity of care for people with pre-existing conditions (such as diabetes, cancer treatments, and HIV) because pandemics impact healthcare workers, who are working within a healthcare system strained by the influx of infected people while also dealing with increased absenteeism of healthcare staff who become ill.

Based on its analysis of exposure, susceptibility, and access to treatment, DOHMH identified population clusters vulnerable to pandemic flu outbreaks in New York City. Clusters of those most susceptible to pandemic influenza are found in Southwest Bronx, Morningside Heights, Bedford-Stuyvesant, East New York, Crown Heights and Coney Island.



DENSITY OF POPULATIONS WITH VULNERABILITY TO PANDEMIC INFLUENZA

SOURCE: NYC DOHMH

N 0 5 10 MILES

MOST VULNERABLE PER SQUARE MILE

82 - 606	607 - 1,284	1,285 - 2420	2,421 - 3,690	3,690 - 10,501

CDC ESTIMATE OF PAN FLU IMPACTS ON NEW YORKERS

SOURCE: NYC EMERGENCY MANAGEMENT H1N1 PLAYBOOK, 2010.

MILD/MODERATE SCENARIO	SEVERE SCENARIO
Similar to seasonal flu and Spring 2009 H1N1 outbreak	Infection and fatality rates much higher than seasonal flu
Increased worker absenteeism	Prolonged and severe worker absenteeism
Affects different populations than seasonal influenza (i.e., mainly different age groups)	Public and private sector firms struggle to maintain critical functions
Public concern greater than normal flu season	Intense demand for information by a concerned public
"Worried well" surge into emergency rooms and stress healthcare system	Sick and worried well could disrupt healthcare system
May be spot shortages of hospital bed availability, medical staff, and supplies	Prolonged and severe shortages of hospital bed availability, medical staff, and supplies
Public expects control measures beyond those for seasonal influenza	Recommended infection control measures (e.g., school closure, cancelled public gatherings) likely to be severe
Lower rates of fatalities in comparison to a severe scenario	Increased rate of fatalities
Economy not as affected in comparison to a severe scenario	Loss of ability to acquire goods and services

EXTENT/SEVERITY

The severity and extent of disease outbreaks according to epidemiological studies follow three levels: endemic, epidemic, and pandemic. Endemic disease spread pertains to specific areas among particular people. An epidemic is much more severe because it happens when new cases of the disease exceed what is anticipated based on previous experiences. A pandemic is an epidemic of infectious disease that has spread across the region and on a global scale. The consequences of a pandemic influenza depend on the severity of the outbreak and can range from daily inconveniences to more devastating outcomes. Some impacts of a mild outbreak include increased worker absenteeism and spot shortages of hospital staff and medical supplies.

In a moderate outbreak, schools and daycare centers may be closed and public events canceled. The outbreak may impact different population groups than a typical flu season. Hospitals may be crowded depending on the number of people who are infected or fear they may be infected.

A more severe scenario would include prolonged and severe worker absenteeism, increase in fatalities, potential disruption of critical services, and strained hospital resources. A pandemic that impacts many people and with a high mortality rate could have severe economic impacts. Because disease outbreaks often occur in waves, some economic sectors might not be able to recover from one wave before the next one hits.

SOCIAL DISTANCING AS A SELECTIVELY APPLIED CONTAINMENT STRATEGY

Because a vaccine might not be ready until six to nine months after an outbreak occurs, reducing influenza exposure by minimizing personal contacts is imperative.

New York City's dense concentration of living and working space and its heavy dependence on public transportation make social distancing particularly challenging. Closing schools and canceling public events during a severe pandemic can have far-reaching social and economic impacts on New Yorkers. These closures would only be recommended if the benefits were considered greater than the impacts.

HOW DO WE MANAGE THE RISK?

While the occurrence of a pandemic influenza may be unpredictable, well-understood strategies can be employed to manage its risks. The City, including DOHMH relies on protocols, communication tools, public education efforts, and promotion of workplace environmental controls in the public and private sectors.

NEW YORK CITY PROTOCOLS FOR PREPAREDNESS AND RESPONSE

DOHMH's Pandemic Influenza Preparedness and Response Plan (2013) defines the operations and protocols for responding to and limiting exposure to pandemic influenza. DOHMH will assess epidemiologic, clinical, and behavioral characteristics of the pandemic strain and recommend containment measures to limit the flu's spread while minimizing social disruption and cost. The Commissioner of DOHMH, in consultation with the Mayor, can issue orders that reduce exposure, such as school closures, cancelation of public gatherings, and hygiene advisories, such as advisories for frequent hand washing and staying home while ill.

In the event of a pandemic influenza outbreak, DOHMH will increase surveillance activities, which include monitoring influenza-like illness activity. DOHMH has a state-of-the-art 24/7 system for monitoring disease patterns. This syndromic surveillance system involves routinely monitoring emergency room visits, ambulance calls, and pharmacy sales to detect early warning signals of a possible outbreak.

DOHMH will also monitor illness within the city to detect further pandemic waves and guide clinical and public health decisions about how to best use limited medical resources.

A STRATEGIC FOCUS ON CONTAINMENT

In the early stages of an influenza pandemic, before a vaccine is available (usually six to nine months), community measures are essential to limiting the spread of disease. Since droplets can reach from three to six feet after they are coughed and sneezed into the environment, increasing the spacing between individuals can reduce exposure.

Measures to promote this – called social distancing strategies or non-pharmaceutical interventions – include limiting or staggering public transportation ridership, closing schools, encouraging alternative modes of travel (driving, carpooling, biking, or walking), canceling public events, implementing alternate work schedules, and encouraging telecommuting and vacations

MOBILIZING RESOURCES FOR A MULTIPRONGED RESPONSE

During a pandemic, hospitals and other healthcare facilities will care for a large number of infected patients. Planning for this demand focuses on developing surge capacity in acute and critical care facilities, and on further strengthening communication between DOHMH and health care providers. DOHMH will work with the State Department of Health to monitor and address staffing, supply, and resource needs.

Antiviral drugs are prescription drugs that can reduce influenza symptoms and may shorten the duration of illness if taken within 48 hours of the first signs of illness. The drugs may also make a person less likely to spread influenza to others. These drugs will be distributed by the government to healthcare facilities as well as through pharmacies, to patients with prescriptions.

Meanwhile, officials at the CDC will work with partners in universities and industry as well as state and local health authorities to produce a vaccine for the virus that is causing a pandemic. Once a vaccine becomes available, it may be administered as a two-dose regimen, with doses 30 days apart, as it was for children under the age of ten during the 2009 H1N1 pandemic. Initial supplies may be limited. DOHMH's distribution systems may include hospitals, clinics, nursing homes, other health care facilities, private physician's offices, and Points of Dispensing (PODS, temporary emergency sites that are publicly accessible to large numbers of people). Information on vaccine availability will be provided through 311, a city-run online vaccination locator, the press, social media, etc.

FOUR STAGES OF PANDEMIC INFLUENZA DEFINED BY THE WORLD HEALTH ORGANIZATION

Interpandemic phase:

The period between influenza pandemics.

Alert phase:

This is the phase when influenza caused by a new subtype has been identified in humans. Increased vigilance and careful risk assessment, at local, national, and global levels, are characteristic of this phase. If the risk assessments indicate that the new virus is not developing into a pandemic strain, a de-escalation of activities towards those in the interpandemic phase may occur.

Pandemic phase:

This is the period of global spread of human influenza caused by a new subtype. Movement between the interpandemic, alert and pandemic phases may occur quickly or gradually as indicated by the global risk assessment, principally based on virological, epidemiological, and clinical data.

Transition phase:

As the assessed global risk reduces, de-escalation of global actions may occur, and reduction in response activities or movement towards recovery actions by countries may be appropriate, according to their own risk assessments.

COMMUNICATION AND EDUCATION CAMPAIGNS

Communicating clear, accurate information to the public throughout an influenza outbreak is critical to limiting exposure, given the ever-changing nature of a pandemic influenza. The City prepares for pandemic influenza by testing communication protocols, developing communication tools, training agency staff, and coordinating with agencies, stakeholders, and community groups to build strong partnerships.

In the event of an influenza pandemic, the government, at the federal, state and local levels, will issue prompt alerts. As an outbreak progresses, the government will keep the public supplied with timely information about the status of the pandemic using television, radio, the Internet (including social media), and call centers.

DOHMH develops messages targeted to high-risk populations including children, caregivers, pregnant women, the elderly, and individuals with chronic health conditions. To communicate important information to non-English-speaking (or less-English-proficient) populations, the City makes critical health information available through translation and interpretation. Language needs have been identified and messages are tailored to meet the needs of special and vulnerable populations.

DOHMH also communicates through its website, which includes an interactive map that visitors can use to locate flu clinics (flu locator) and widgets that deliver vital flu information to users. Through the media, 311, and many other outlets, DOHMH provides practical information about flu symptoms, when to go to the doctor, when to stay home, where to go for treatment, how to care for people who are sick, and where to get a vaccination when vaccines are available.

NYC Emergency Management's Ready New York Pandemic Flu guide, available on the agency's web site, explains possible pandemic influenza symptoms, how a pandemic may affect the city, and what steps the public can take to prevent its spread. NYC Emergency Management coordinates closely with DOHMH to ensure that messaging is clear, accurate, and consistent.

POLICEMEN WEARING MASKS PROVIDED BY THE AMERICAN RED CROSS IN SEATTLE, 1918

THE 1918 SPANISH FLU

In 1918, the virus eventually called Spanish flu was first identified in the United States. Cities' response to the outbreak influenced the consequences.

In Philadelphia, four months after Spanish flu was identified, more than 12,000 people had died. Despite the outbreak, the City continued to allow large public gatherings, including citywide parade in support of the war effort.

In St. Louis, doctors persuaded the City to register influenza cases with the health department. Police officers helped shut down schools, churches, and other gathering places. The death rate in St. Louis was less than half the rate in Philadelphia.

In New York City, health officials also encouraged behavioral modifications to limit the flu's spread. For example, business hours were staggered to reduce demand on public transit systems in the mornings and afternoons. The City promoted health education efforts by urging New Yorkers to cover their mouths when coughing and sneezing and encouraged people to stop spitting in public. Although these measures were not strictly enforced, violators could face misdemeanor fines. The death rate during the pandemic was lower than Philadelphia's.

Lessons learned: The varied death rates could be attributed to the timing of strategies for carrying out prevention measures. Cities that instituted social distancing early in the epidemic had peak death rates 30 to 50 percent lower than those that did not. The most successful interventions were in communities where the political and health authorities broadly agreed on what needed to be done and the public cooperated.

PROMOTING WORKPLACE CONTROLS

Flu can easily spread in the workplace. Both employers and employees can exercise environmental controls to limit its spread. Employers can:

- Maintain standard workplace cleaning routines.
- Encourage employees to stay home if they are sick and to not return to work until they have been fever-free for 24 hours without the use of fever-reducing medications.
- Ensure access to hand-washing facilities or to alcohol-based hand sanitizer if soap and water are not available.
- Promote vaccination.
- Promote respiratory etiquette, which includes encouraging covering coughs and sneezes, keeping hands clean and away from your face, and discouraging hand shaking.

In 2009 the City created the Agency Influenza Health and Safety Program aimed at reducing the occupational exposure of non-medical City employees. It is designed to help City agencies develop their own agency-specific plans for limiting the spread of flu. The program includes a Job Risk Assessment that entails careful examination of a workplace and the tasks each worker performs. The objective is to identify workplace hazards and determine whether existing precautions are sufficient, or if further controls should be put in place.

The approach can be adapted to differing agency conditions and can be used for multiple-scale influenza scenarios. It can also be used by private sector parties as a guide for developing their own Influenza Health and Safety Plans.

The City's Awareness Level Training program helps City agencies promote staff awareness through employee training that covers influenza health effects, modes of transmission, preventive measures, and job risk assessments. Control measures include safe work practices, administrative controls, engineering controls, and the use of Personal Protective Equipment.

Mitigation minimizes the repeated cycle of disruption and damage. Every recovery phase following a hazard even becomes an opportunity for learning for the next.

It also means that our work is never done.

CHAPTER 5

BEHIND THE SCENES: OUR RISK MANAGEMENT PROCESS, AND WHAT LIES AHEAD

A ROBUST PLAN FOR A GLOBAL CITY

The *2014 Hazard Mitigation Plan* identifies hazards that can affect New York City and the risks associated with them, and it documents strategies for lowering those risks. It differs from other New York City plans that address risk in that it addresses a broader range of hazards.

MOBILIZING OUR RESOURCES

Why did New York City produce a 551-page Hazard Mitigation Plan? Technically, it is a compliance document designed to satisfy FEMA requirements for hazard mitigation funding. FEMA requires that such plans be updated every 5 years.

But to say that our 2014 Plan "updates" the 2009 Plan understates the case. The 2014 Plan adds several non-natural disasters to the previous portfolio of solely natural hazards. It results from a planning process that converged with Hurricane Sandy and the City's response to that catastrophic storm. It addresses climate change extensively. And while some of its content is necessarily similar to that of some other City plans, no other City plan addresses such a broad a range of hazards.

Producing the 2014 Plan took a year and required the expertise of stakeholders from City agencies, researchers, and community and industry partners. Taking the lead was a team from New York City Emergency Management, the Department of City Planning, and the Mayor's Office of Recovery and Resiliency. The team convened and guided these bodies:

- A 13-member Steering Committee drawn from City agencies and regional organizations responsible for some of the city's largest infrastructure systems with expertise in emergency management, land use planning, building codes, housing recovery, public health, public safety, transportation, infrastructure protection, climate change, regional planning, and natural resource protection.

- A 41-member Mitigation Planning Council drawn heavily from City agencies, with representation from State and federal agencies, various authorities, nongovernmental organizations, and the private sector, academic institutions, community organizations, and citizens

FEMA defined the contents of the Plan, which was designed to identify specific risk management measures –termed “mitigation actions” – that serve these goals:

- protect public health and safety, with a focus on our most vulnerable populations
- protect the built environment: property and infrastructure, including complex systems
- promote a sustainable economy
- protect the natural environment
- strengthen preparedness for disasters
- overall, promote resiliency and sustainability

The goals seem simple and straightforward. New York City’s risks are not. The planners elaborated the goals above into a set of 28 objectives and, with the 2009 Plan as their point of departure, drew from their own extensive knowledge, the historical record, the latest scientific and technical information, consultation with hundreds of external parties, and many City plans and reports.

One important source was *PlaNYC 2030*, the City’s comprehensive plan – updated every four years – for achieving citywide sustainability goals. Another source was *A Stronger, More Resilient New York*, the City’s resiliency plan that guides and reports on recovery from Sandy and presents strategies and initiatives for managing risks associated with extreme weather and climate change.

PURSUING A RIGOROUS, INCLUSIVE APPROACH

The development of the hazard risk assessment for the 2014 Plan included a structured, rigorous approach to assessing the risks.

- Identify hazards that pose a serious risk, and for each one of them considered

- likely severity
- probability
- geographic areas likely to be impacted
- historic data

- Determine which features of our city are vulnerable to each hazard; primarily,
  - people (particularly the most vulnerable groups)
  - the built environment, including infrastructure and complex systems
  - the natural environment
  - our economy
  - future conditions to the extent they can be reasonably foreseen
- Estimate potential losses using loss estimate software for hurricane winds, flooding, and earthquakes.

Defining a citywide suite of mitigation actions

Mitigation actions considered for inclusion in the plan were those undertaken or planned by City, State, and federal agencies; utilities; and other players. The actions can generally be characterized as:

- statutory and regulatory measures, including zoning law and construction codes
- policies, programs, projects, and special initiatives
- physical property protections such as seismic retrofitting and flood-proofing
- natural resource protections such as projects that protect wetlands
- major infrastructure projects like construction of City Water Tunnel Number 3
- in-depth, well-coordinated emergency-response capabilities
- communication tools and programs that promote preparedness and recovery

To assemble an inventory of candidate actions, planners next

- identified existing strategies – those already being implemented, or for which funding was already secure
- determined potential strategies – programs, plans, projects, and policies for which funding had not yet been secured

The result was over 200 pages of detailed tables that identify a set of 330 existing actions and 332 potential actions. The tables capture the scope, variety, and dynamism of the city's risk management efforts. Their feasibility was evaluated against social, technical, administrative, political, legal, economic, and environmental considerations. (A proposed action's inclusion in the Plan did not constitute an official commitment to implementing it.)

After a public comment period, the draft Plan was revised, submitted to FEMA, and approved. By Executive Order, on April 15, 2014, the Mayor adopted it as the City's official Hazard Mitigation Plan.

LOOKING AHEAD

A PLAN THAT IS MORE THAN A DOCUMENT

Besides satisfying FEMA requirements for mitigation funding eligibility, the 2014 Plan equips us to take advantage of funding opportunities as they arise – we are fully prepared to make the case.

But the Plan's value extends far beyond funding goals. The planning process itself strengthened collaboration among participants, with benefits that continue to this day. And while the process described above may sound mechanistic, it entailed considerable learning

DISTRIBUTED RESPONSIBILITIES AND KEY PLAYERS IN OUR CITY'S MANAGEMENT OF RISK

Beyond the large cast of parties who produced the *2014 Hazard Mitigation Plan* is an even larger cast who contribute to the daily work of managing risks. Responsibility is distributed widely: City, State, and federal agencies, various authorities, nongovernmental organizations, and the private sector all play important roles.

Characteristically, for any one hazard, multiple parties exercise responsibilities. Conversely, a single party's responsibilities may span multiple hazards. This makes for a complex network of relationships that are purposely decentralized across many organizations.

Emerging as a central player is the **Mayor's Office of Recovery and Resiliency** (ORR), created in March 2014 to work with City agencies to implement strategies of long-term climate resiliency efforts as laid out in *A Stronger, More Resilient New York*, while also incorporating resiliency into ongoing City operations. on the City's resiliency priorities are strengthening coastal defenses, upgrading buildings, protecting infrastructure and critical services, and making Neighborhoods safer and more economically resilient. ORR is also engaging with State and Federal rebuilding programs to ensure complementary recovery approaches.

Billions of dollars in federal funding are contributing to Sandy recovery and long-term hazard mitigation efforts across the city. Augmenting this are investments by the City and its partners.

WORK SESSION FOR *NYC'S RISK LANDSCAPE*

and the continual application of expert judgment. The planners' expanded knowledge base and seasoned judgment inform their ongoing management of risk.

Importantly, the Plan is more than a compliance document that sits on a shelf. This makes it an extremely useful tool. For each mitigation action, it identifies the responsible party, the timetable, costs, and funding sources. It is frequently consulted as a resource, and it directly supports the monitoring and evaluation that contribute to results.

The responsibility for implementing strategies is distributed among many parties. The Mitigation Unit at the City's Emergency Management Department serves as lead coordinator for tracking implementation – working through the Mitigation Planning Council – and for updating the 2014 Plan. It convenes meetings, conducts research relevant to the Plan, shares information about funding opportunities, and widely promotes awareness of risk management.

Annually, New York City Emergency Management will obtain status reports from City agencies and private partners and update the Plan to reflect them. As the Plan is updated, it will remain online. Comments on it are welcome at any time.

It is truly not only our City government's plan but our entire city's plan.

A PROCESS THAT STEADILY GAINS IN POWER

For our Hazard Mitigation Plan's fullest value to be realized, this set of conditions must be satisfied:

- Risk management strategies must be seamlessly integrated into the agendas, plans, and operating and capital budgets of all parties responsible for them.
- The effectiveness of strategies must be assessed.
- Changing conditions must be assessed – for example, fluctuations in available funding; new laws, regulations, and policies; significant new study findings; impacts of major hazard events.
- Strategies must be modified as needed.

> Climate change deservedly commands growing attention. But it must not obscure the very real threat of other hazards.

Driving the hazard mitigation process is a proactive approach informed by continuous learning. In the past, hazard mitigation was usually reactive – undertaken in response to a disaster that had just occurred, as illustrated by the regulatory timeline in Chapter 4 that chronicles incremental improvements in the City's building codes. Today we aim to prospectively fashion strategies that can minimize or break cycles of repeated destruction. This means that every recovery phase following a hazard event becomes an opportunity for learning. It also means that our work is never done, because the nature of some risks evolves, as do some measures for managing them.

THE LONGER-TERM OUTLOOK

Not only is our approach to risk proactive. As Chapter 2 explains, the field of risk management has gained power and sophistication, the concept of risk has expanded, and sustainability and resiliency have become paramount twin goals. The long-term, strategic approach to risk management is gaining traction at all levels of government, and within the private and nonprofit sectors.

A few examples illustrate this reality. The White House has incorporated climate change into many of the Sandy recovery policies and programs. New York City has pioneered urban sustainability and resiliency efforts, its goals are becoming increasingly ambitious, and more and more of its partners and stakeholders are stepping up to the challenge. Con Edison puts its climate change principles online and has dedicated $1 billion to fortify critical infrastructure and equipment across its system. The Port Authority of New York and New Jersey's environmental initiatives encompass climate change. The MTA devotes many web pages to sustainability, including a page on climate adaptation. Many major corporations have Sustainability Officers. Many colleges and universities offer degrees in sustainability and disaster management. The Rockefeller Foundation is pushing the resiliency agenda globally, starting with New York City's selection for the 100 Resilient Cities Network.

These examples illustrate that sustainability and resiliency initiatives have been growing in the City. Deservedly, climate change is now dominant in risk management discussions, and it will become only more so. But it must not obscure the very real threat of other hazards.

Ahead, we foresee, along with climate change, greater levels of risk due to population growth and the strain it puts on aging infrastructure. We see the potential for budget shortfalls as repair and recovery costs for hazard impacts erode public and private sector budgets. Investing in mitigation measures is fiscally prudent. But will those investments be made? Other urgent needs are competing for scarce funds.

But while the future is uncertain, post-Sandy New York City is "coming back stronger." We foresee our management of risk growing ever stronger as mitigation measures are steadily implemented and strengthened, as we continue to learn, and as new technologies improve and fall in cost and we determine how best to capitalize on them.

We also foresee more parties in the private and nonprofit sectors and the general public gaining a clearer understanding of the hazards New Yorkers face and greater insight into the nature of risk itself, thereby becoming better prepared to withstand, respond to, and recover from hazard events.

Toward this end, if you found this Guide helpful, please share it!

RESOURCES

* Primary Sources

CHAPTER 3:

FEMA, *Children Vulnerable To Disaster-Related Stress*, December *8, 2012.*

Bond, Shannon. "How cities are revamping their coastal defenses." *Financial Times*, September 5, 2014.

Metropolitan Transportation Authority. *Public Transportation for the New York Region.* Accessed September 2014.

New Jersey Transit. *NJ Transit Facts at a Glance: Fiscal Year 2012.*

NYC Department of City Planning. *MapPLUTO 13V1.* 2013.

NYC Department of City Planning. *Population Division.* Accessed August 15, 2014.

NYC Department of Finance. *Mass Appraisal System.* 2013.

NYC Department of Health and Mental Hygiene. *Community Health Survey.* 2012.

NYC Department of Health and Mental Hygiene. *Epiquery: NYC Interactive Health Data System.* Accessed August 15, 2014.

NYC Department of Transportation. *Ferries and Buses.* Accessed August 15, 2014.

NYC Economic Development Corporation. *September 2013 Economic Snapshot.* Accessed August 15, 2014.

New York Metropolitan Transportation Council. *The 2014-2040 Regional Transportation Plan.* September 4, 2013.

New York State Department of Labor. *Labor Statistics for the New York City Region.* Accessed August 15, 2014.

New York State Department of Labor. *Significant Industries: A Report to the Workforce Development System.* 2011.

New York State Office for People with Development Disabilities. *Facts about Developmental Disabilities.* July 25, 2013.

NYC & Company. *New York City Tourism: A Model for Success.* 2012.

McGeehan, Patrick. "For Head of New York Tourism, 55 Million Visitors Isn't Enough." *The New York Times.* July 7, 2014.

The Port Authority of New York and New Jersey. *2012 Trade Statistics.* May 2013.

The Port Authority of New York and New Jersey. *Port Authority Trans Hudson: 2012 Passenger Traffic.* Accessed December 04, 2013.

U.S. Census Bureau. *American Community Survey 2010, 2011, 2012.* Accessed August 15, 2014.

U.S. Department of Health and Human Services. *2014 Poverty Guidelines.* Accessed August 15, 2014.

US Geological Survey. *National Park Research: Coastal Processes.* Accessed August 15, 2014.

COASTAL STORMS

FEMA. *L0320 Hurricane Preparedness for Decision Makers – New York: Student Manual.* Washington, D.C.: Federal Emergency Management Agency, 2013.

Hurricane Science. *Aquatic Impacts.* Accessed July 28, 2014.

* Lane, K. et al. "Health Effects of Coastal Storms and Flooding in Urban Areas: A Review and Vulnerability Assessment." *Journal of Environmental and Public Health*, 2013 (2013): 33.

National Hurricane Center. *NOAA Technical Memorandum NWS NHC 38: The National Hurricane Center Risk Analysis Program (HURISK).* Coral Gables: National Hurricane Center, 1991.

* National Hurricane Center. *Hurricane Preparedness – Hazards, Storm Surge Overview, Tropical Storm Climatology,* Accessed March 19, 2014.

* National Oceanic and Atmospheric Administration. *Tides and Water Levels, Frequently Asked Questions,* and *Tidal Datums.* Accessed October 21, 2014.

* NYSERDA. *ClimAID: Responding to Climate Change in New York State.* July 21, 2014.

Weather Underground. Storm Surge Basics. Accessed July 30, 2014.

COASTAL EROSION

H. John Heinz III Center for Science, Economics and the Environment. *Evaluation of Erosion Hazards.* Washington, D.C.: Federal Emergency Management Agency, 2000.

New York City Department of Buildings. *Coastal Erosion Hazard Area Map.* Accessed July 28, 2014.

New York State Department of Environmental Conservation, Division of Water, Coastal Erosion Management Unit. *Coastal Erosion Hazard Area Maps, Richmond, Kings and Queens Counties.* New York City: New York State Department of Environmental Conservation, 1988.

* New York State Department of Environmental Conservation. *CEHA Map Revision Process* and *Coastal Management.* Accessed July 28, 2014.

O'Neill Jr., Charles R. *A Guide to Coastal Erosion Processes.* Ithaca: Cornell University, 1985.

O'Neill Jr., Charles R. *The New York State Coastal Erosion Act, Coastal Erosion Regulation Fact Sheet.* Brockport: State University College, 1989.

* Tanski, J. *Long Island's Dynamic South Shore: A Primer on the Forces and Trends Shaping Our Coast.* New York: Sea Grant New York, 2007.

United States Geological Survey. *National Assessment of Shoreline Change Project.* Accessed July 28, 2014.

FLOODING

Center for an Urban Future. *Caution Ahead.* 2014.

Coastal Wetlands Planning. Protection and Restoration Act, *Barrier Islands.* Accessed July 28, 2014.

FEMA. *Flood Insurance Study, City of New York, New York.* December 5, 2013.

FEMA. *The National Flood Insurance Program.* Last Updated July 24, 2014.

Karamouz, M., S. Nazif and M. Fallahi. *Hydrology and Hydroclimatology: Principles and Applications.* CRC Press: Boca Raton, 2013.

NYC Department of City Planning. *Designing for Flood Risk. June 2013.*

NYC Department of City Planning. *Retrofitting Buildings For Flood Risk.* October 8, 2014.

NYC Department of City Planning. *Resilient Neighborhoods Studies.* Accessed August 15, 2014.

NYC Department of City Planning. *Flood Resilience Zoning Text Amendment.* October 9, 2013.

NYC Department of Health and Mental Hygiene. *Epiquery: NYC Interactive Health Data System.* Accessed December 4, 2013.

NYC Emergency Management. *Flash Flood Emergency Plan.* 2008.

NYC Special Initiative for Rebuilding and Resiliency. *FEMA Flood Map Update.* Accessed August 15, 2014.

NYC Department of Environmental Protection. *Wastewater Resiliency Plan.* October, 2013.

NYC Mayor's Office, Flood Mitigation Taskforce. *Stormwater Mitigation Study Area (SMSA) Report,* April 2008.

O'Connor, Anahad and Bowley, Graham. "Tornado Hits Brooklyn; Subway Back in Service," *The New York Times*, August 8, 2007.

Regional Plan Association. *Lessons From Sandy: Federal Policies to Build Climate Resilient Coastal Regions.* 2014

Regional Plan Association and Lincoln Institute of Land Policy. *Building Coastal Resilience: Using Scenario Planning to Address Uncertainty and Change.* 2014

U.S. Census Bureau. *American Community Survey 5-Year 2007-2011.* Accessed August 15, 2014.

Watson, Donald and Adams, Michele. *Design for Flooding: Architecture Landscape and Urban Design for Resilience to Climate Change.* Wiley: West Alton, 1993.

EXTREME HEAT

Anderson, G. B. and Bell, M. L. "Lights Out: Impact of the August 2003 Power Outage on Mortality in New York, NY." *Epidemiology*, 23(2012): 189-193.

Bowean, L. "Lessons from '95 Disaster Help City Bear Latest Heat Wave." Chicago Tribune, July 8, 2012.

Brucker, G. "Vulnerable Populations: Lessons Learnt From the Summer 2003 Heat Wave in Europe." *Eurosurveillance*, 10(2005): 551.

Cadot, E., Rodwin, V., and Spira, A. "In the Heat of the Summer: Lessons from the Heat Waves in Paris." *Journal of Urban Health*, 84(2007): 466-468.

CDC. "Heat Illness and Deaths - New York City, 2000-2011." *MMWR*, 62(2013): 617–621.

The City of New York. *Environmental Public Health Tracking.* Accessed July 30, 2014.

Con Edison. *Demand Response: Get Paid to Use Less Energy.* Accessed July 30, 2014.

* Gaffin, S.R., et al. "Bright Is The New Black—Multi-Year Performance Of High-Albedo Roofs In An Urban Climate." *Environmental Research Letters*, 7(2012): 1-12.

* Gaffin, S.R., et al. "Variations in New York City's Urban Heat Island Strength over Time and Space." *Theoretical Applied Climatology*, 94(2008): 1-11.

* Graber N. and Lane K. "Planning to Beat the Heat: Heat-Health and Climate Adaptation in New York City." *NACCHO Exchange*, 11(2012).

Holusha, J. "New York's Heat Wave Prompts Record Power Use." *The New York Times*, August 1, 2006.

Klinenberg, E. "When Chicago Baked: Unheeded Lessons from another Great Urban Catastrophe." *Slate,* September 2, 2005.

Kovats, S.R. and Kristie, E.L. "Heatwaves and Public Health in Europe." *European Journal of Public Health*, 16(2006): 592-599.

* Lane, K., et al. "Extreme Heat Awareness and Protective Behaviors in New York City." *Journal of Urban Health,* 91(2013): 403-414.

Li, T., R. M. Horton, and P.L. Kinney. "Projections of Seasonal Patterns in Temperature-Related Deaths for Manhattan." *Nature Climate Change*, 3(2013): 717-721.

Lin S., et al. "Extreme High Temperatures and Hospital Admissions for Respiratory and Cardiovascular Diseases." *Epidemiology*, 20(2009): 738-746.

* Metzger, K. B., Ito, K., and Matte, T. D. "Summer Heat and Mortality in New York City: How Hot Is Too Hot?" *Environmental Health Perspectives*, 118(2010): 80-86.

National Weather Service. *Natural Hazard Statistics* and *Heat: A Major Killer.* Accessed July, 2014.

* National Weather Service Office for New York. *Excessive Heat.* Accessed June 18, 2010.

NYC Department of Buildings. *Green Roofs* and *Sustainability.* Accessed October, 2014.

NYC Department of Health and Mental Hygiene. "New York City Vital Signs: Deaths Associated with Heat Waves in 2006." November 2006.

NYC Department of Health and Mental Hygiene. "Health Advisory #8: Heat-Related Morbidity and Mortality in New York City." May 26, 2011.

* NYC Department of Health and Mental Hygiene. *Heat Illness and Heat Waves.* Accessed July 30, 2014.

NYC Department of Health and Mental Hygiene. "Health Department Releases Report on Summer 2006 Heat Wave Deaths." Press Release November 15, 2006.

NYC Emergency Management. *Emergency Planning: Heat Emergency Plan.* Accessed October 21, 2014.

* NYC Emergency Management. NYC Hazards: Extreme Heat Basics. Accessed July 30, 2014.

New York State Assembly. "Report of the New York State Assembly Queens Power Outage Task Force Concerning the July 2006 Power Outage in Consolidated Edison's Service Territory." January 30, 2007.

* New York State Energy Research and Development Authority. *Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces*. Albany: New York State Energy Research and Development Authority, 2006.

NYC Cool Roofs. *How Cool Roofs Work.* Accessed October 21, 2014.

NYC Greenhouse. *An Owner's Tool Kit for Saving Money by Going Green.* Accessed October 21, 2014.

Pengelly, L.D., et al. "Anatomy of Heat Waves and Mortality in Toronto: Lessons for Public Health Protection." *Canadian Journal of Public Health*, 98(2007): 364-368.

PlaNYC Green Buildings & Energy Efficiency. "Welcome to PlaNYC Green Buildings and Energy Efficiency." Accessed October, 2014.

The University of Chicago. "Dying Alone: An Interview with Eric Klinenberg, author of Heat Wave: A Social Autopsy of Disaster in Chicago." Accessed July 16, 2014.

U.S. Department of Energy. *Tips: Sealing Air Leaks.* Accessed July 22, 2014.

WebMD. *Fitness and Exercise: Heat Exhaustion.* Accessed October 21, 2014.

EARTHQUAKES

Ascher, Kate. *The Heights: Anatomy of a Skyscraper.* Penguin Press, New York 2011.

"Earthquakes: Updating information about U.S. regional earthquake hazards." *Homeland Security News Wire,* July 22, 2014.

Entergy Corporation. "Indian Point Considers Seismic Safety." Accessed April 8, 2011.

* Eschenasy, D. "Cases of Failure of Unreinforced Brick Walls Due to Out-Of-Plane Loads." *Structural Magazine,* May 1, 2011.

Fahey, M. "Don't Forget About Earthquakes, Feds Tell City." Crain's New York Business, July 18, 2014.

FEMA, *HAZUS MH Estimated Annualized Earthquake Losses for the Unites States FEMA 366b.* Washington, D.C.: FEMA, 2008.

* FEMA P-750. *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures.* 2009.

* FEMA P-774. *Unreinforced Masonry Buildings and Earthquakes: Developing Successful Risk Reduction Programs.* October 2009.

Khinda, Jagtar S and Feng-Bao Lin. Seismic Isolation of Bridges in New York City. Proceedings, *Building an International Community of Structural Engineers.* Chicago, Illinois: April 15-18, 1996.

Khinda, Jagtar S. New York City's new Seismic Design Criteria Guidelines for the new Millennium and an Update on the Seismic Retrofit of New York City Bridges. Proceedings, *International Bridge Conference*, Pittsburgh, PA: June 14-16, 1999.

Lamont-Doherty Earth Observatory of Columbia University. *Largest Earthquakes Near New York City*. Accessed December 23, 2013.

Murphy, D.E. "Quake Leaves New York Slightly Stirred, but Not Shaken Up." *The New York Times*, January 18, 2001. Accessed July 30, 2014.

National Earthquake Hazards Reduction Program. *Effect of Soil and Rock Types.* Accessed October 21, 2014.

New York City Department of Transportation. *2012 Bridges and Tunnels Annual Condition Report*. New York: New York City Department of Transportation, 2012.

* Nikolaou, S. et al. "Geo-Seismic Design in the Eastern United States: State of Practice." American Society of Civil Engineers (ASCE) Library. 2012.

* Nikolaou, S. "Local Geology of New York City and Its Effect on Seismic Ground Motions." Proceedings: Fifth International Conference on Case Histories in Geotechnical Engineering. New York, New York, April 13-17, 2004.

Nikolaou, S. "We had an Earthquake in Virginia – Now what?" *Structure Magazine*, March 1, 2013, 12-15.

Post, N. M. "Latin America's Tallest Sports Super-Efficient Damper-Studded Diamonds." *Engineering News Record*, 250: 34-38, 2003.

Sykes, L.R. et al. "Observations and Tectonic Setting of Historic and Instrumentally Located Earthquakes in Greater New York City-Philadelphia Area." *Bulletin of the Seismological Society of America*, 98: 1696-1719, 2008.

Tantala, M., et al. *Earthquake Risks and Mitigation in the New York, New Jersey, Connecticut Region*, The New York City Area Consortium for Earthquake Loss Mitigation (NYCEM), Buffalo: University at Buffalo Multidisciplinary Center for Earthquake Engineering Research, 2003.

* U.S. Geological Survey. *Documentation for the 2014 Update of the United States National Seismic Hazard Maps.* Reston, Virginia: 2014.

U.S. Geological Survey. *Historic World Earthquakes.* Accessed March 6, 2013.

Weidlinger Associates. *New York City Seismic Hazard Study And Its Engineering Applications: Final Report.* New York: Weidlinger Associates Prepared for the NYC Department of Transportation, 1998.

PANDEMIC INFLUENZA:

* Aimone, F. "The 1918 Influenza Epidemic in New York City: A review of the Public Health Response." *Public Health Reports*, 125(2010): 71-79.

* Blumenshine, P., et al. "Pandemic Influenza planning in the United States from a Health Disparities Perspective." *Emerging Infectious Diseases*, 14(2008): 709-715.

CDC. *Plague.* Last updated November 28, 2012.

CDC. *About Coronavirus.* Last updated June 5, 2014.

CDC. *Division of Vector-Borne Disease (DVBD).* Last updated August 26, 2014.

"City Reports 10% Hit by Asian Flu." *The New York Times,* January 2, 1958.

Eng-Wong, Taub & Associates. *Recommended Social Distancing Strategies for Public Transportation and Impact Analysis.* New York: Eng-Wong Taub & Associates, 2008.

Hatchett, Richard J. *"Public health interventions and epidemic intensity during the 1918 influenza pandemic."* Proceedings of the National Academy of Sciences (PNAS) volume 104, no. 18: May 1, 2007.

Henderson, D.A., et al. "Public Health and Medical Responses to the 1957-58 Influenza Pandemic." *Biosecurity and Bioterrorism*, 7(2009): 265-273.

NYC Department of Health and Mental Hygiene. *Protecting Public Health in New York City: 200 Years of Leadership 1805-2005.* New York: New York City Department of Health and Mental Hygiene, 2005.

* NYC Department of Health and Mental Hygiene. *Pandemic Influenza Preparedness and Response Plan.* New York: New York City Department of Health and Mental Hygiene, 2006.

NYC Department of Health and Mental Hygiene. *New York City Agency Influenza Health and Safety Plan for Non-Medical Personnel.* New York: New York City Department of Health, 2009.

* NYC Department of Health and Mental Hygiene. *A Measure to Characterize the Spatial Distribution of Those Most At-Risk During an Influenza Pandemic in New York City Combined Metropolitan Statistical Area.* New York: New York City Department of Health and Mental Hygiene, Office of Emergency Preparedness and Response for the NY-NJ Regional Catastrophic Planning Team, 2013.

* NYC Emergency Management. *H1N1 Influenza Playbook.* New York: Office of Emergency Management, 2010.

Regional Catastrophic Planning Team. *Catastrophic Hazard Analysis.* New York: Regional Catastrophic Planning Team, 2011.

U.S. Department of Health and Human Services. *Pandemic Flu History.* Accessed October 12, 2013.

World Lung Foundation. *Influenza.* Accessed August 4, 2014.

The World Health Organization. *Pandemic Influenza Risk Management: WHO Interim Guidance.* June 10, 2013.

WATER SHORTAGE:

Ascher, Kate. *The Works: Anatomy of a City.* Penguin Books, New York 2005.

Alliance for Water Efficiency. *Manufacturing Introduction.* Accessed August 4, 2014.

Centers for Disease Control and Prevention, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Agency, and American Water Works Association. *When Every Drop Counts: protecting public health during drought conditions – a guide for public health professionals.* U.S. Department of Health and Human Services, Atlanta 2010.

Geology.com. *Expansive Soils and Expansive Clays.* Accessed September 25, 2013.

Gittleman, M., et al. *Community Garden Survey New York City Results 2009/2010.* New York: GrowNYC and Green Thumb, Department of Parks & Recreation, 2010.

Gutis, Philip S. "New York Facing Major Water Shortage." *The New York Times*, March 16, 1989.

Kalis, M.A., et al. "Public Health and Drought." *Journal of Environmental Health* 72 (2009): 10-11.

National Climatic Data Center. *U.S. Drought Indicators*. Last updated April 12, 2012.

National Weather Service. *Drought: Public Fact Sheet.* Accessed November 27, 2013.

New York City Council. *Food Works: A Vision to Improve NYC's Food System.* New York: New York City Council, 2013.

NYC Department of Environmental Protection. *Drought Management and Contingency Plan.* New York: New York City Department of Environmental Protection, 2012.

* NYC Department of Environmental Protection. *Water Demand Management Plan.* New York: New York City Department of Environmental Protection, 2012.

NYC Department of Environmental Protection. *New York City 2013 Drinking Water Supply and Quality Report.* New York: New York City Department of Environmental Protection, 2013.

NYC Department of Environmental Protection, *History of Drought and Water Consumption.* October 21, 2014.

NYC Office of Long Term Planning and Sustainability. *New York City Wetlands Strategy*. New York: New York City Office of Long Term Planning and Sustainability, 2012.

Revkin, A.C. *Extended Drought Strains Resources Along East Coast. The New York Times,* April 21, 2002.

* Seager, Richard et al. *The 1960s Drought and Subsequent Pluvial In New York City's Catskill Mountains Watershed.* Lamont-Doherty Earth Institute of Columbia University. October 1, 2012.

Urban Green Council. *NYC Green Codes Task Force: Full Proposals.* New York: Urban Green Council, 2010.

STRONG WINDSTORMS:

Ascher, Kate. *The Heights: Anatomy of a Skyscraper.* Penguin Press, New York 2011.

Enten, H.J. "How Climate Change May Reshape Tornado Season." *Atlantic Monthly,* May 21, 2013.

FEMA. *Declared Disaster by Year or State*. Accessed August 8, 2013.

FEMA. *Disaster Assistance for Queens and Brooklyn Tops More than $7.2 Million, Wind Zones in the United States*, and *Tornado.* Accessed August 2014.

* National Institute of Building Sciences. *Wind Safety of the Building Envelope.* Last updated June 18, 2010.

The National Oceanic and Atmospheric Administration. *Windstorm*. Accessed October 29, 2013.

The National Oceanic and Atmospheric Administration. *New York Tornadoes (1950-2012).* Accessed October 21, 2014.

The National Oceanic and Atmospheric Administration. *Tri-State Tornado Climatology 1950-2013.* Accessed October 21, 2014.

National Severe Storms Laboratory. *Severe Weather 101: Tornado Basics*. Accessed October 21, 2014.

National Severe Storms Laboratory. *Research at NSSL.* Accessed October 21, 2014.

National Weather Service. *Thunderstorms, Tornadoes, Lightning…Nature's Most Violent Storms.* Accessed October 21, 2014.

Texas Tech University National Wind Institute. *Protection from Extreme Wind.* Accessed October 14, 2012.

* Urban Green Council. "Task Force Proposal 11: Prevent Wind Damage to Existing Buildings." in *NYC Green Codes Task Force: Full Proposals*. New York: Urban Green Council, 2013.

* Urban Green Council. "Task Force Proposal 12: Analyze Wind Risks." in *NYC Green Codes Task Force: Full Proposals*. New York: Urban Green Council, 2013.

WINTER WEATHER:

Armstrong, L. "106,000 Potholes Already Filled This Year as Winter Leaves a Rough Ride." DNAinfo.com, February 20, 2014.

Current Results Nexus. *Average Annual Snowfall in New York.* Accessed August 4, 2014.

FEMA. *Disaster Information, Winter Storms and Extreme Cold.* Accessed January 8, 2014.

Grynbaum, M.M. "December Blizzard Will Cost Over $68 Million." *The New York Times,* January 24, 2011. Accessed August 4, 2014.

Hevesi, A.G. *The Winter's Tale: The Fiscal and Economic Impact of the Deep Freeze 1993-1994.* New York: City of New York Office of the Comptroller and Office of Policy Management, 1994.

Kuhne, M. "One of the Coldest Winters in 20 Years Shatters Snow Records." Accuweather.com, March 26, 2014.

National Climatic Data Center. *Northeast Snowfall Impact Scale.* Accessed September 30, 2013.

The National Oceanic and Atmospheric Administration. *Weather Extremes: Central Park, New York 1869 to Present.* Last updated January 6, 2012.

The National Oceanic and Atmospheric Administration National Severe Storms Laboratory. *Severe Weather 101: Frequently Asked Questions about Winter Weather.* Accessed November 29, 2013.

NYC Department of Buildings. *Newsflash.* January 2005.

NYC Department of Transportation. "The Daily Pothole." Accessed August 4, 2014.

Robbins, L. and Healy, J. "Many Without Power as Storm Pounds Northeast." *The New York Times,* February 26, 2010. Accessed August 4, 2014.

Roseen, R.M., et al. "Water Quality and Hydrologic Performance of Porous Asphalt Pavement as a Storm-Water Treatment Strategy in a Cold Climate." *Journal of Environmental Engineering*, 138(2011): 81-89.

U.S. Bureau of Labor Statistics. *CPI Inflation Calculator.* Accessed August 26, 2008.

Weather 2000. *Historical Snowstorms Impacting New York City.* Last updated November 8, 2011.

MULTI-HAZARDS:

* National Climatic Data Center. *Storm Events Database.* Accessed October 21, 2014.

National Weather Service, *National Weather Service Glossary*. Accessed August 15, 2014.

* NYC Department of Buildings. *Preparing Sites for Extreme Weather – For Industry Professionals.* Accessed August 6, 2014.

NYC Department of City Planning. *The Waterfront Revitalization Program.* October 30, 2013.

* NYC Department of City Planning. *Urban Waterfront Adaptive Strategies.* June 2013.

NYC Department of City Planning. *Vision 2020: New York City Comprehensive Waterfront Plan.* March 14, 2011.

NYC Department of City Planning. *MapPLUTO 13V1.* 2013.

NYC Department of Health and Mental Hygiene. *Data and Statistics*. Accessed August 15, 2014.

NYC Mayor's Office of Long-Term Planning and Sustainability. *PlaNYC: A Greener, Greater New York*. Accessed July 30, 2014.

NYC Parks and Recreation. *Parks*. Accessed July 2014.

* NYC Special Initiative for Rebuilding and Resiliency. *A Stronger, More Resilient New York*. New York: The City of New York, 2013.

New York State Division of Homeland Security and Emergency Services. *2014 New York State Hazard Mitigation Plan.* January 2014.

* Rosenzweig, C. and Solecki, W., eds. *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps*. New York: New York City Panel on Climate Change, 2013.

* Urban Green Council. *Baby It's Cold Inside.* February 2014.

* Urban Green Council. *Building Resiliency Task Force.* June 2013.

PHOTO CREDITS

Chapter 2:

Page 6 (top to bottom): NYC Skyline/E Palen, Coastal Storms, Coastal Erosion, Flooding, Strong Windstorms, Extreme Heat, Winter Weather are stock images, Earthquakes and Pan Flu/ Samantha Celera

Chapter 4:

Page 44 (top to bottom) Iwan Baan/New York Magazine, 9/11 (unknown), Natural Resources Canada, New York Architecture, Cornell (Kheel Center), NYC DOMH, and New York Public Library Digital gallery.

Chapter 4.1 (Coastal Storms):

Page 46, Hurricane Isabel/Image taken from International Space Station; page 49, Sandy West St underpass flooding/MTA

Chapter 4.2 (Coastal Erosion):

Page 58, Storm Damage-Jones Beach/DEC; page 60, USACE/ Brooklyn Daily; page 62, NYC OEM/NYC DoITT, page 63 – NYC DCP, page 65 – NYC DCP, Page 66 Beach Nourishment/USACE

Chapter 4.3 (Flooding):

Page 68, stock image, page 71, Stuyvesant Cove flooding from East River surge/Marianne O'Leary; page 85, NYC DCP; page 85, NYC DCP

Chapter 4.4 (Strong Windstorms)

Page 86, stock image; page 96, stock image, Page 97, Adam Gimpert

Chapter 4.5 (Extreme Heat)

Page 98, stock image; Page 107, NYC DOB (pending)

Chapter 4.6 (Winter Weather)

Page 111, stock image

Chapter 4.7 (Water Shortages)

Page 124, NYS DEC; page 128-129, NYC DEP

Chapter 4.8 (Earthquakes)

Page 136, CIR Online, page 138 Rodrigo Hernandez; page 140 Mueser Rutledge Consulting Engineers

Chapter 4.9 (Pandemic Influenza)

Page 152, stock image

Page 156, Work Session NYC DCP

Acronyms in *NYC's Risk Landscape*...

ACS American Community Survey **ASCE** American Society Civil Engineers **AQI** Air Quality Index **BFE** Base Flood Elevation **CD** Community Districts **CDC** Centers for Disease Control **CEHA** Coastal Erosion Hazard Area **CEQR** City Environmental Quality Review **CERT** Community Emergency Response Team **CSO** Combined Sewer Overflow **CUNY** City University of New York **DCP** New York City Department of City Planning **DEP** New York City Department of Environmental Protection **DHS** New York City Department of Homeless Services **DOB** New York City Department of Buildings **DOF** Department of Finance **DOHMH** New York City Department of Health and Mental Hygiene **DOITT** New York City Department of Information Technology and Telecommunications **EF-Scale** Enhanced Fujita Scale **EPA** United States Environmental Protection Agency **FDNY** New York City Fire Department **FEMA** United States Federal Emergency Management Agency **FIRM** Flood Insurance Rate Map **F-Scale** Fujita Scale **ft** Feet **FHWA** Federal Highway Administration **GIS** Geographic Information Systems **HAZUS-MH** Hazards U.S. Multi-Hazard **ICC** International Code Council **JFK** John Fitzgerald Kennedy Airport **LGA** LaGuardia Airport **MapPLUTO** Property Land Use Tax Lot Output **MERS-CoV** Middle Eastern Respiratory Syndrome Coronavirus **MOM** Maximum of MEOWs **mph** Miles Per Hour **MTA** Metropolitan Transportation Authority **NEHRP** National Earthquake Hazards Reduction Program **NESIS** Northeast Snowfall Impact Scale **NFIP** National Flood Insurance Program **NHC** National Hurricane Center **NOAA** United States National Oceanic and Atmospheric Administration **NPCC** New York City Panel on Climate Change **NWS** National Weather Service **NYC** New York City **NYCEM** NYC Area Consortium for Earthquake Loss Mitigation **NYCHA** New York City Housing Authority **NYS** New York State **NYSDEC** New York State Department of Environmental Conservation **NYS DHSES** New York State Division of Homeland Security and Emergency Services**NYSGS** New York State Geological Survey **OLTPS** New York City Office of Long-Term Planning and Sustainability **ORR** Office of Recovery and Resiliency **PATH** Port Authority Trans-Hudson **PlaNYC** PlaNYC: A Greener, Greater New York **PSEG** Public Service Electric and Gas Company **SFHA** Special Flood Hazard Area **SLOSH** Sea, Lake, and Overland Surges from Hurricanes Model **USACE** United States Army Corps of Engineers **USGS** United States Geological Survey

Thank you

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Many thanks to our Mitigation Planning Council members who provided the foundation for developing this Guide and continue to be partners and leaders in reducing New York City's risk.

City University of New York, NYC Department of Citywide Administrative Services, NYC Department of Design and Construction, NYC Department for the Aging, NYC Department of Homeless Services, NYC Parks and Recreation, NYC Department of Correction, NYC Department of Information Technology and Telecommunications, NYC Economic Development Corporation, NYC Fire Department, NYC Health and Hospitals Corporation, NYC Department of Housing Preservation & Development, NYC Human Resources Administration, NYC Build It Back, NYC Landmarks Preservation Commission, Metropolitan Transit Authority, NYC Housing Authority, NYC Police Department, NYC Office of the Chief Medical Examiner, Public Service Electric & Gas Company, Office of Management and Budget, The Port Authority of NY & NJ, Regional Planning Association, and NYC Small Business Services.

This project was supported by a grant administered by the New York State Division of Homeland Security and Emergency Services and the U.S. Department of Homeland Security. Points of view in this document are those of the author and do not necessarily represent the official position of policies of the the New York State Division of Homeland Security and Emergency Services or the U.S. Department of Homeland Security.

NYC Hazard Mitigation