





# 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.



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.

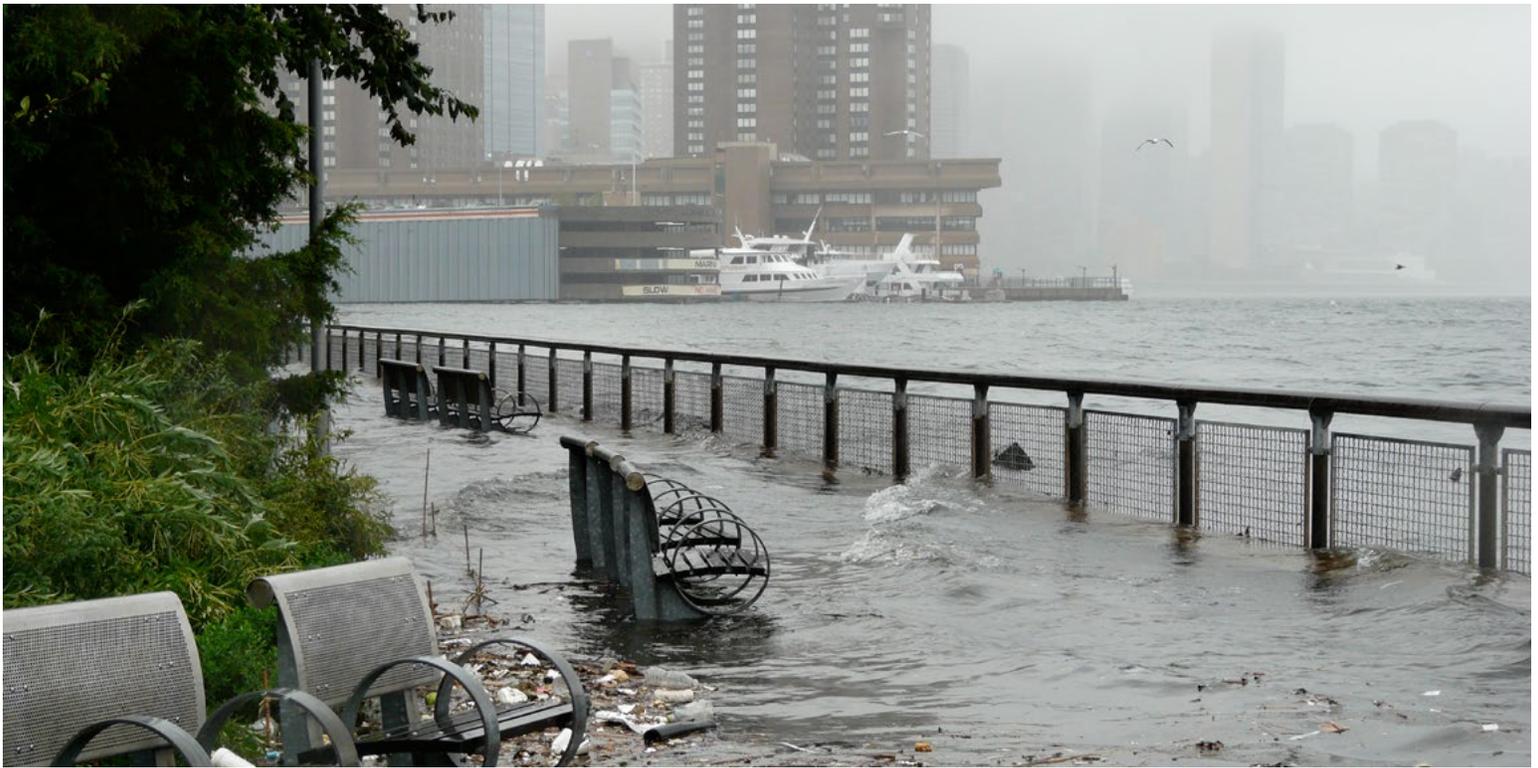
**Riverine flooding**

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

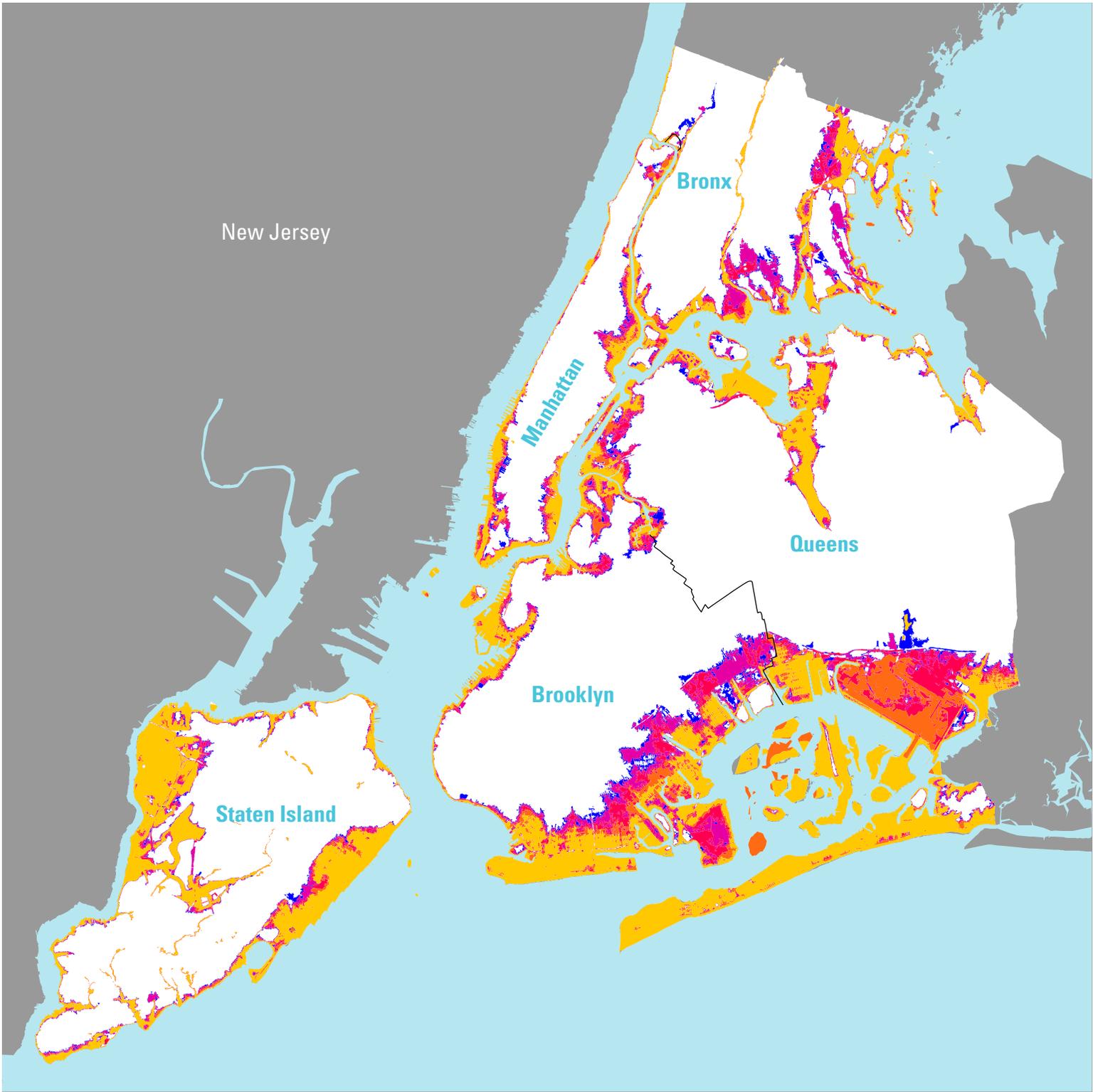
To understand our flood risk, we need to understand the likelihood of flood events, the extent of our exposure, and the potential impact of each flood type.

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



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.

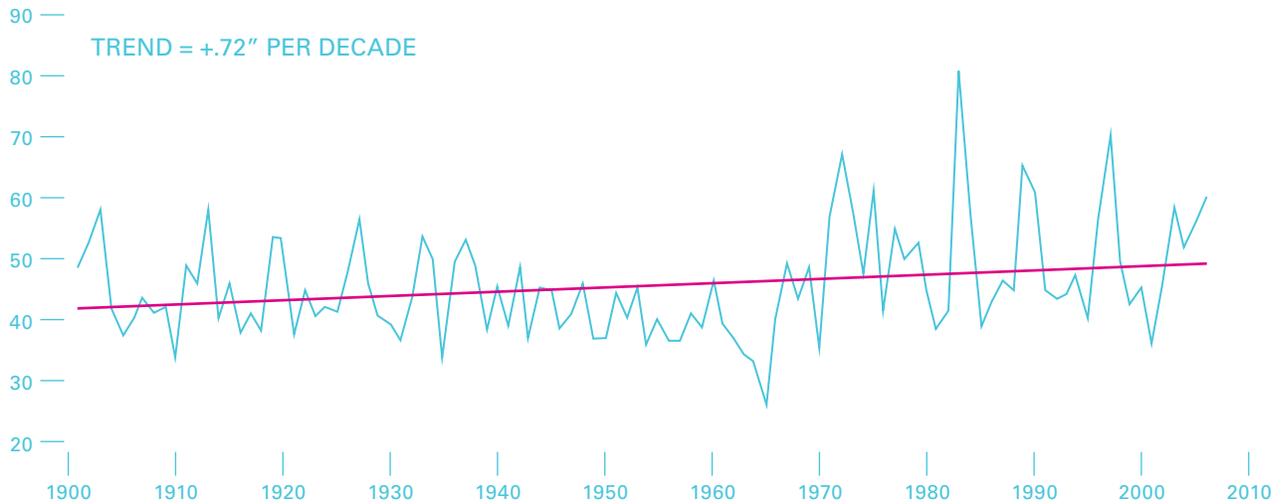
Another complicating factor is the City's sewer system, much of which collects and conveys runoff from rainstorms and snowmelt in the same sewer lines that carry wastewater from buildings and industrial facilities. The system was designed to meet an engineering assumption about rainfall intensity for 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*

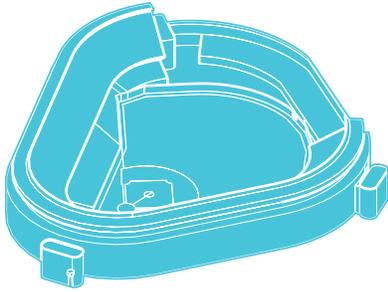
Parts of our critical infrastructure are vulnerable to flooding.

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 |
|----------------------------|-------------|
| <b>Residents</b>           | 400,000     |
| <b>Buildings</b>           | 71,500      |
| <b>1-4 Family</b>          | 57,400      |
| <b>Floor Area (Sq Ft.)</b> | 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 Affordability 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-resilient buildings by removing disincentives or restrictions to meeting or exceeding 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 of 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.

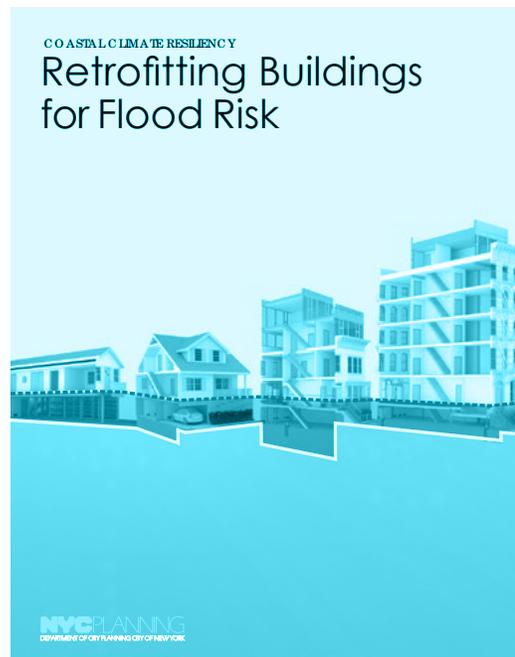
"Green infrastructure" expands the water infiltration and storage properties of urban drainage systems. It can help reduce sewer overflow and in some instances it may help minimize flooding. By enhancing vegetation in densely developed areas and on rooftops, it can also lower the amount of energy needed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

## 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.

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,

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 damaged 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 park's 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.