RECORD RAIN IN NYC

THE IMPACTS OF POST-TROPICAL CYCLONE IDA

DAMAGE ANALYSIS REPORT

NYC Emergency Management

September 2024

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Purpose

NYC Emergency Management (NYCEM) plans and prepares for emergencies, educates the public about preparedness, coordinates emergency response and recovery, and collects and disseminates emergency information. In addition, the Risk Analysis and Recovery Unit advances the city's mitigation and recovery capabilities by developing tools that enhance all-hazards risk awareness and connect to risk-reduction projects. The unit is responsible for developing and updating the city's Hazard Mitigation Plan, which identifies natural hazards (e.g., flooding, coastal storms, extreme heat) that pose a risk to the city and actions the City is taking to reduce the impacts of emergency events. Additionally, the unit develops tools to enhance our understanding of risk, including the Hazard History & Consequence tool, which looks at the impacts of past hazard events, and the Community Risk Assessment dashboard, which provides a neighborhood assessment of hazards. This report is the culmination of storm impact analyses conducted following Post-Tropical Cyclone Ida (PTC Ida). The Risk Analysis and Recovery Unit aims to use this analysis to better understand the City's risk to inland flooding to inform mitigation investments and recovery capabilities and better protect New Yorkers from future flood events.

Post-Tropical Cyclone Ida (PTC Ida) posed a new challenge for the City's response: unlike past coastal storms like Hurricane Sandy, a great majority of the most severe flooding occurred in inland neighborhoods inside of private buildings and homes, publicly undetectable from street or aerial survey. To understand the extent of these impacts, city agencies had to identify damage in new ways, relying heavily on data reported by the public and other indicators. As more data became available in the days, weeks, and months following PTC Ida, NYCEM and its partner agencies combined, processed, and analyzed the data thoroughly to discover new findings which helped inform emergency operations and recovery programs, and helped to bring several forms of federal aid to the city.

These storm impact analyses are living documents; as new data becomes available, NYCEM works to integrate these updates to continuously enhance our understanding of flooding in New York City and bolster the city's preparedness against future severe weather. This report has seen several iterations with new analyses that have helped bolster recovery efforts and the City's understanding of flash flooding impacts in time for each annual coastal storm and flash flood season. Some of the most influential datasets on the impacts of PTC Ida took several months and, in some cases, years, to obtain and analyze. The findings have been used by the City to inform potentially lifesaving operations in storms since PTC Ida. NYCEM is now pleased to share these findings with the public to facilitate further learning and resilience efforts to better protect New Yorkers from future flooding events.

Executive Summary

In the summer of 2021, New York City experienced two 100-year rain events followed by Post-Tropical Cyclone Ida (PTC Ida), a 1000-year storm. The rain intensity and resulting inland flooding from PTC Ida were unprecedented. As climate change brings sea level rise, greater coastal storm activity, and extreme rainfall frequency, PTC Ida provides an example of New York City's changing risk landscape for flooding.

The Ida Damage Analysis Report provides a comprehensive view of flood impact. It quantifies damage and aims to add to the growing knowledge base of stormwater flooding in New York City, ultimately supporting hazard mitigation and resiliency efforts of New York City Emergency Management (NYCEM) and its partners. By combining disparate data, the report shows where and what was damaged. Additionally, the analysis presents findings to inform future analysis and study.

Key Findings

- **Data collected by the City alone underestimates the scale of impact.** Approximately 65% of PTC Ida damage was identified exclusively through federal data from FEMA Individual Assistance and Public Assistance programs and the National Flood Insurance Program. This means that for future events, it's imperative for City, State, and Federal partners to work closely together to share data in order to get a comprehensive look at storm impacts.

- **Extensive impact outside of modelled flood risk areas.** Over half of impacted buildings were outside of any mapped flood risk scenarios. Only ~43% of impacted buildings were located within the NYC Extreme Stormwater Flood Scenario. This emphasizes the severity of PTC Ida, which arrived in the city as a 1000-year storm shortly after two 100-year rainfall events, while the Extreme Stormwater Flood Scenario maps models a single 100 year storm. The extensive flooding documented outside of the mapped stormwater flood risk areas demonstrates the need for more comprehensive mapping of stormwater flood risk to private property in the city, including a range of possible storm sequences, durations, and intensities.

- **Over half of impacted buildings had subgrade spaces or basement apartments, primarily in Brooklyn and Queens.** Utilizing data on subgrade spaces in New York City's building stock, it is estimated that 56% of buildings with recorded impacts from PTC Ida also have some type of subgrade space, especially in Brooklyn and Queens, where it's more prevalent.

POST-TROPICAL CYCLONE IDA FACTS

Precipitation

1000-year storm recurrence interval

3.46 inches/hour maximum rainfall rate measured at the Western Bronx weather station

9.1 inches total rain accumulation recorded at the Southwest Staten Island weather station

Damage

~33,500 buildings with indicators of storm damage, including 400 City-owned buildings

3.3% of New York City residential buildings impacted

52% of damage recorded outside FEMA floodplains and New York City stormwater scenarios

Communities

Queens sustained the most damage of any borough, with over 13,000 buildings impacted

Bronx Community District 10 had highest rate of damage, with ~9% of all buildings impacted

Residents & Resources

1 in 16 New Yorkers reside in buildings impacted by Ida

~24,700 buildings with households receiving insurance or federal disaster assistance funds, averaging 1.25 Individual Assistance awards per building

Introduction

POST-TROPICAL CYCLONE IDA

As Post-tropical Cyclone Ida (PTC Ida) moved from the Tennessee Valley to the Mid-Atlantic on September 1, 2021, it merged with a stationary front, producing widespread heavy rainfall in New York City. The extreme weather conditions prompted the National Weather Service to issue a first-ever catastrophic flash flood emergency for the five boroughs. Over 11 hours, the city accumulated more than nine inches of rain. Central Park recorded an all-time high of 3.15 inches of rain in one hour.[1] In some areas, localized rainfall rates measured 3.46 inches per hour (in/hr).[2]

The record-breaking rate of rain surpassed the capacity of stormwater infrastructure, contributing to widespread inland flooding. Tragically, 13 New Yorkers died in flash floods. Eleven of those deaths were caused by drowning due to basement apartment flooding between 12 a.m. – 3 a.m. on September 2, 2021. Reports of flood damage spanned all boroughs and all Community Districts, amounting to an estimated $900 million in repair and recovery costs.

PTC Ida was the third heavy rain event driven by coastal storms in New York City in two months. On July 8, Tropical Storm Elsa (TS Elsa) produced two periods of heavy rainfall with peak rainfall rates of 1.35 in/hr. Six weeks later, on August 21 and 22, Tropical Storm Henri (TS Henri) broke city hourly rainfall records with 1.94 in/hr measured in Central Park. While TS Elsa and TS Henri produced once in 100-year rainfall, PTC Ida's intensity and widespread coverage were unprecedented and detrimental.[3] Estimates for PTC Ida suggest it was a 1000-year storm, meaning a 0.1% chance in any given year.[4]

Coordinating emergency response and recovery operations relies heavily on data collection and analysis. New York City Emergency Management (NYCEM) provided data analytics services to responding agencies throughout the initial response and recovery phases of PTC Ida. Additionally, the team conducted a preliminary retrospective analysis to create a more detailed and comprehensive view of PTC Ida flood damage to residential properties. This report expands on the initial damage analysis utilizing additional data sources that NYCEM has worked to build and analyze since the event. This has facilitated broader inquiry to quantify damage and analyze risk factors associated with flood hazards in New York City.

CLIMATE AND EMERGENCY MANAGEMENT CONTEXT

Flooding is one of the most frequent natural disasters in the United States and a growing concern in New York.[5] Beyond vulnerabilities attributed to stormwater infrastructure and land cover, New York City faces an increasing risk of inland flooding from climate change and extreme weather events.

The New York City Panel on Climate Change (NPCC) anticipates the increased frequency of heavy rain events will spur more frequent inland flooding and wider flooding from higher flood peaks caused by increased event rainwater volume. By the 2050s, New Yorkers could experience as much as:

- Five days annually with hourly rainfall rates greater than two inches, up from a baseline of three days.
- 0.4 days annually of rainfall four inches per hour or greater, rain up from a baseline of 0.2 days.

“PlaNYC” and “Rainfall Ready NYC” document these risks, detailing City initiatives and actions to mitigate flood hazards from extreme rain. At the same time, climate experts acknowledge a need for more inland flooding data to develop precise inland flood risks further. Data on historical flood events and alternative flood measurement techniques are vital to advancing inland risk modeling and assessment.

REPORT OVERVIEW

This report reflects newly combined data on PTC Ida, which are critical in mitigating and preparing for inland flood risk in New York City. It quantifies the extent of flood damage and examines the impact by risk factors like physical infrastructure, financial resources, geography and environment, and demographic characteristics. These insights can inform ongoing emergency response and resiliency planning efforts across the City – from stormwater flood risk maps and land use planning to sensor deployment and resident outreach.

Approach and Methodology

While there is an abundance of information collected during and after emergency events, there is no standard definition of storm impact across the City and other responding agencies, nor is there a central data repository of damage. NYCEM's primary analytical goals were to unite disparate reports of PTC Ida storm damage to create a comprehensive and geographically precise record of impact. This record serves as a central base of knowledge for analysis and planning for NYCEM and other agency partners.

DATA SELECTION

NYCEM's Ida Damage Building Composite dataset draws on more than 20 data sources to provide over 140 fields for the ~1.1 million buildings in New York City. NYCEM created this citywide, building-level dataset by combining and standardizing multiple data sources, using an approach similar to one developed in the 2012 Hurricane Sandy recovery effort. This approach presents a unique count of buildings impacted by PTC Ida. For each building in New York City, the dataset provides information associated with the event, like localized rainfall accumulation, flood damage indicators, and disaster recovery aid received, as well as information on property and land use, topography, and neighborhood demographic characteristics.

Administrative datasets provided essential information on New York City land, building, and households. Key sources include:

- Building footprints from NYC Office of Technology and Innovation (OTI)
- MapPLUTO from NYC Department of City Planning (DCP)
- American Community Survey (ACS) from the US Census Bureau
- Social Vulnerability Index (SVI) from the US Centers for Disease Control and Prevention (CDC)

Defining Impact

Unlike coastal flooding, where damage is typically visible from aerial images or the street, damage from inland flooding may not be easily visible from the exterior. Without visual assessments, alternative approaches to identifying damage and estimating impacts are needed. NYCEM defined impact by considering various indicators of storm damage and utility disruption derived from data provided to the City by residents or emergency management partners during and after the flood. This data includes:

- Resident-reported damage: The City directed residents to report damage via the Severe Weather Damage Assessment Tool and 311 service requests. In addition, the Mayor's Public Engagement Unit collected damage reports through phone canvassing efforts.
- Verified damage and disruptions: Utility providers like Con Edison and National Grid reported outages directly to NYCEM. Federal insurance and disaster recovery programs require physical damage assessments in the claim and grant application process.

From this data, NYCEM created damage indicators that reflect the following conditions:

- Health and housing issues: post-storm building vacates, mold, plumbing disruptions, paint and plaster problems, floor and stair damage, repair requests, and debris removal requests
- Water and flooding issues: sewer and sewage complaints, and reports of water leaks
- Utility disruption: electric and gas outages
- Claims and awards: approved claims from the National Flood Insurance Program (NFIP), and grants from the Federal Emergency Management Agency (FEMA) Individual Assistance (IA) and Public Assistance (PA) programs

While resident-reported damage is not a verified source of damage, the analysis treats all indicators equally as a signal of damage.

See Appendix B: Data Sources and Appendix C: Indicator Details for a full list of data sources and indicator parameters.

ANALYSIS

NYCEM performed an analysis quantifying PTC Ida damage as it relates to physical infrastructure (building characteristics, use, and ownership), geography and environment (flood and stormwater risk), and demographic characteristics (social vulnerability, race and ethnicity, language spoken at home, and income). The analysis estimated that PTC Ida impacted 3.3% of all residential buildings in NYC, 3 times more buildings than initial City estimates shortly after the storm. Additionally, the analysis provided residential damage trends by borough, building size, type of damage, flood and stormwater scenarios, and subgrade space.

LIMITATIONS

Data Collection and Availability

Although the Ida Damage Building Composite dataset compiles an abundance of information, additional data could expand analysis and provide a deeper understanding of damage and hazard risk. While a high water study is now available from the United States Geological Survey, the lack of an available inundation model from the event at the time of this analysis limited the study of street-level conditions and increased reliance on weather station data. Improved data collection on flood depth and rate would heighten awareness of local conditions in an inland flood and inform stormwater modeling and resiliency planning. More widely deployed sensors are a promising measurement tool that could augment traditional methods like field observations of high water marks from seed or stain lines. The City is currently exploring ways to expand sensor coverage across the city.

With few exceptions, data regarding the financial cost of flood damages and repair at the building level are not widely available to NYCEM. Additionally, the citywide repair cost estimates do not provide insight into the total economic impact or revenue loss due to PTC Ida. Unmet needs assessments would also require more granular financial data, specifically federal disaster recovery grant and loan award amounts at the building or household level. Such data would also support an effort to estimate the severity of flood damage.

Data Bias

Since the mid-2010s, several researchers have documented differences in 311 reporting behaviors based on neighborhood income and resident demographics. These differences can lead to bias in data, which overestimates the conditions of some groups and underestimates others. In the context of PTC Ida, the real or perceived risk of reporting impact from PTC Ida may be more significant for New Yorkers who are undocumented or residents living in unauthorized housing units, leading to underreporting of damage.

However, the severity of the event may mitigate typical bias patterns in 311 data. More threatening life and safety issues result in more active use of 311 by residents of lower income or socioeconomic status neighborhoods than higher income residents, due in part to limited resources to solve the issues. Additionally, by design, the analysis included a range of indicators independent of resident action, further reducing reporting behavior bias in damage estimates.

Ida Weather Details

PTC Ida brought record hourly rainfall, producing a total of 9.1 inches of rain in approximately 11 hours. NYCEM estimates that 70% to 80% fell within the first two hours. Seventeen weather stations in the city and nearby New Jersey captured storm conditions across the boroughs. Sensors are associated with six locations in or near Staten Island; three locations in Brooklyn, Manhattan, and Queens each; and one in or near the Bronx.

The data show the intensity of the storm exceeded typical sewer capacity of 1.5 - 2 in/hr, with eight stations measuring hourly rainfall over 2 in/hr and an additional four stations above 1.5 in/hr. Peak hourly precipitation reached 3.46 in/hr, as recorded at the Western Bronx weather station. Similar rates were observed at the Mid Island Staten Island (3.12 in/hr) and Middle Village Queens (2.78 in/hr) stations, suggesting the wide extent of intense rainfall.

Without citywide flood sensors, rainfall rate and totals are the best approximation for the speed and severity of the flash flooding. While total rainfall varied around the city, the sharp rise of the accumulation slope is consistent across most weather stations. Weather stations in areas vulnerable to coastal flooding like JFK, and LaGuardia, recorded the lowest event rainfall totals and maximum hourly precipitation rates (less than 0.8 inches), which may reinforce the inland nature of the event.

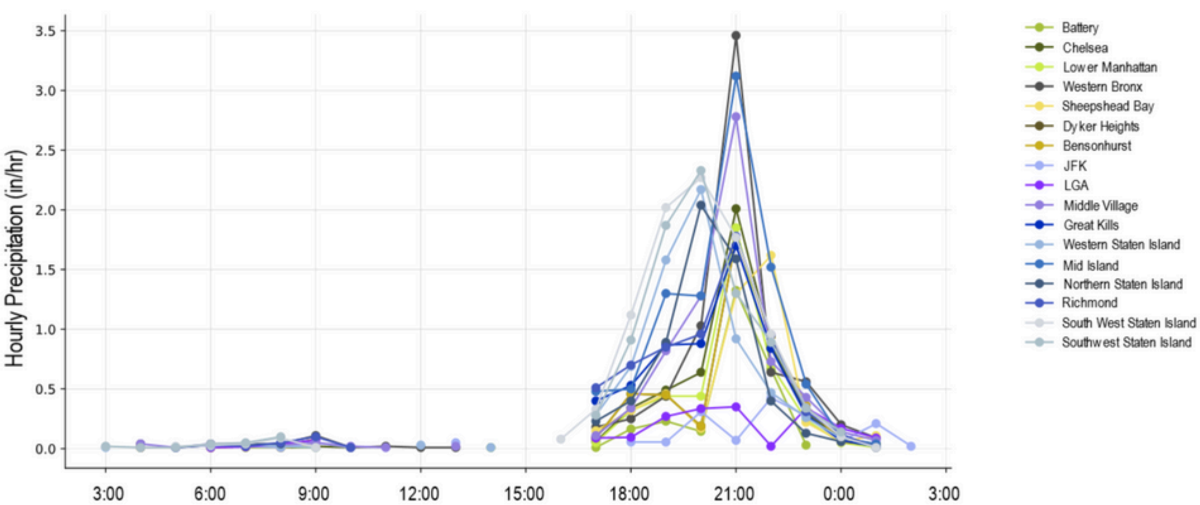


Figure 1: Precipitation Rates By Weather Station
Source: National Oceanic and Atmospheric Administration (NOAA) Meteorological Assimilation Data Ingest System (MADIS) via NYCEM

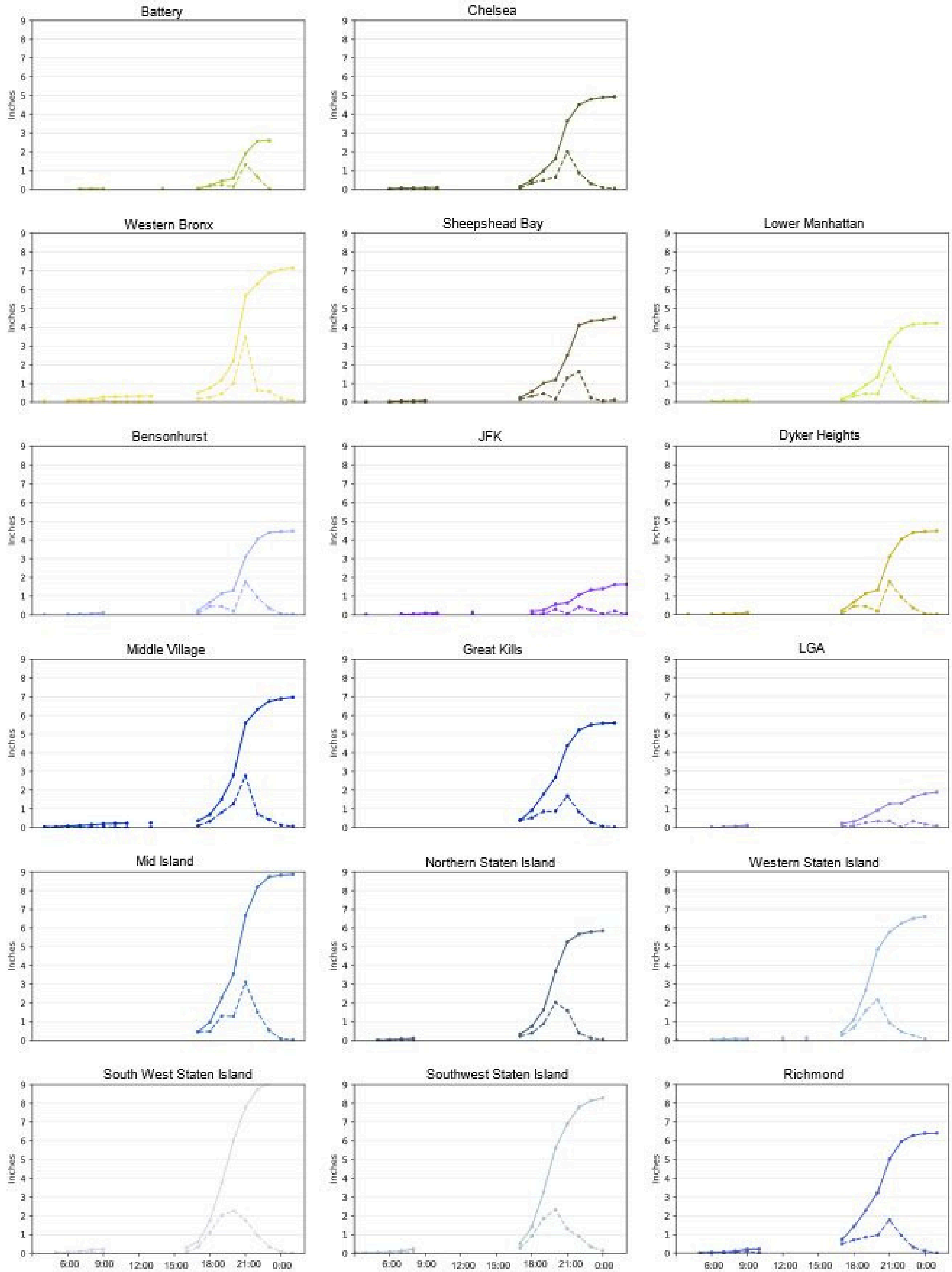


Figure 2: Precipitation Rates and Total Rainfall By Weather Station
Source: National Oceanic and Atmospheric Administration (NOAA) Meteorological Assimilation Data Ingest System (MADIS) via NYCEM

Extent of Damage

CITYWIDE AND COMMUNITY TRENDS

Impact from PTC Ida extends across the five boroughs. An estimated ~33,500 New York City buildings sustained damage from PTC Ida, equivalent to 3.1% of all buildings in the city. Two-thirds of the damage occurred in Queens (~40%) and Brooklyn (~27%) combined, followed by the Bronx (~19%), Staten Island (~13%), and Manhattan (~2%).

While Queens was the hardest hit borough, community-level data shows a more nuanced picture of the impact across the city. Twenty percent of damage in the city occurred in only three communities:

- **Queens Community District 7**: Flushing - Murray Hill - Whitestone
- **Staten Island Community District 1**: North Shore
- **Bronx Community District 10**: Co-op City – Throgs Neck.

Figure 5 illustrates impact by Community District Tabulation Areas (CDTA), showing the communities with the highest counts of buildings with damage. This includes large sections of northern and eastern Queens (QN3: Jackson Heights - East Elmhurst, QN7: Flushing - Murray Hill - Whitestone, QN8: Fresh Meadows - Hillcrest - Briarwood, QN11: Auburndale - Bayside - Douglaston), as well as Central Queens (QN5: Middle Village - Ridgewood - Maspeth), northeastern Bronx (BX10: Coop City - Throgs Neck, and QN 12: Wakefield - Williamsbridge -Eastchester), the North Shore of Staten Island (SI1 - North Shore), and the Canarsie - Flatlands section of Brooklyn (BK18).

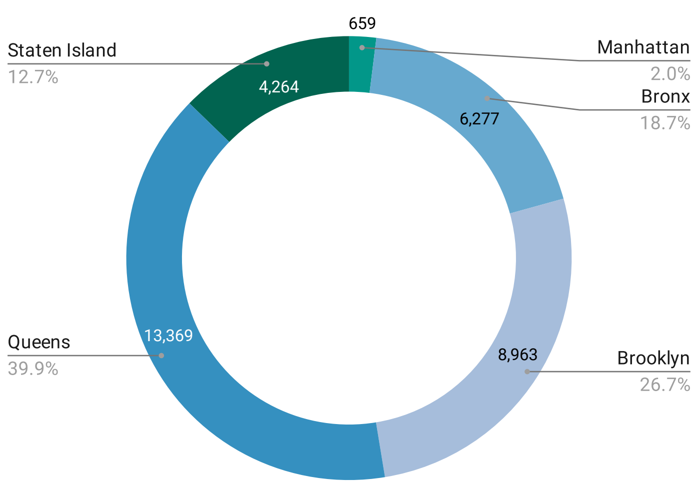


Figure 3: Distribution of Building Damage
Source: NYCEM

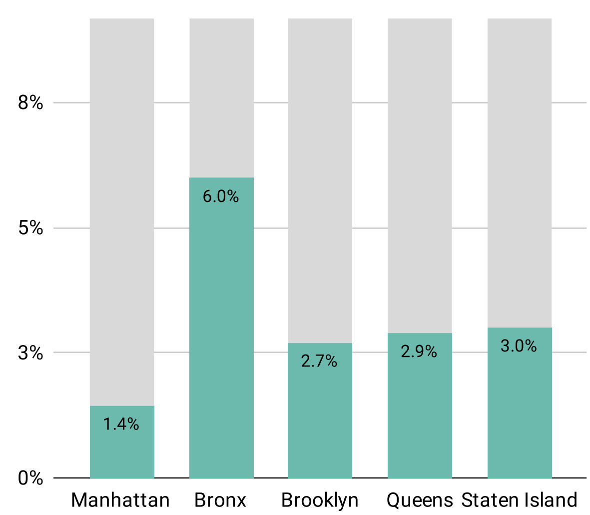


Figure 4: Rate of Building Damaged
Source: NYCEM

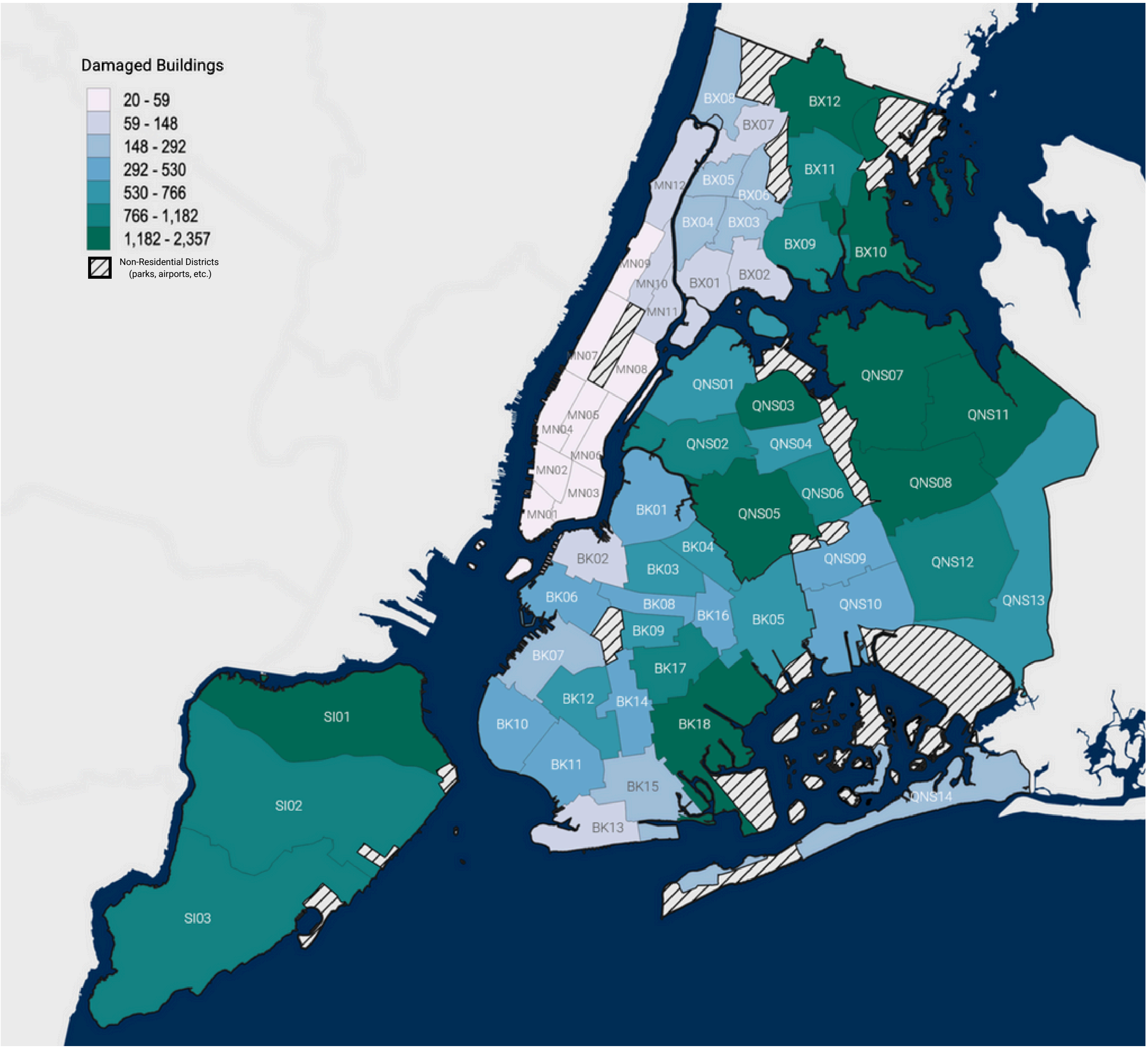


Figure 5: Impacted Buildings by Community District Tabulation Area
Source: NYCEM

The map of the Bronx reveals a stark difference in impact across communities in the borough, where community districts east of the Bronx River experienced some of the highest amounts of damage per CDTA in the city, and communities west of the Bronx River had low levels of damage.

Notably, the rate of damage is highest in the Bronx, with 6% of all Bronx buildings sustaining damage, double the rate of other boroughs. In the most extreme case, 9% of buildings in Bronx Community District 10: Coop City - Throgs Neck reported damage by PTC Ida.

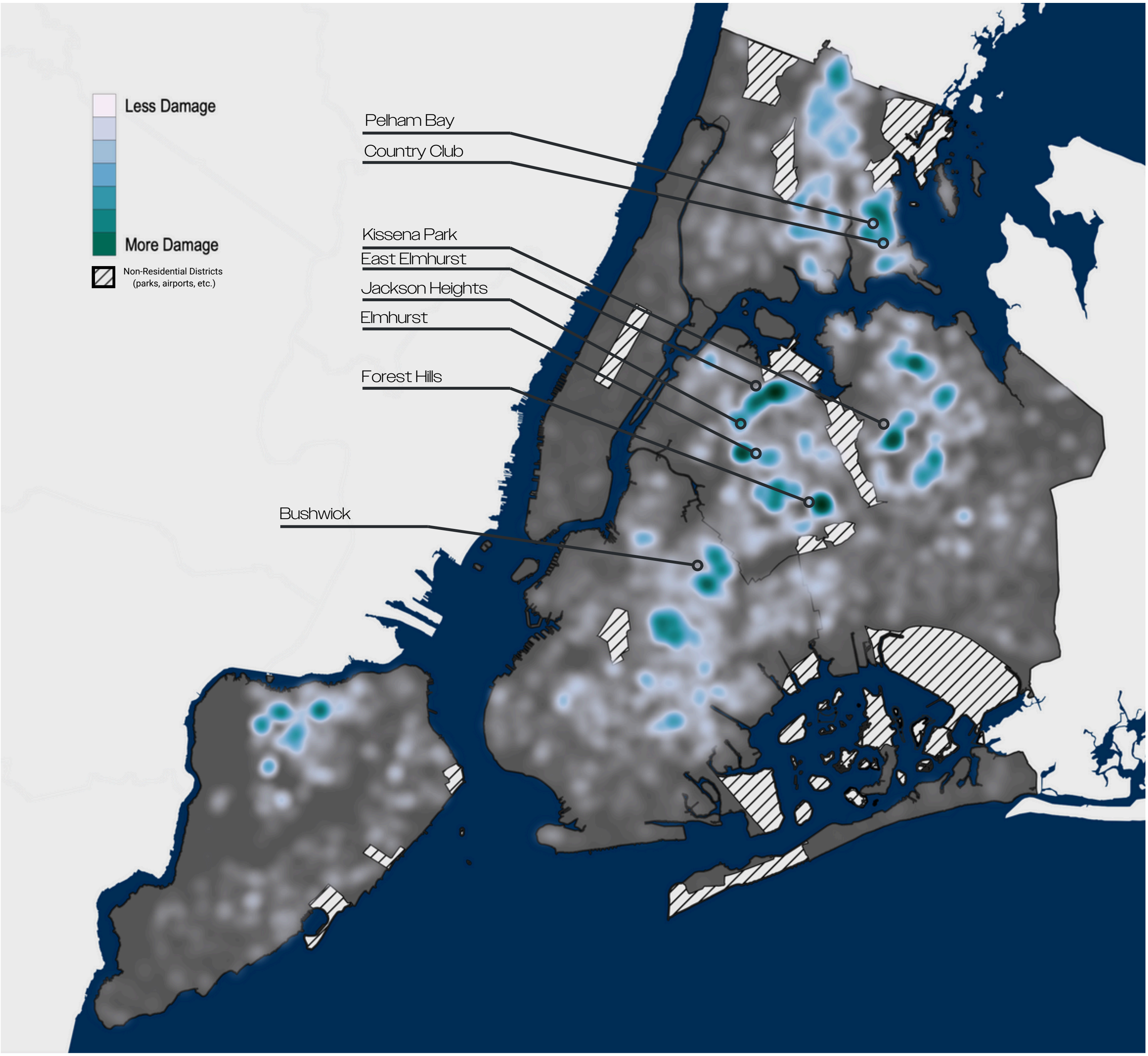


Figure 6: Cluster Map of Impacted Buildings
Source: NYCEM

Figure 6 further highlights the spatial clustering of damaged buildings across New York City neighborhoods, underscoring the localized character of inland flooding. The heaviest concentrations of damage appear in Queens: East Elmhurst, Jackson Heights, Kissena Park, Forest Hills, and Elmhurst. Clusters are also in Bushwick in Brooklyn and sections of Pelham Bay and Country Club in the Bronx.

TYPES OF DAMAGE

Indicator Trends

The analysis considered a wide range of damage indicators, reflecting the nature of flood impact and the compensation of damage. Indicators follow the following categories and unique building counts:

- Health and housing issues: 6,036
- Water and flooding reports: 6,177
- Utility disruptions: 582
- Claims and awards: 25,032

(*For details on data selection and parameters, see Approach and Methodology and Appendix C: Indicator Details.*)

Indicators for health and housing issues and water and flooding reports are similar in total number and follow a similar spatial pattern (See Figure 7). Health and housing issues are relatively more dispersed within boroughs than water and flooding reports and show high concentrations in areas like Forest Hills - Rego Park in Queens and Bushwick and South Williamsburg in Brooklyn. Several water and flooding indicators appear concentrated in the Flatlands section of Brooklyn, while there are few health and housing issues indicators. These patterns may reflect the composition of the housing tenure, where owners are unlikely to report health or housing issues but may report flood damage and sewer issues.

Few utility disruptions occurred in general, though present in all boroughs. Small clusters of outages appear in the Starrett City development in Brooklyn, South Jamaica - St. Albans, and Kissena Park in Queens.

Three-quarters of all impacted buildings received an insurance payment or federal disaster recovery program award, reflecting the large number of buildings with households receiving FEMA IA Awards (~23,800). Overall, 2.3% of all New York City buildings received federal assistance through IA, PA, or NFIP due to Ida. Figure 8 provides additional detail on the distribution of claims and awards. With ~1,000 claims, only 3.2% of impacted buildings received NFIP payments. As expected, these buildings are generally located near the coastline, as only homeowners with federally-backed mortgages in the 100-year floodplain are required to hold flood insurance policies. The claims are prominent in Staten Island, along the Hudson River on the west side of Lower Manhattan, around Pelham Bay, along the East River in Williamsburg and Greenpoint, Red Hook, and around Jamaica Bay.

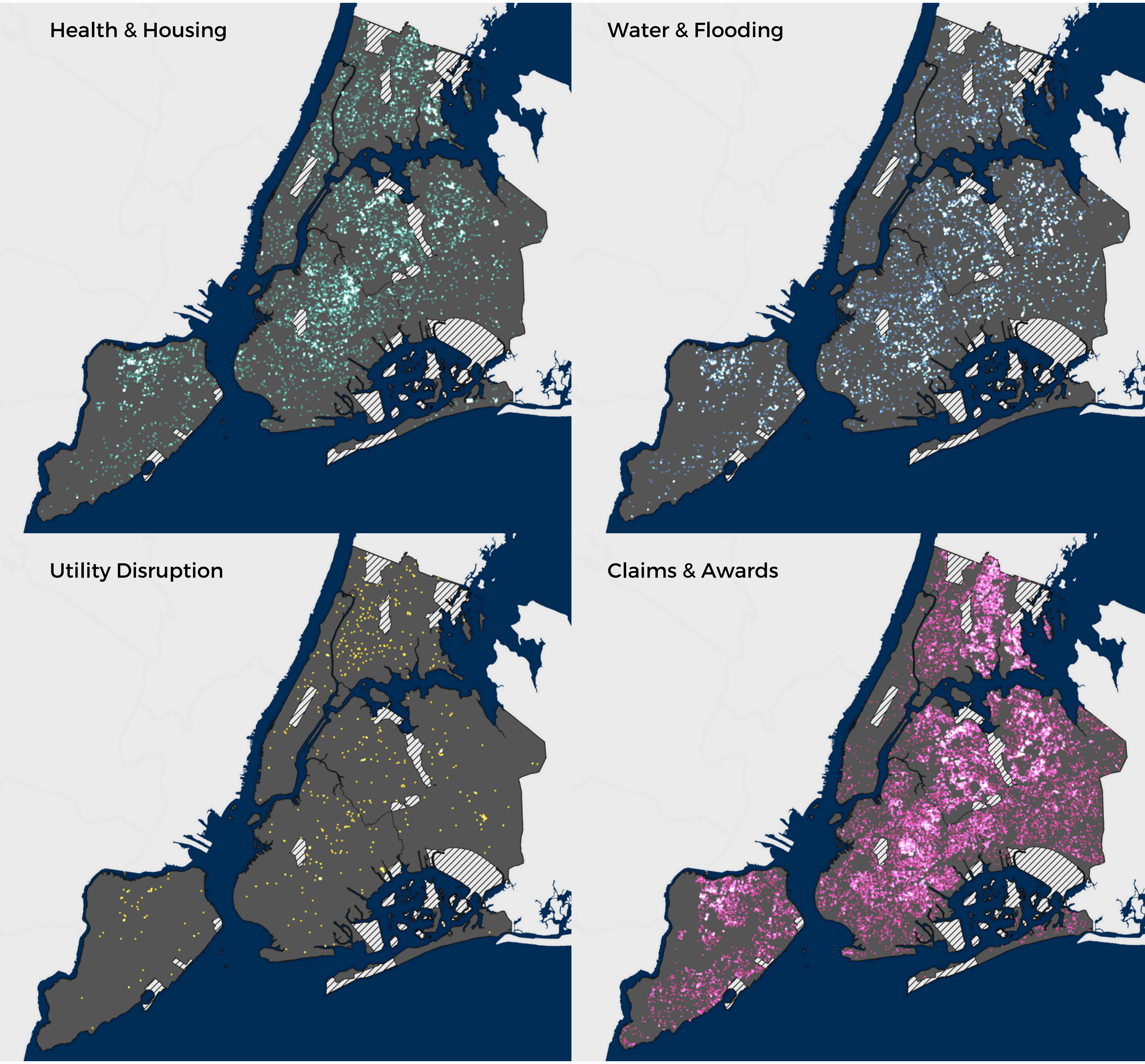


Figure 7: Flood Damage Indicators by Type
Source: 311, DOB, FEMA, NFIP, PEU, NYCEM

Reported And Verified Damage

Eighty-four percent of impacted buildings have only one indicator of damage (See Figure 9). Moreover, ~21,650 impacted residential buildings appear only in NFIP and IA records, meaning without access to Federal data sources, the NYCEM estimates alone could underestimate damage by nearly 65%. While resident-reported damage provides context into the type of flood damage, relying heavily on resident-reported damage sources may undercount impact substantially.

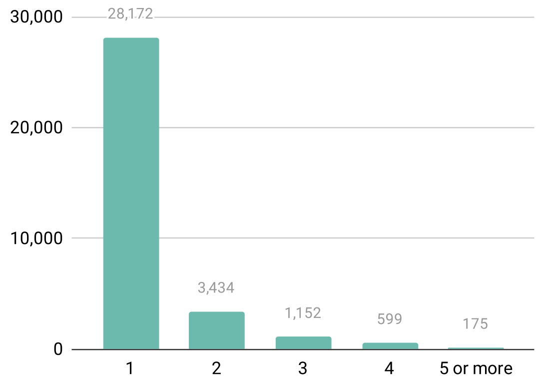


Figure 9: Frequency of Damage Indicators per Building
Source: 311, DOB, FEMA, NFIP, PEU, NYCEM

FOR EVERY BUILDING WITHOUT VERIFIED DAMAGE, THERE ARE FOUR BUILDINGS WITH VERIFIED DAMAGE

Approximately 7,300 buildings, or ~22% of impacted buildings, are associated only with resident reports. With the exception of Manhattan, for every building without verified damage citywide, there are four buildings with verified damage.

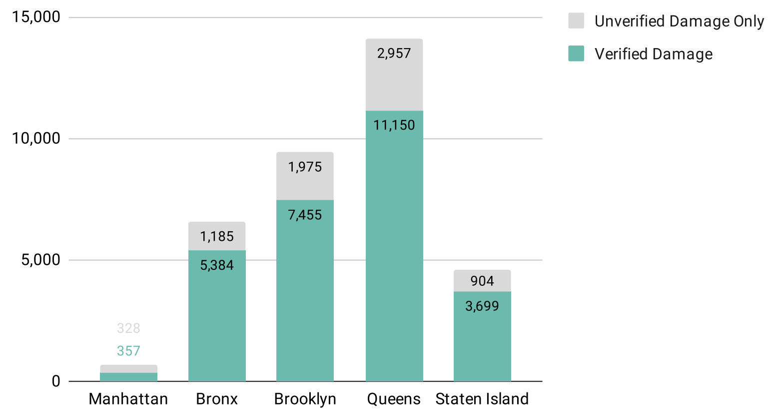
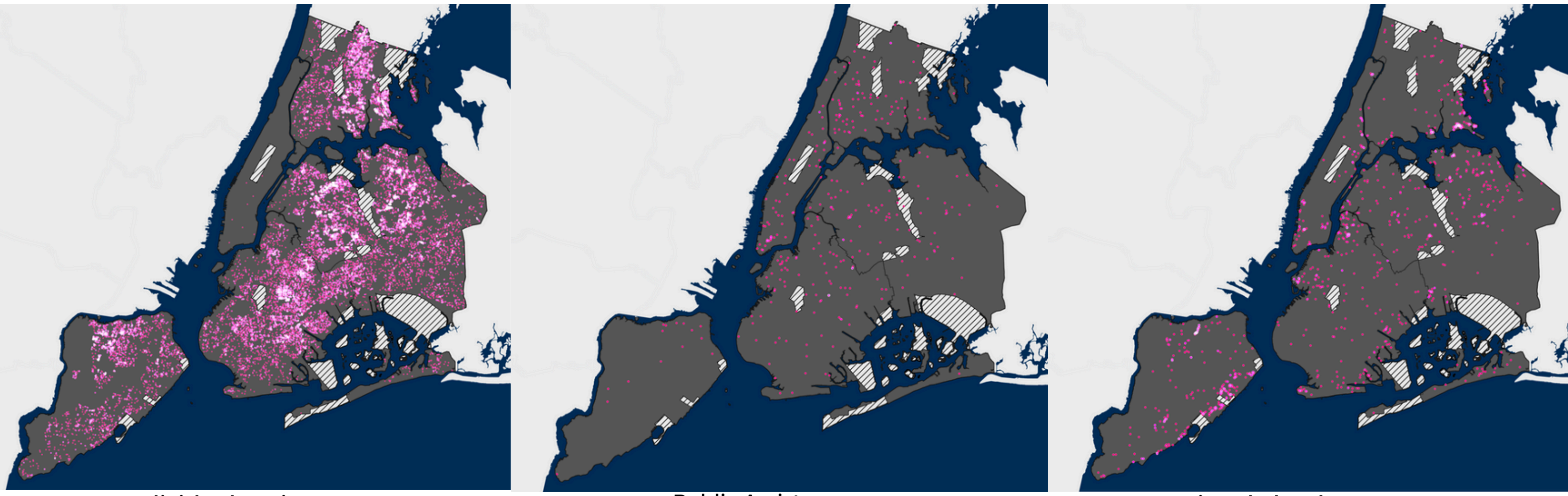


Figure 10: Verified and Unverified Damage by Borough
Source: NYCEM



Individual Assistance
23,781 Buildings

Public Assistance
328 Buildings

National Flood Insurance
1,059 Buildings

Figure 8: Claims & Award Damage Indicators: Federal Disaster Recovery Programs and Flood Insurance
Source: FEMA, NFIP, NYCEM

Physical Infrastructure

BUILDING CHARACTERISTICS

The analysis examined trends in building use, size, class, and age with a particular focus on residential buildings, given PTC Ida's uneven impact on residential buildings. Of the ~33,500 buildings with damage, 92% are residential, compared to ~87% of buildings citywide. An additional ~5% of impacted buildings are mixed-use (residential and commercial) and another ~2% are solely commercial. Given the localized impact of PTC Ida, building characteristics correspond to the general neighborhood character of the most impacted communities – low-rise, outer-borough residential neighborhoods.

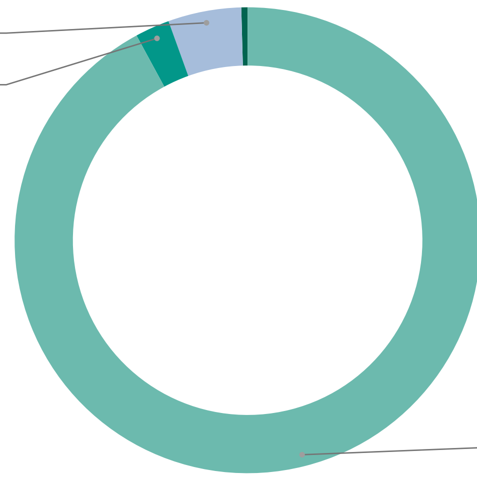


Figure 11: Distribution of Impacted Buildings by Use
Source: NYCEM, DCP

	ALL BUILDINGS	RESIDENTIAL BUILDINGS	COMMERCIAL BUILDINGS	MIXED-USE BUILDINGS
NYC BUILDINGS	1,084,672	940,377 (86.7% of all buildings in the city)	61,278 (5.7% of all buildings in the city)	67,739 (6.2% of all buildings in the city)
BUILDINGS WITH DAMAGE	33,532 (3.09%)	30,879 (3.3%)	803 (1.3%)	1,704 (2.5%)
BUILDINGS WITH VERIFIED DAMAGE	28,045 (2.59%)	26,403 (2.8%)	589 (1.0%)	946 (1.4%)
BUILDINGS WITH UNVERIFIED DAMAGE	7,349 (0.68%)	6,243 (0.7%)	231 (0.4%)	832 (1.2%)

Table 1: Impacted Buildings by Use
Source: NYCEM, DCP

Verified Damage: *resident-reported damage that has been verified by a responding City, State, or Federal agency.*
Unverified Damage: *resident-reported damage that has not been verified by a responding City, State, or Federal agency.*

Residential

Approximately 30,900 solely residential buildings, with a total of ~145,300 residential units, reported damage from PTC Ida. While flooding did not damage all units, units in buildings with damage likely experienced some level of disruption from the storm. Most residential buildings had damage verified, with ~20% of buildings (~6,200) with unverified indicators of damage. Overall, the impacted buildings and units account for 3.3% of all residential buildings and 8.4% of all residential units in New York City. An estimated ~383,300 New Yorkers [18] live in impacted residential buildings. An additional ~171,000 live in mixed-use buildings, bringing the total to over half a million, roughly equal to 1 in 16 New Yorkers.

Small residential buildings sustained the most impact. As Figure 12 shows, ~75% of impacted residential buildings are one- to two-unit homes, and another ~12% are three to four units. Of the ~24,400 one- to two-unit homes, ~44% are located in Queens, compared to ~23% in Brooklyn, and ~17% in the Bronx and Staten Island.

The breakdown by building class in Figure 14 further reinforces building size observations by a slightly different measure. One family and two family homes were disproportionately impacted by PTC Ida, comprising 71% of impacted buildings despite only accounting for 52% of buildings citywide.

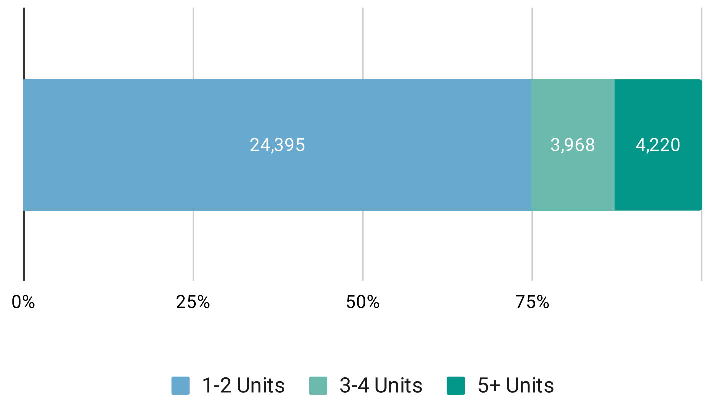


Figure 12: Distribution of Impacted Residential Buildings by Building Size
Source: NYCEM, DCP

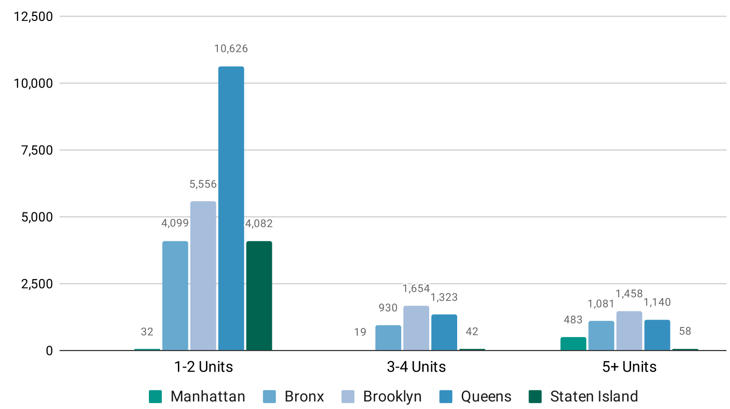


Figure 13: Impacted Residential Buildings by Size and Borough
Source: NYCEM, DCP

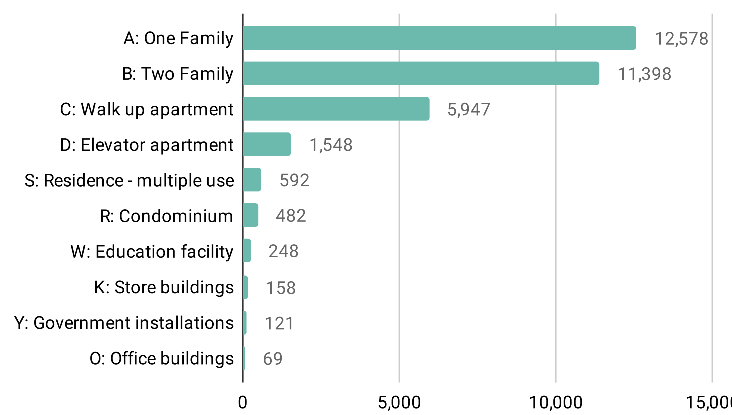


Figure 14: Damaged Residential Buildings by Building Class
Source: DCP, NYCEM

Commercial

Buildings with commercial space, including mixed-use buildings, account for ~2,500 or 7.5% of buildings impacted. Approximately 800 buildings are solely commercial, 2.4% of all impacted buildings. Overall, an estimated ~194,000 commercial units are in buildings impacted by PTC Ida, though high-rise buildings in Manhattan drive this large number.

Over half of impacted buildings with commercial space are in Brooklyn (~32%) and the Bronx (~27%), including a large cluster of buildings in the Eastchester section.

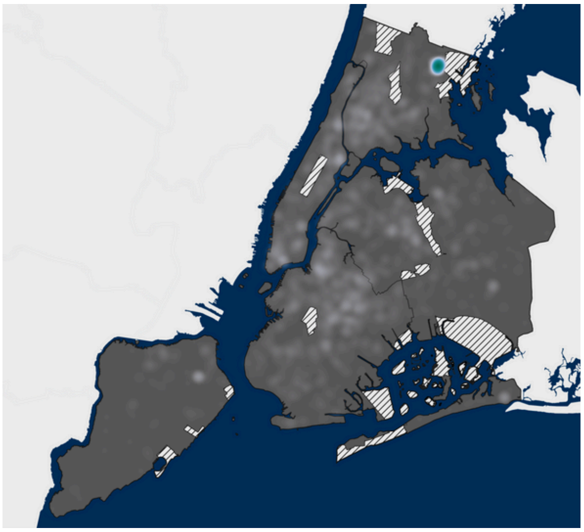


Figure 15: Impacted Buildings with Commercial Space
Source: NYCEM, DCP

Nearly half of impacted commercial buildings are large commercial spaces, with commercial area in the top quartile of New York City buildings. The large average square footage (compared to the median) reinforces the large size of these buildings, suggesting industrial and warehousing activities.

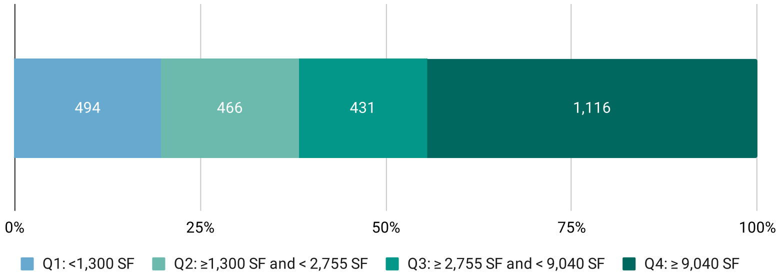


Figure 16: Impacted Buildings by Commercial Area
Source: NYCEM, DCP

	COMMERCIAL AND MIXED BUILDINGS	AVERAGE SIZE (SF)	MEDIAN SIZE (SF)
Manhattan	375 (15.0%)	89,525	11,943
Bronx	683 (27.2%)	149,714	32,684
Brooklyn	804 (32.1%)	53,027	2,250
Queens	538 (21.5%)	58,615	5,586
Staten Island	107 (4.3%)	125,108	6,408

Table 2: Distribution of Damaged and Mixed Buildings by Borough
Source: DCP, NYCEM

SUBGRADE SPACE

Residential use of the basement and cellar – grouped here as "subgrade space" – presents a serious risk to life in a flash flood and other emergencies. According to recent estimates, as many as 100,000 New York City residents occupy often illegal and unregulated subgrade apartments despite the higher flood risk and sometimes lack of adequate egress. This is often due to a lack of other affordable housing options and is disproportionately comprised of communities of color who cannot find or afford safer options. Additionally, many residents are unaware of the legal status of their basement units and the potential associated risks. Tragically, during PTC Ida, eleven deaths occurred in subgrade apartments caused by drowning between 12 a.m. – 3 a.m. on September 2, 2021.

NYCEM ESTIMATES ~56% OF IDA-IMPACTED BUILDINGS FEATURE SUBGRADE SPACE.

Following PTC Ida, the City has worked to combat the specific dangers flooding poses for those living in subgrade units. In 2023, NYC Department of City Planning released the Building Elevation and Subgrade (BES) dataset, which contains records for the grade and first floor elevation for every building and indicates if subgrade space exists.

The subgrade space indication was performed strictly from the street view and cannot identify if subgrade space is used as a dwelling or living space. This analysis compared the BES dataset to damage data to understand the impact PTC Ida had on buildings with subgrade space.

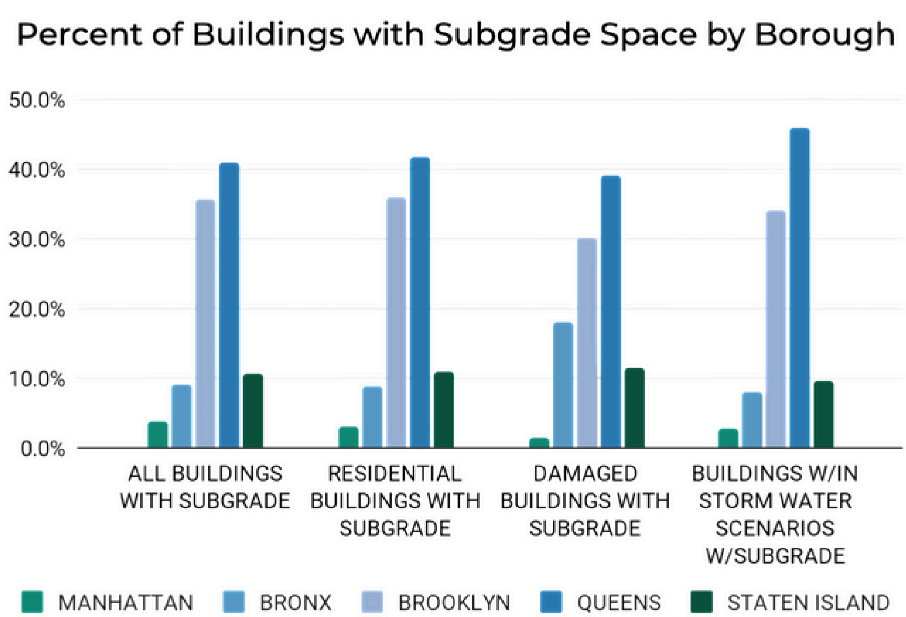


Figure 18: Subgrade Space by Borough
Source: NYCEM, DCP, MOCEJ

Citywide, 43% of buildings have recorded subgrade space. over three quarters (~358,000) of buildings with subgrade space are in Brooklyn and Queens. these two boroughs also contain many of the most heavily impacted communities in the city. almost 70% (~12,800) of PTC Ida damaged buildings with subgrade spaces were located in Brooklyn and Queens. For future flash flooding events, the city has created specific messaging for these areas with lifesaving information for those living in basement and subgrade spaces.

Figure 19 shows clusters of damaged buildings with subgrade space. The clusters highlight several Queens neighborhoods – Jackson Heights, Woodside, Whitestone, East Flushing, Woodhaven, and Ozone Park; Bushwick in Brooklyn; and Soundview, Westchester Square, and Van Nest in the Bronx. Many of these areas are part of the community districts with the highest counts of flood damage.

	ALL NYC BUILDINGS	RESIDENTIAL BUILDINGS	DAMAGED BUILDINGS	BUILDINGS W/IN STORM WATER SCENARIOS
SUBGRADE	466,786 (43.0%)	450,949 (48.0%)	18,595 (55.5%)	95,324 (43.5%)
NO SUBGRADE	372,934 (34.4%)	266,684 (28.4%)	13,211 (39.4%)	87,352 (39.8%)
UNKNOWN	244,952 (22.6%)	222,744 (23.6%)	1,723 (5.1%)	36,610 (16.7%)
TOTAL	1,084,672	940,377	33,529	219,286

Table 4: Subgrade Building Features
Source: DCP, NYCEM, MOCEJ

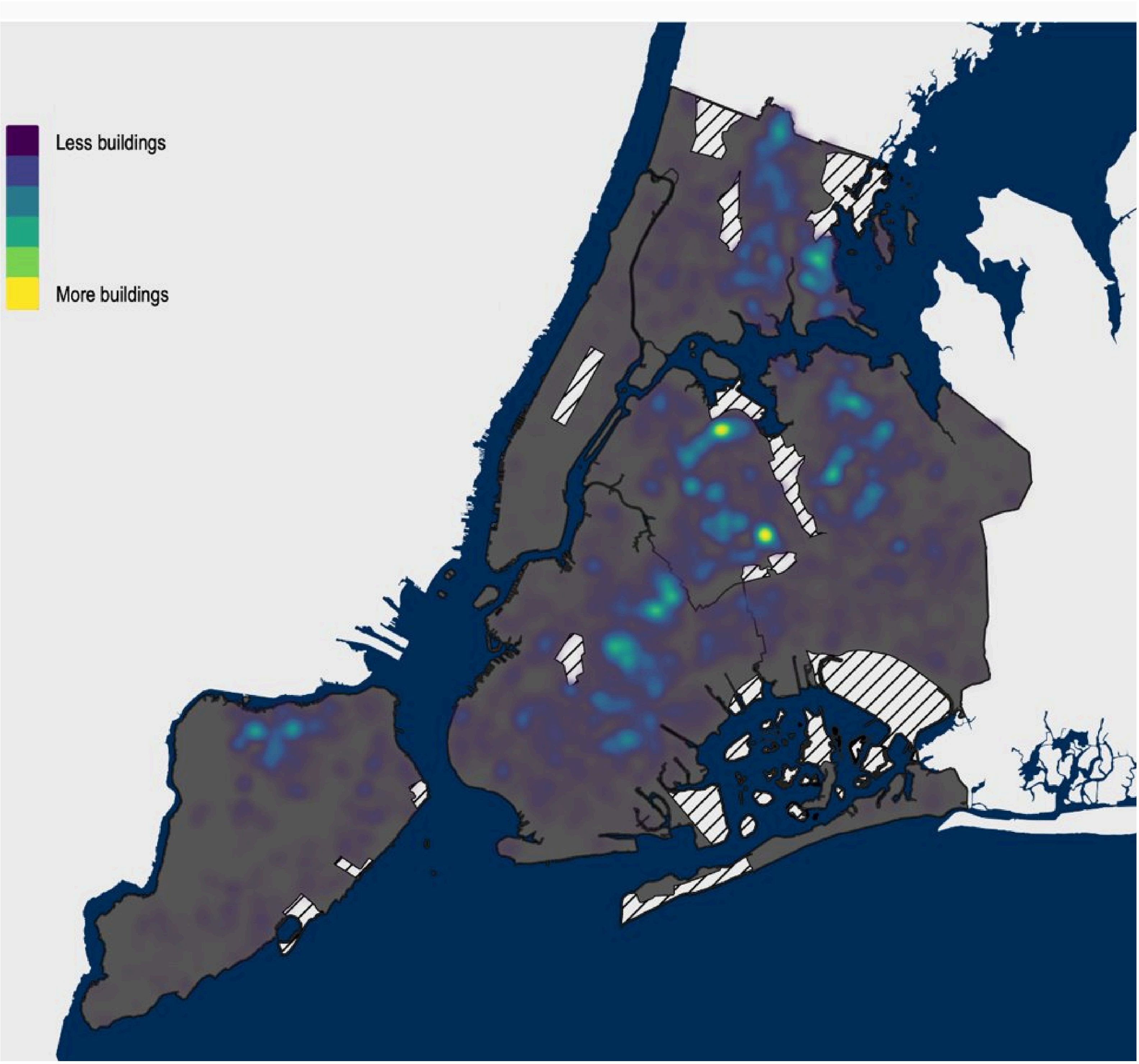


Figure 19: Impacted Buildings with Subgrade Space
Source: DCP, NYCEM

Property Financial Profile

OWNERSHIP AND RECOVERY RESOURCES

The analysis examines trends in ownership and property values to understand better flood impact and potential resources for recovery.

Privately-owned Property

Over 95% of identified damage is to privately owned buildings. Of the ~32,100 privately owned buildings with damage, 77% of buildings (~24,700) received NFIP or IA to aid repairs or replacements from the storm. Of the ~7,400 buildings with damage but without federal disaster recovery assistance, the largest clusters are concentrated in Queens neighborhoods of Oakland Gardens, Hollis Hills, and Fresh Meadows, and to a lesser extent in East Elmhurst and Forrest Hills.

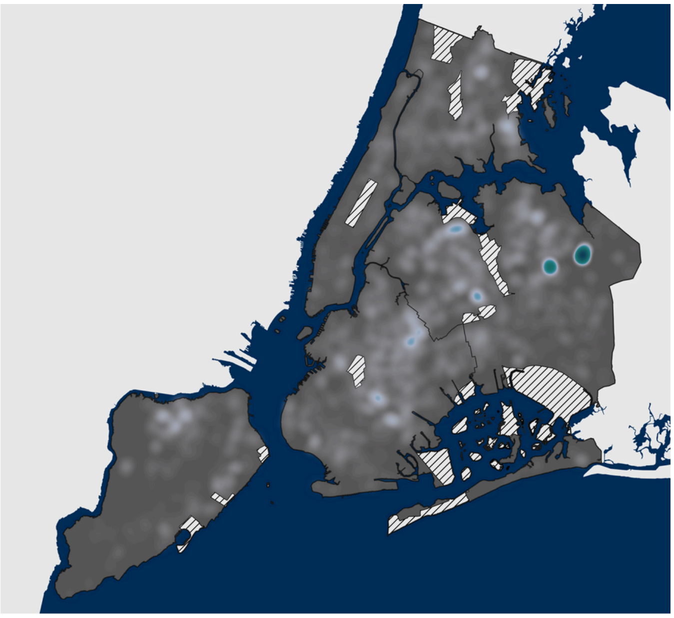


Figure 20: Privately-owned Impacted Buildings without NFIP or IA
Source: DCP, NFIP, FEMA, NYCEM

OWNERSHIP	NYC BUILDINGS	DAMAGED BUILDINGS	% OF NYC BUILDINGS DAMAGED
PRIVATE	1,051,407 (96.9%)	32,128 (95.8%)	3.1%
TAX EXEMPT	21,985 (2%)	750 (2.2%)	3.4%
CITY OWNED	7,530 (0.7%)	398 (1.2%)	5.3%
OTHER PUBLIC	3,373 (0.3%)	253 (0.8%)	7.5%
MIXED	377 (.03%)	3 (0.01%)	0.8%
TOTAL	1,084,672 (100%)	33,532 (100%)	3.1%

Table 5: Impacted Buildings by Property Owner
Source: DCP, NYCEM

City-Owned or Administered Property

Few City-owned or administered (e.g., NYCHA) buildings sustained damage, though City- and public authority-owned buildings are over-represented proportionally in damaged buildings. For example, City-owned buildings make up 0.7% of buildings citywide, yet account for 1.2% of all buildings with damage, a rate 1.7 times higher than expected. Less than 400 City-owned buildings sustained damage, equivalent to ~5% of all City buildings. Nearly 40% of these properties are Department of Education (DOE) facilities. Notably, nearly 40% of Police Department (NYPD) buildings reported damage.

While few residential buildings remain in City-ownership, ~230 New York City Housing Authority (NYCHA) buildings reported storm damage. This is equivalent to ~8% of all NYCHA buildings.

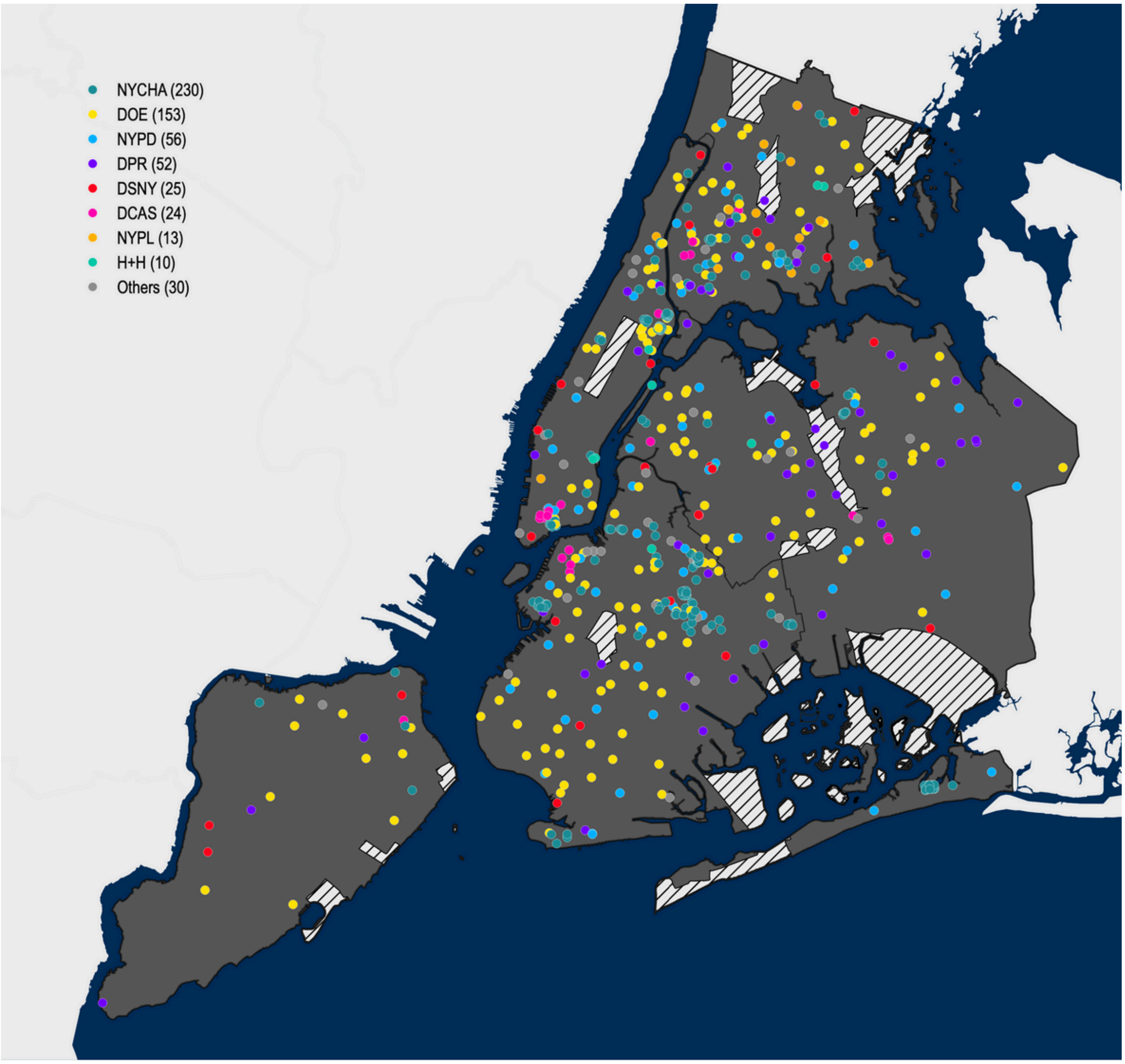


Figure 21: Damaged City-Owned Buildings by Agency
Source: DCP, FEMA, NYCEM

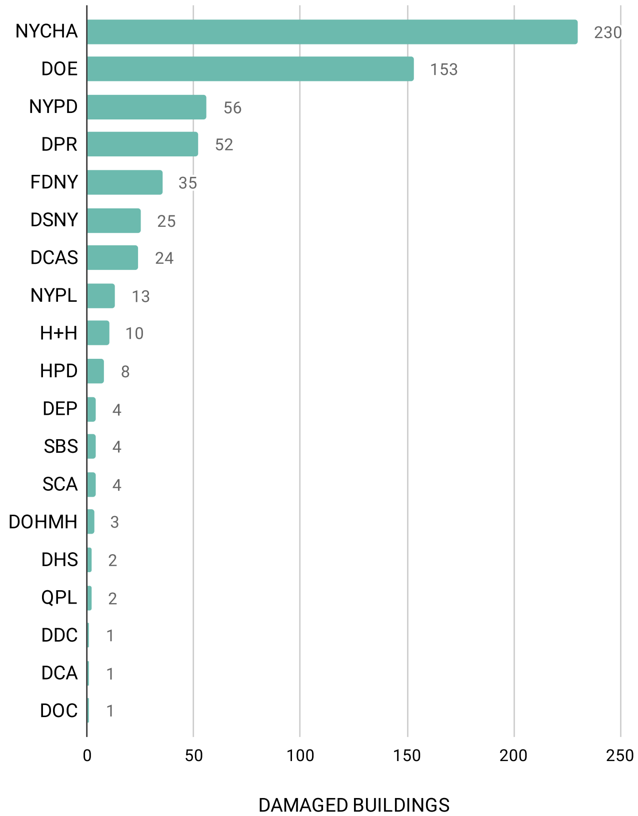


Figure 22: Damaged City-owned Buildings by Agency
Source: DCP, FEMA, NYCEM

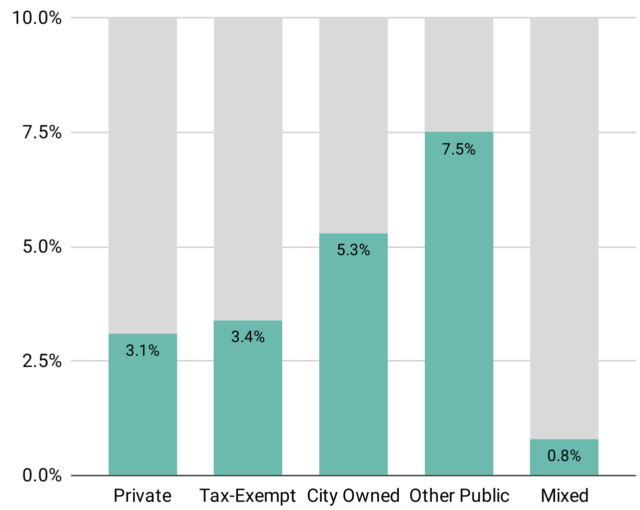


Figure 23: Percent of Buildings Impacted by Property Owner
Source: DCP, NYCEM

FEMA Public Assistance

The City is tracking potential recovery resources from FEMA Public Assistance (PA) for City-owned properties. Estimates totaled to ~$311.57 million to reimburse the repair, recovery, and protective measure costs across the City. Two-thirds of all PA costs are attributed to parks and school facilities. Park-related damage is an estimated $15.6 million, while school-related repairs from the School Construction Authority amount to ~$187.9 million.

Nearly 80% of all PA-eligible expenses are for the repair or replacement of buildings, their contents and systems, heavy equipment, and vehicles (PA Category E), amounting to ~$248.9 million in damage.

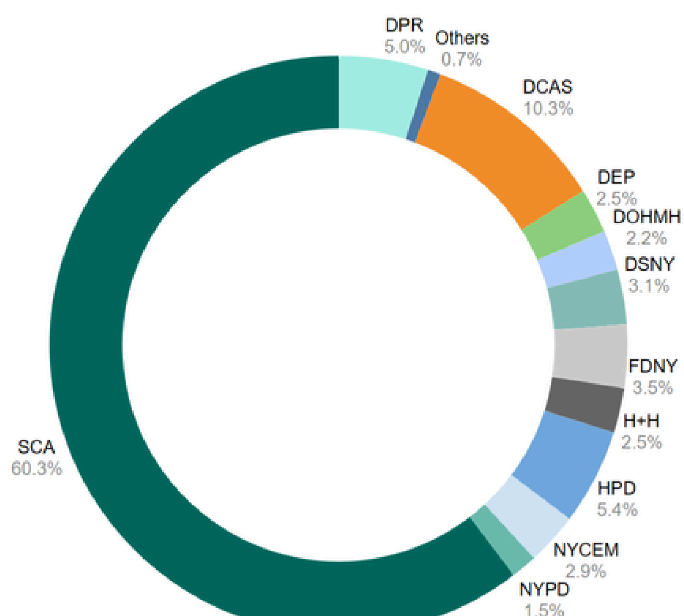


Figure 24: Distribution of Estimated Repair Costs by Agency
Source: FEMA

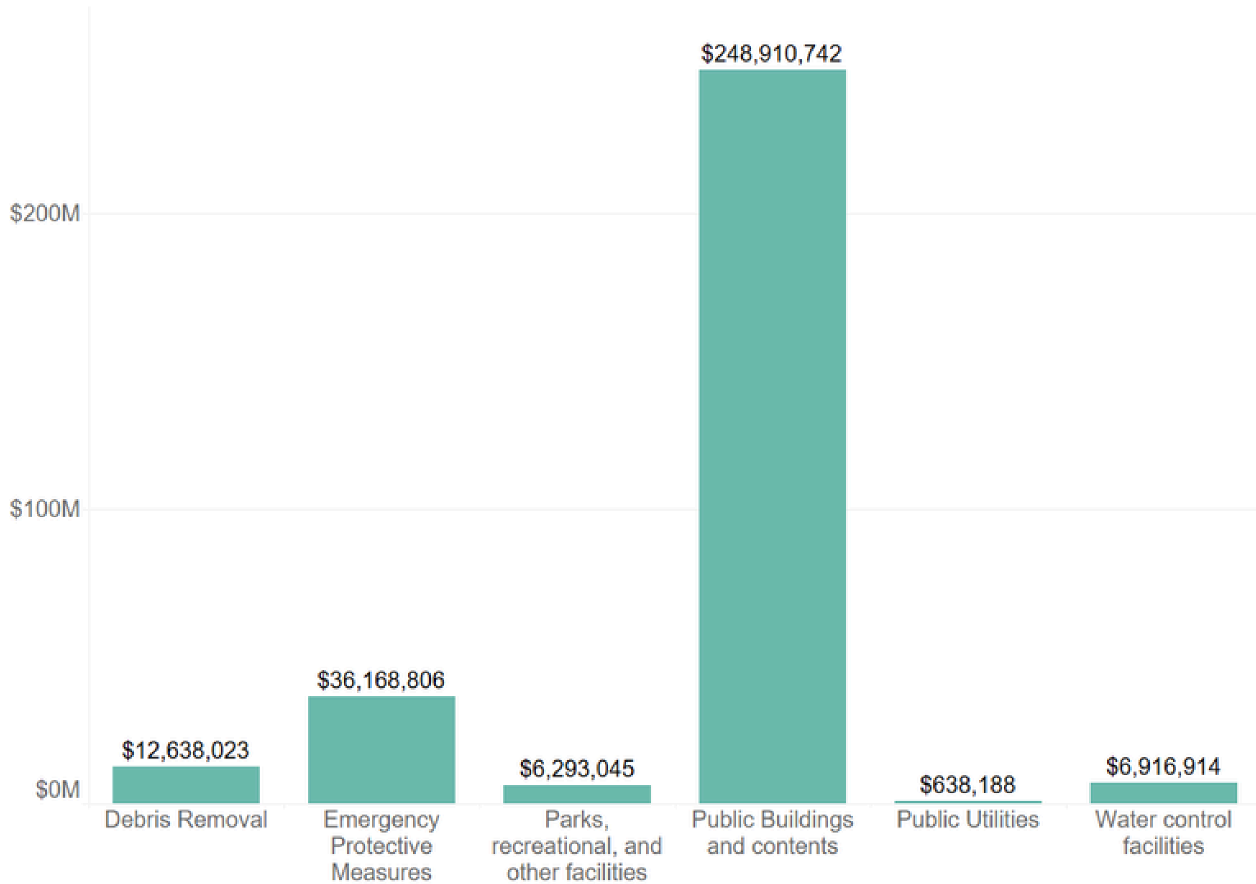


Figure 25: Public Assistance Estimated Costs by Category
Source: FEMA

NEARLY 330 CITY-OWNED BUILDINGS WITH REPAIRS ELIGIBLE FOR PUBLIC ASSISTANCE GRANTS

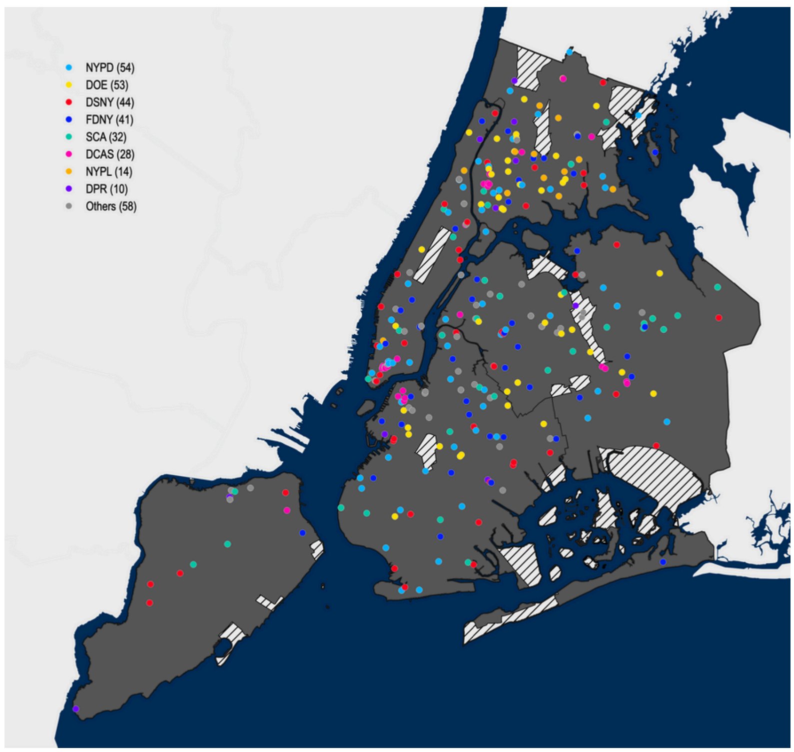


Figure 26: City Buildings with Public Assistance Category E Repairs
Source: FEMA

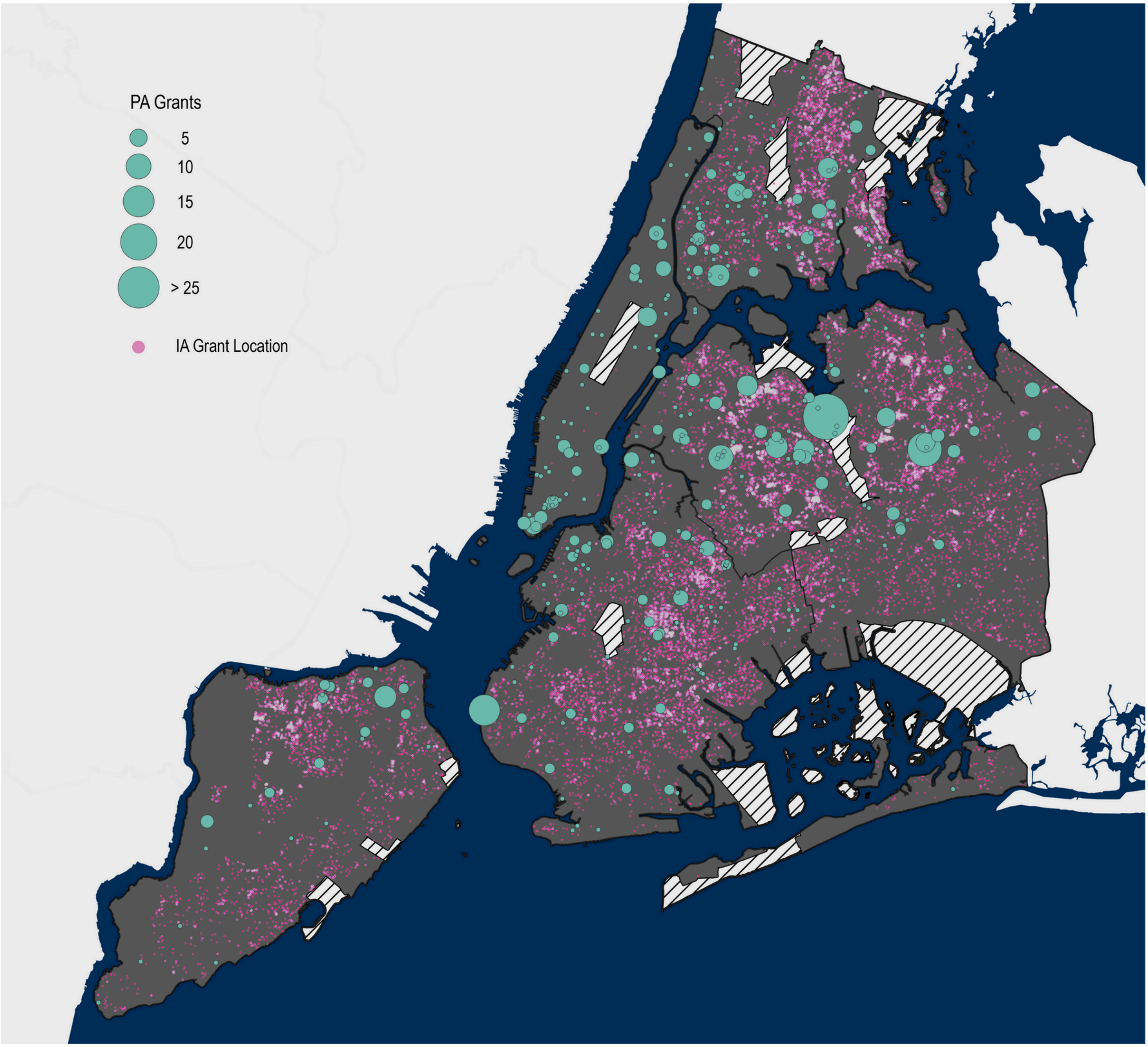


Figure 27: Public Assistance and Individual Assistance Locations
Source: FEMA

Figure 27 shows the location of PA grants and IA awards. Except for Manhattan, where households were not eligible for federal disaster assistance, PA eligible damage is in or near areas receiving IA awards. A small number of PA grants are in Eastchester in the Bronx and Downtown Brooklyn, places with few to no IA awards.

PROPERTY VALUES

Property values typically reflect the risks of natural hazards in the surrounding environment. Comparing the pre-storm property values of damaged and undamaged buildings from PTC Ida, the analysis shows a difference at both the city and community scale. Damaged buildings have lower per unit market values than undamaged buildings, with differences ranging from -8% to -23%, depending on building size (see Figure 28).

At the community scale, there is sizable variation across Community Districts. Most communities have lower property values for damaged buildings than buildings without damage, though communities with the most damage from PTC Ida show much smaller differences between damaged and undamaged buildings (see Figure 29). The communities with the least impact from PTC Ida have the greatest difference in property values between damaged and undamaged buildings.

While purely descriptive analysis, it suggests that property values may already account for hazard risk based on location. As climate risks accelerate, economists expect to see more changes in property valuation – a trend observed in Miami but with implications for New York City. With chronic flooding and sea level rise since the early 2000s, property values for higher elevations in the Miami region increased while property values at low elevations decreased, independent of proximity to the coastline. From a community resiliency perspective, New York City property values may be an area for future study. Concerns of "climate gentrification" range from reduced city tax rolls from decreased property values in areas with chronic flooding, to resident displacement because of resiliency-driven property value increases or the cost burden of insurance and repairs.

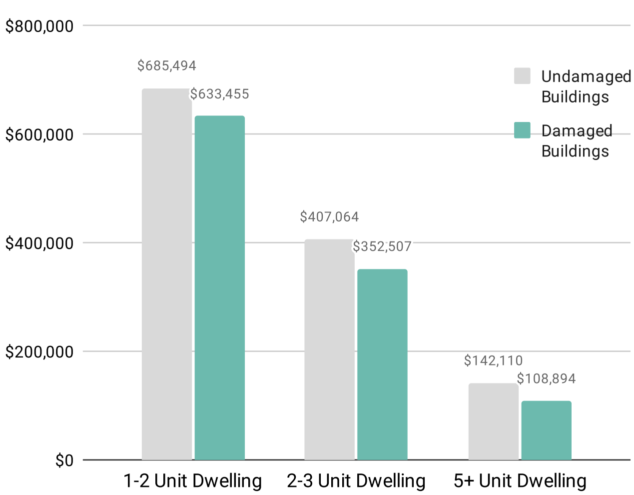


Figure 28: Median Residential Property Values
Source: DOF, NYCEM

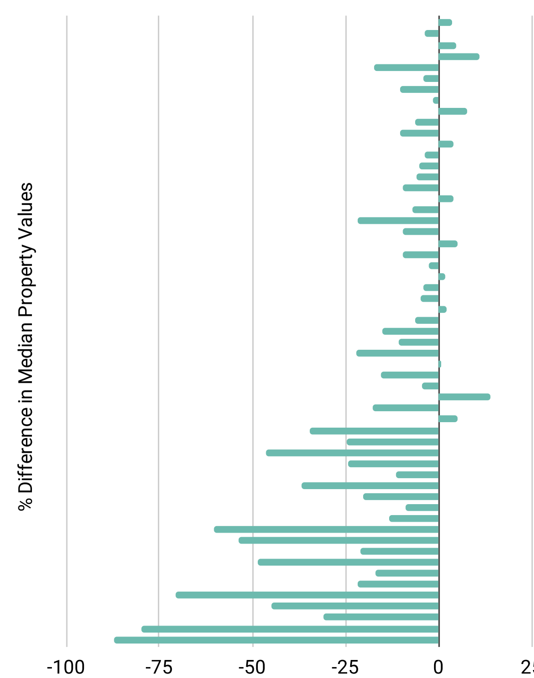


Figure 29: Difference in Median Residential Property Values of Damaged and Undamaged Buildings by CDTA
Source: DOF, NYCEM

Geography and Environment

FLOOD RISKS

In May 2021, the NYC Mayor's Office published the city's first Stormwater Resiliency Plan, detailing stormwater flood maps that model the risk of inland flooding from rain. In identifying areas of inland flood risk, the models consider several factors, including topographic characteristics, like low-lying areas, areas of low green or vegetated density, hourly rainfall projections, and blocked rainwater infrastructure, like sewer outflows and storm drains from sea level rise. The Moderate Stormwater Flood scenario presents the risk of a "10-year storm" with rainfall rates of two inches per hour and 2.5 feet of sea level rise. The Extreme Stormwater Flood scenario, also called a "100-year storm," considers the risk from 3.5 inches per hour of rain and 4.8 feet of sea level rise.

In some parts of the city, PTC Ida presented the conditions of a "1000-year storm," dropping over nine inches of rain in only a handful of hours, far beyond the intensity these flood scenarios visualize. Roughly 57% of impacted buildings were outside the Extreme Stormwater Flood map. Figures 30 through 33 show Moderate and Extreme Stormwater Scenarios with clusters of PTC Ida damage for each borough. In general, impacted buildings outside the stormwater zones tend to be nearby or an extension of the zones, following the same general pattern of the scenarios. This is consistent with Ida being a more intense storm than those used to create these models, causing overflow to extend out further than the model boundaries. Notable exceptions include Wakefield and Williamsbridge in the Bronx and Crown Heights in Brooklyn, which all have widespread damage far beyond the stormwater zones.

In addition to these stormwater scenarios, the analysis considered the FEMA 100-year and 500-year floodplains. However, it is important to note the FEMA floodplain maps were designed to identify the risk of coastal flooding, whereas PTC Ida in New York City was a pluvial flooding event with impacts primarily more inland. Therefore, comparison between the location of Ida damages and FEMA floodplains in this analysis are made to demonstrate the different threats posed by these variations of flooding. Approximately 86% to 93% of damaged buildings are located outside the FEMA 100-year to 500-year floodplains. Figure 34 highlights the inland nature of the flooding during Ida and reinforces the importance of considering both stormwater flood maps and floodplain maps when assessing the risk and potential impacts of flooding due to an incoming heavy rainfall event.

Overall, about half (51.8%) of impacted buildings (17,357) from PTC Ida were outside any flood risk scenario. Table 6 compares impacted buildings inside and outside the different flood risk scenarios. The Extreme Stormwater Flood scenario aligned the closest with PTC Ida impacts with ~43% of impacted buildings within the scenario. The data collected from PTC Ida and this analysis can help provide further context and support to stormwater flood risk modeling and may help identify additional stormwater flood areas in the future.

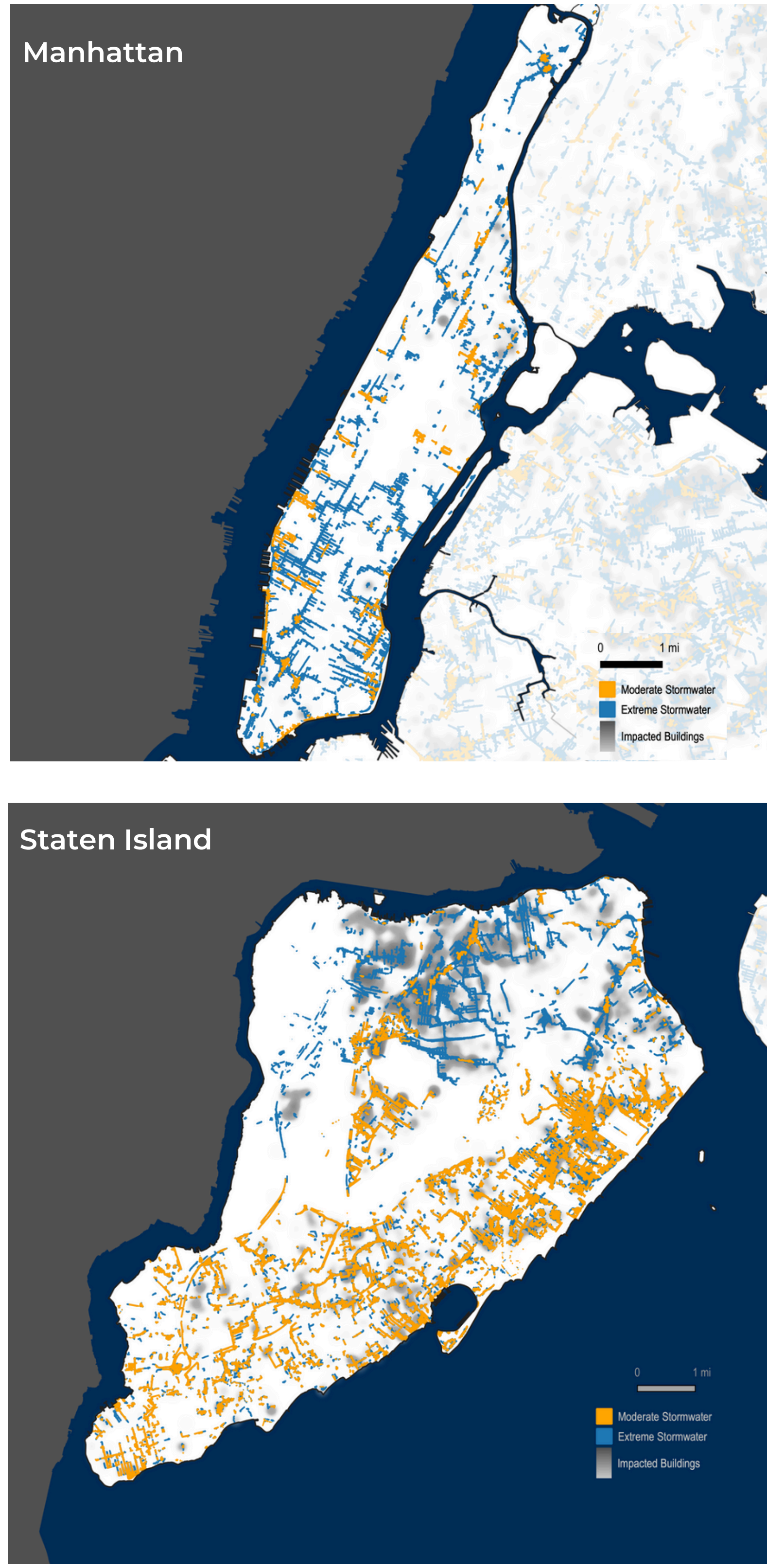


Figure 30: Stormwater Flood Risk Scenarios and Impacted Buildings in Manhattan and Staten Island
Source: NYCEM, MOCEJ

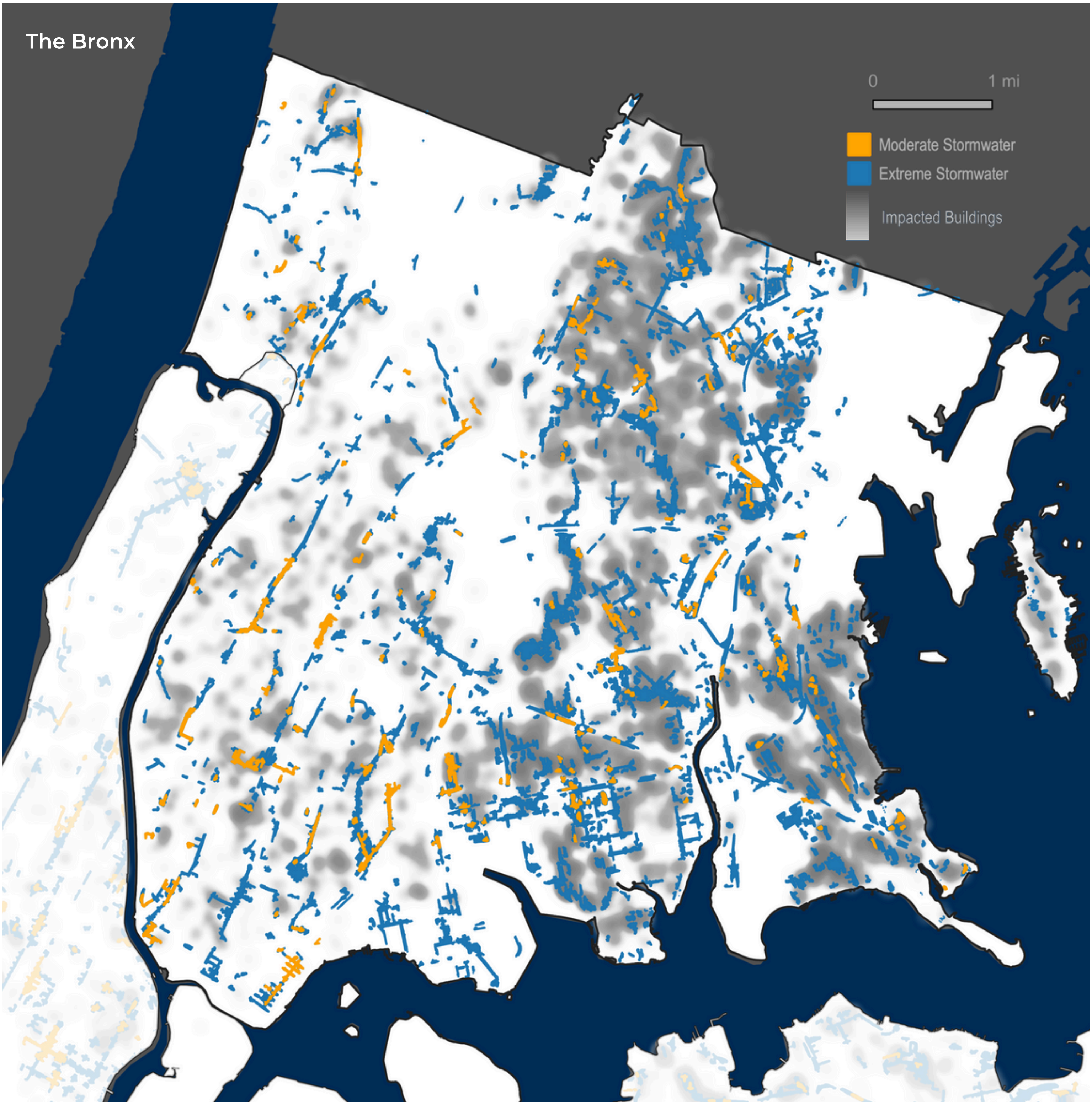


Figure 31: Stormwater Flood Risk Scenarios and Impacted Buildings in the Bronx
Source: NYCEM, MOCEJ

Figure 32: Stormwater Flood Risk Scenarios and Impacted Buildings in Brooklyn
Source: NYCEM, MOCEJ

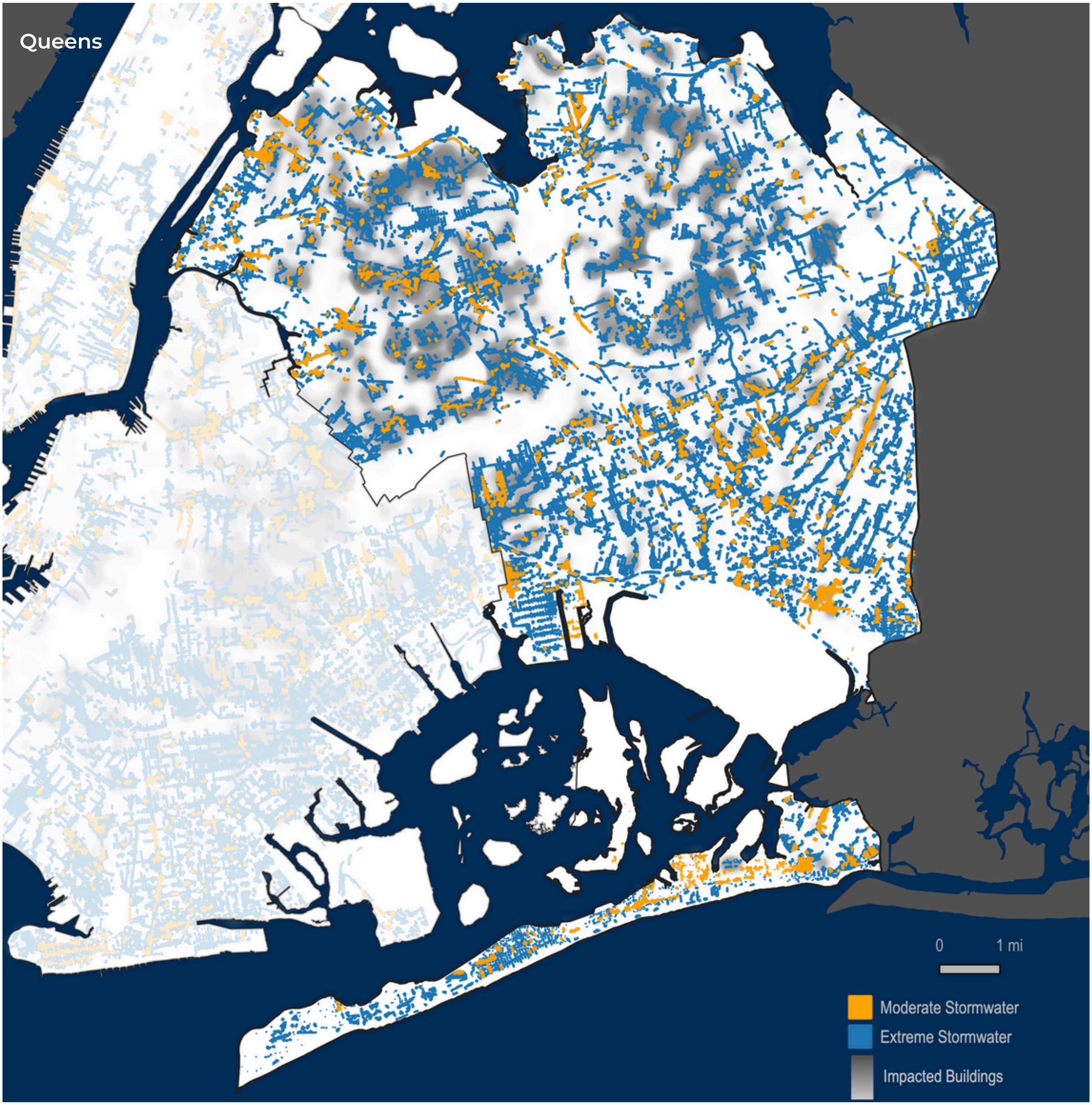


Figure 33: Stormwater Flood Risk Scenarios and Impacted Buildings in Queens
Source: NYCEM, MOCEJ

	BUILDINGS IN THE SCENARIO	IMPACTED BUILDINGS IN THE SCENARIO	IMPACTED BUILDINGS OUT OF THE SCENARIO	RESIDENTIAL UNITS IN THE SCENARIO	IMPACTED RESIDENTIAL UNITS IN THE SCENARIO	IMPACTED RESIDENTIAL UNITS OUT OF THE SCENARIO
FEMA 100 YEAR FLOOD	90,810	2,305	31,227	341,312	27,421	190,138
	8.4% of NYC buildings	6.9% of impacted buildings	93.1% of impacted buildings	9.7% of NYC housing units	12.6% of impacted housing units	87.4% of impacted housing units
FEMA 500 YEAR FLOOD	148,634	4,591	28,941	548,680	46,117	171,442
	13.7% of NYC buildings	13.7% of impacted buildings	86.3% of impacted buildings	15.6% of NYC housing units	21.2% of impacted housing units	78.8% of impacted housing units
MODERATE STORMWATER	40,943	3,598	29,934	175,024	19,565	197,995
	3.8% of NYC buildings	10.7% of impacted buildings	89.3% of impacted buildings	5.0% of NYC housing units	9.0% of impacted housing units	91.0% of impacted housing units
EXTREME STORMWATER	219,286	14,331	19,201	861,275	81,764	135,796
	2 0 % of NYC buildings	42.7% of impacted buildings	57.3% of impacted buildings	24.5% of NYC housing units	37.6% of impacted housing units	62.4% of impacted housing units

Table 6: Impact by Flood Risk Scenario
Source: NYCEM, MOCEJ, DCP

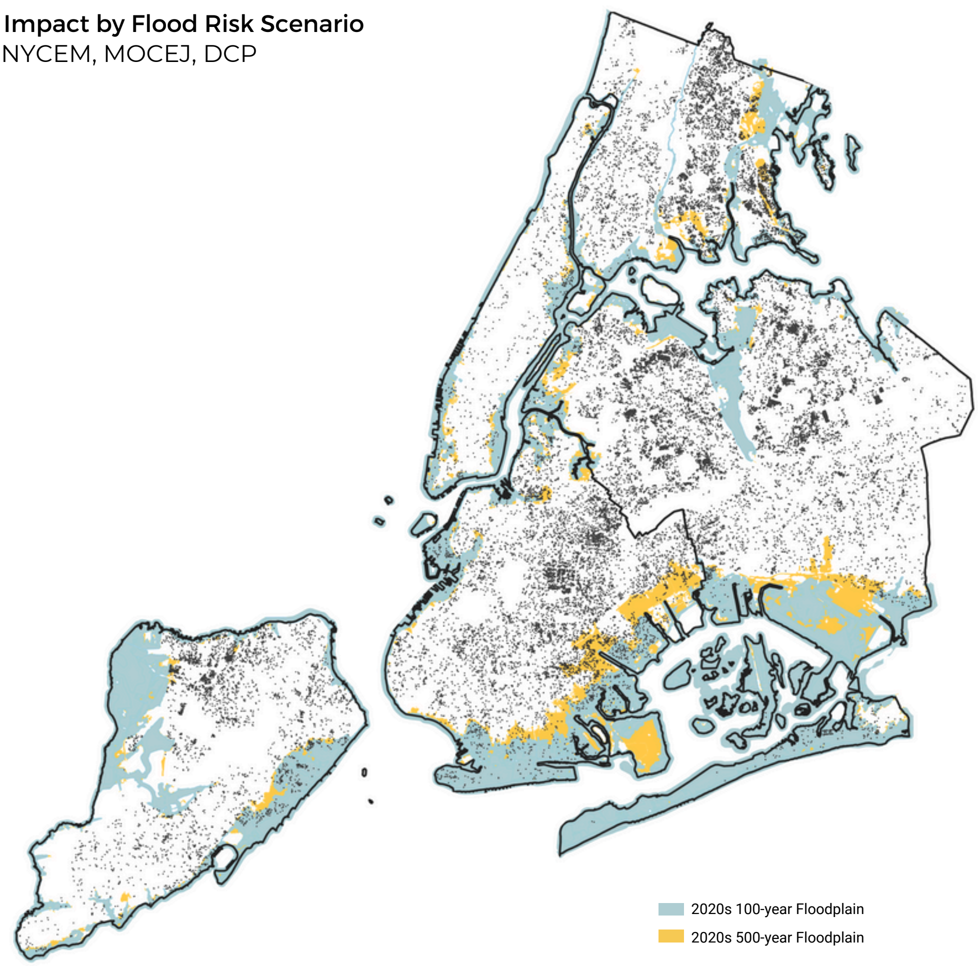


Figure 34: FEMA Floodplains and Impacted Buildings
Source: NYCEM, MOCEJ

SURFACE PERMEABILITY

Along with stormwater infrastructure, land cover permeability influences runoff potential in precipitation events and affects flood risk. The NYC Department of Environmental Protection's (DEP) 2020 Impervious Area Study used orthoimagery, LIDAR, planimetrics, parcel, and building footprints to classify the percent imperviousness of each lot in New York City. The level of imperviousness was determined by a combination of land cover (e.g., metal, concrete, gravel, grass, sand, etc.) and associated runoff factors of the cover material.

The analysis examined the relationship between impacted buildings and the level of imperviousness at both the citywide and community district scale. Citywide, there is no statistically significant difference between the permeability of lots with buildings with damage and buildings without damage. At the community level, some CDTAs show a statistically significant difference between properties with damage and properties without; however, the direction of the difference varies.

Figure 35 shows the general similarity between the average level of imperviousness for a community and the damaged buildings within it. It also shows that in some CDTAs, damaged buildings are located on more impervious lots than buildings without damage. In contrast, in other communities, damaged buildings are located on less impervious lots than buildings without damage, making more conclusive observations difficult.

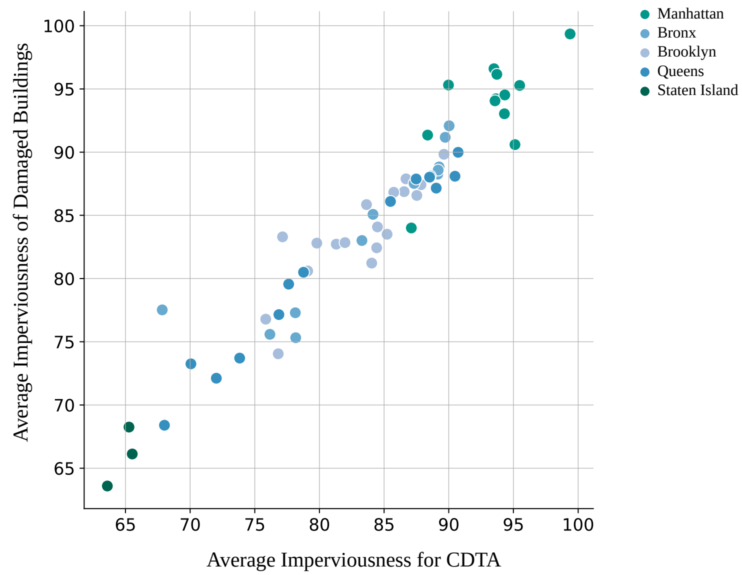


Figure 35: Magnitude of Community Impact and Imperviousness of Damaged Buildings
Source: NYCEM, DEP

There is a weak negative correlation (ϱ = -0.21) between the number of impacted buildings in a CDTA and the average imperviousness for damaged buildings in the CDTA (see Figure 36). This suggests that communities with less impervious (i.e., more permeable) spaces have greater damage.

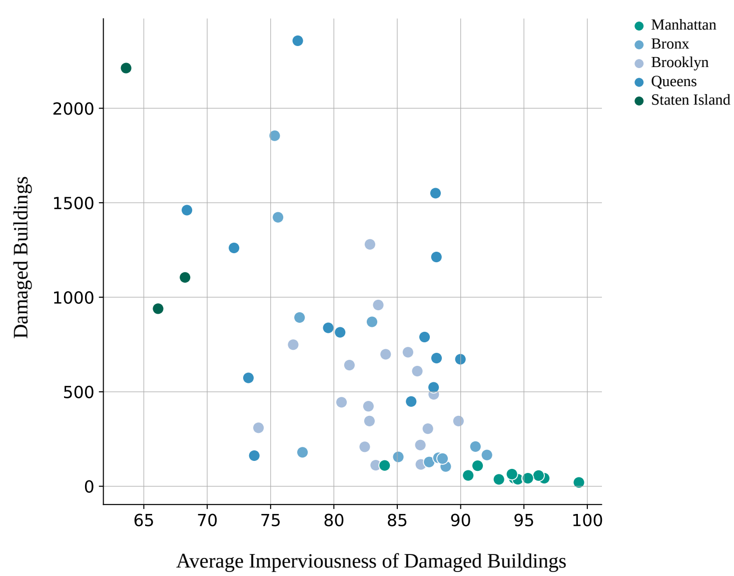


Figure 36: Magnitude of Community Impact and Imperviousness of Damaged Buildings
Source: NYCEM, DEP

Figure 37 further illustrates that the communities with greater damage from PTC Ida, like Queens CDTA 7 (Flushing - Murray Hill - Whitestone), Staten Island CDTA 1 (North Shore), and Bronx CDTA 10 (Co-op City - Throgs Neck), are more permeable (i.e., less impervious) than areas with less damage.

A possible explanation for these results is that the areas were waterlogged from previous storms (TS Henri). Additional modeling could help determine how ground saturation impacts flooding of green or more permeable surfaces.

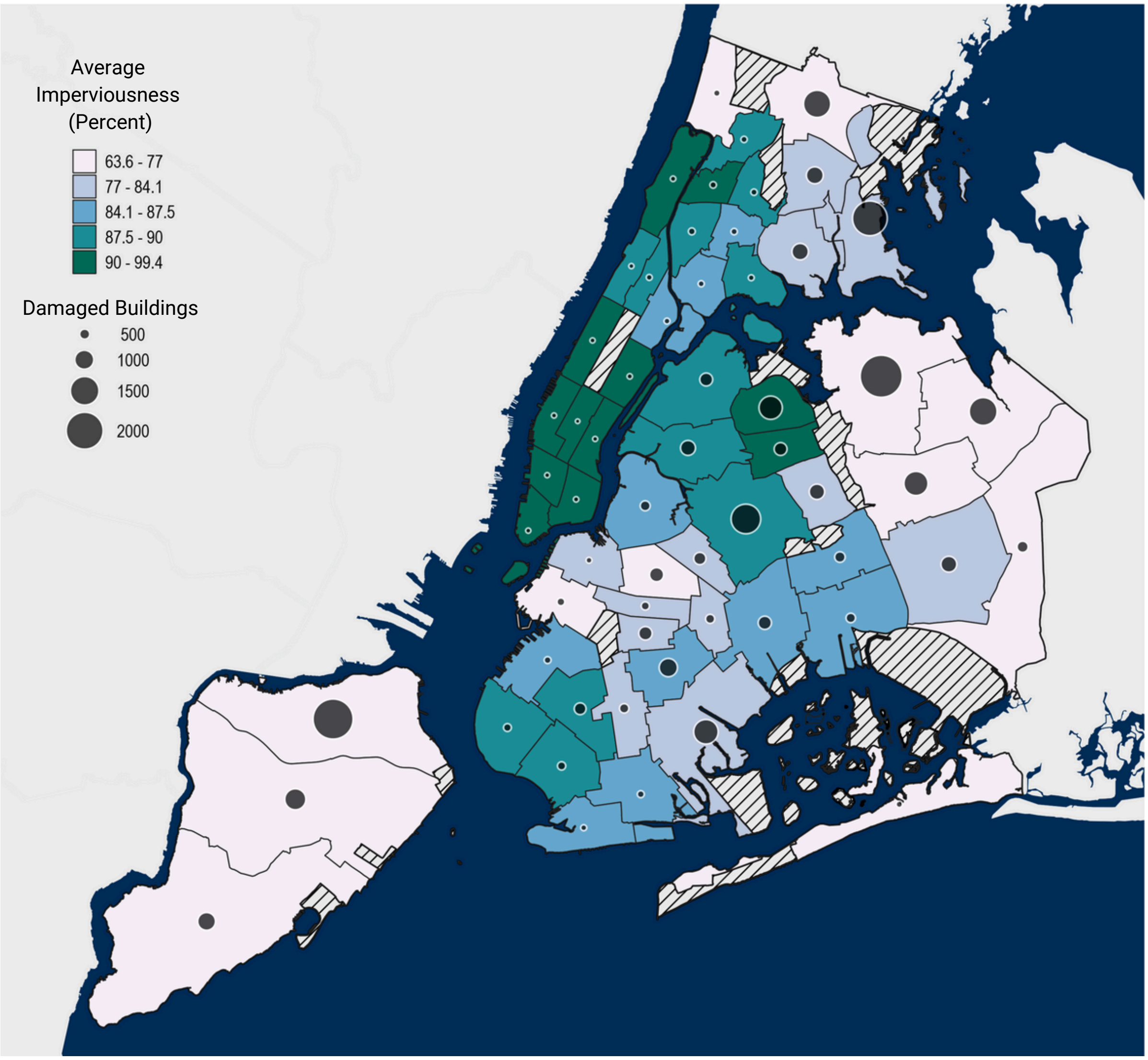


Figure 37: Average Community Imperviousness and Impacted Buildings by CDTA
SOURCE: NYCEM, DEP

Demographic Characteristics

SOCIAL VULNERABILITY

The CDC's Agency for Toxic Substances and Disease Registry publishes the Social Vulnerability Index (SVI), which measures and scores a community's "ability to prevent human suffering and financial loss in a disaster." Communities with greater ability to manage the consequences of a disaster have lower SVI scores, while communities with low ability have high SVI scores. The index is a tool for disaster planning, response, and recovery for emergency managers.

By comparing damage with social vulnerability, the analysis shows that the buildings impacted by PTC Ida have a similar level of social vulnerability as the rest of the community in most community districts (see Figure 38). This indicates low disparity between the buildings impacted in a community and the community in general.

The Rockaways is one notable exception, where damaged buildings are in census tracts with much higher social vulnerability than the rest of the CDTA.

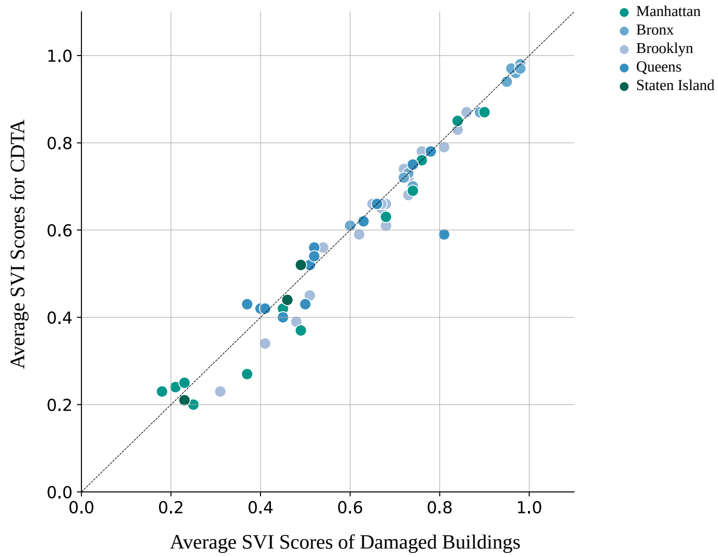


Figure 38: Social Vulnerability Similarity in Community District and Damaged Buildings
Source: NYCEM, CDC

	OVERALL SVI		THEME1: SOCIOECONOMIC		THEME2: HOUSEHOLD COMPOSITION & DISABILITY		THEME3: MINORITY STATUS & LANGUAGE		THEME4: HOUSING TYPE & TRANSPORT	
	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS
High	3,062	9.1%	2,781	8.3%	8,757	26.1%	229	0.7%	7,080	21.1%
Mod-High	7,458	22.2%	7,838	23.4%	8,790	26.2%	3,388	10.1%	7,904	23.6%
Low-Mod	11,055	33%	11,683	34.8%	7,840	23.4%	12,678	37.8%	7,880	23.5%
Low	9,046	27%	8,334	24.9%	5,250	15.7%	14,343	42.8%	7,758	23.1%
Unspecified	2,911	8.7%	2,896	8.6%	2,895	8.6%	2,894	8.6%	2,910	8.7%
Total	33,532	100%	33,532	100%	33,532	100%	33,532	100%	33,532	100%

Table 7: Impacted Buildings by Social Vulnerability Index
Source: NYCEM, CDC

Citywide, the majority of impacted buildings (60%) are located in CDTAs with low or low-moderate social vulnerability; however, nearly a third of impacted buildings are in areas with high or moderate-high social vulnerability.

The map in Figure 39 displays that many communities with the highest levels of storm damage have moderate-high to high SVI scores, indicating a need for support through emergency events.

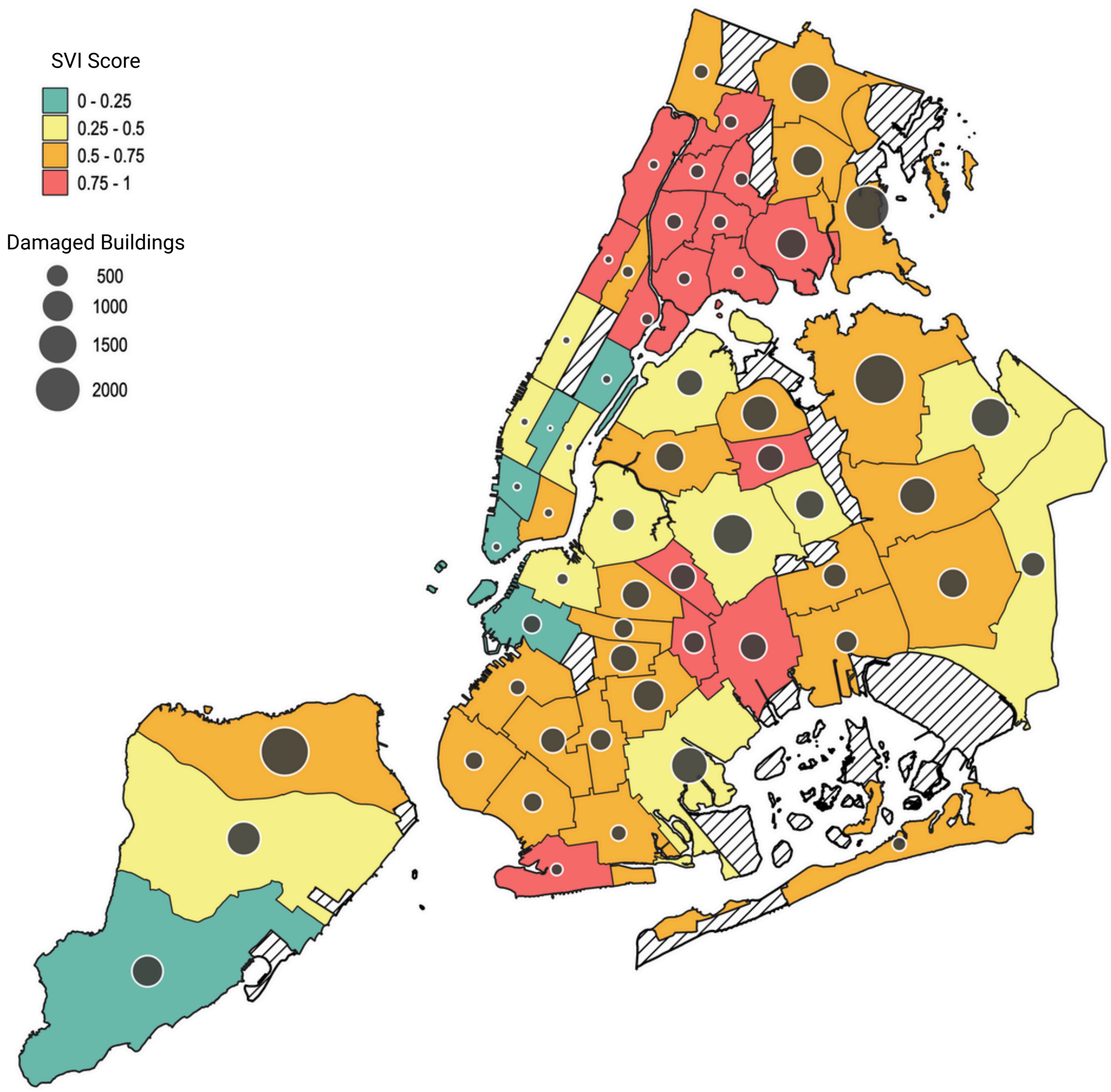


Figure 39: Social Vulnerability and Damaged Buildings by CDTA
SOURCE: NYCEM, DEP

Using SVI thematic scores provides a clearer sense of the type of risks influencing vulnerability in communities based on socioeconomic status, household composition and disability, minority status and language, and housing type and transport (see Figure 40). Like trends in the overall SVI score, most damaged buildings are in CDTAs with low or low-moderate thematic scores. Yet, communities with the most damaged buildings score high to moderate-high vulnerability in socioeconomic status, and minority and language themes, signaling a continued need for recovery support from the flood.

Remarkably, CDTAs with the greatest damage from PTC Ida have low-moderate SVI scores for housing type and transport. This suggests that the housing and transport theme index, which was developed for all communities in the US, uses measures that may not reflect the landscape of New York City. Additionally, it may reinforce a common critique of vulnerability indexes: many vulnerabilities are hazard specific. For example, housing and transport vulnerabilities may differ greatly from flooding hazards to hazardous material releases or earthquakes.

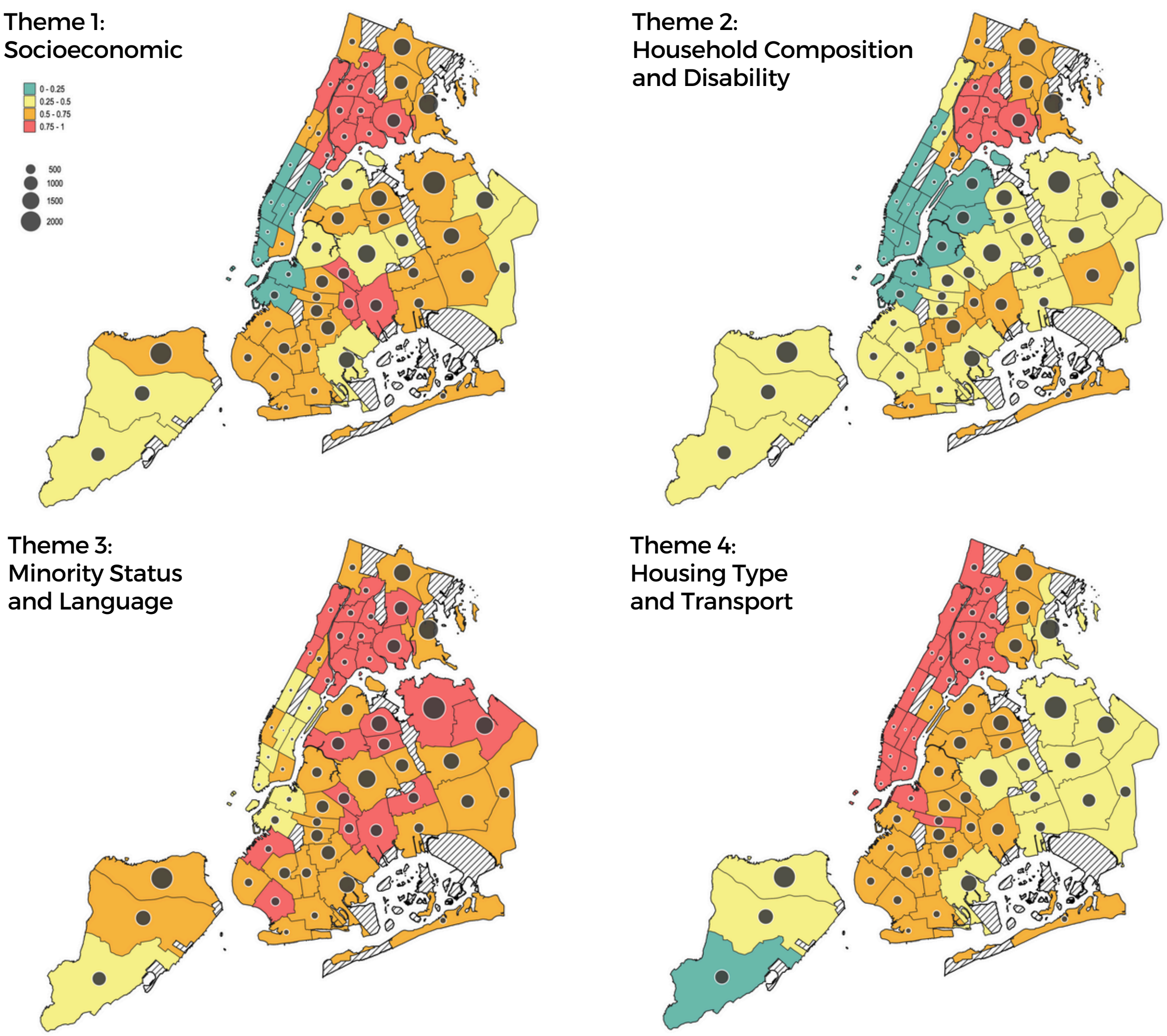


Figure 40: Social Vulnerability Themes and Damage Buildings by CDTA
Source: NYCEM, CDC

RACE AND ETHNICITY

In addition to the SVI theme on minority status and language, the analysis examined race and ethnicity to provide more detail on residents in neighborhoods impacted by PTC Ida. Figure 41 displays both the total and rate of damage, illustrating that neighborhoods with a majority or plurality of Black, Asian, or Hispanic residents experienced the highest rates of damage.

Hispanic New Yorkers are a majority or plurality in six of the ten most impacted neighborhoods (by the rate of damage). Only one community within the ten most impacted neighborhoods (QN06: Forest Hills - Rego Park) has a white plurality. In contrast, most of the least damaged communities have a majority or plurality of white residents.

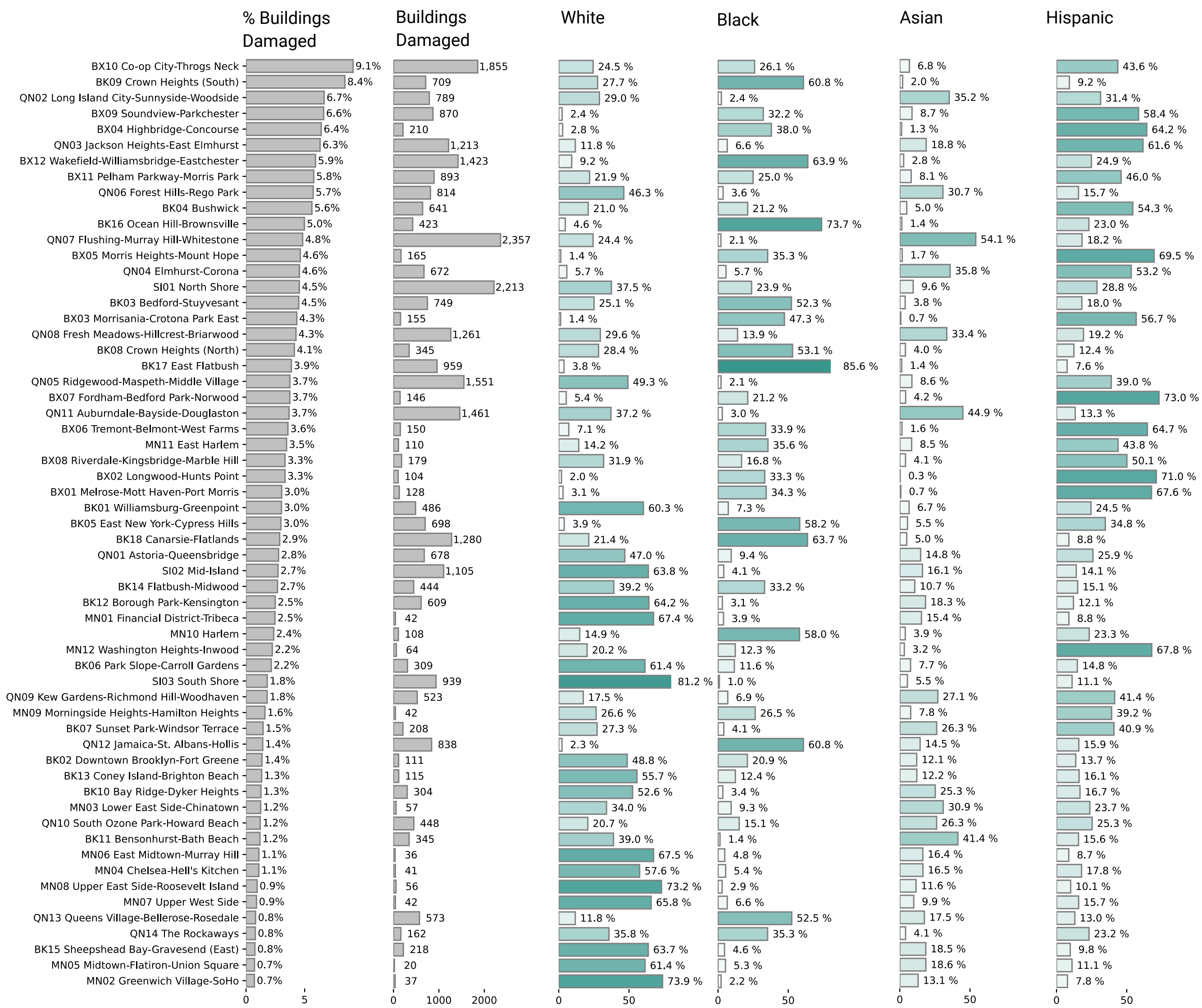


Figure 41: Building Damage, Race and Ethnicity by CDTA
Source: NYCEM, Census Bureau

Figure 42 further confirms the observation, presenting a strong to moderate correlation between community damage rate and the percentage of Hispanic (positive correlation) and white residents (negative correlation).

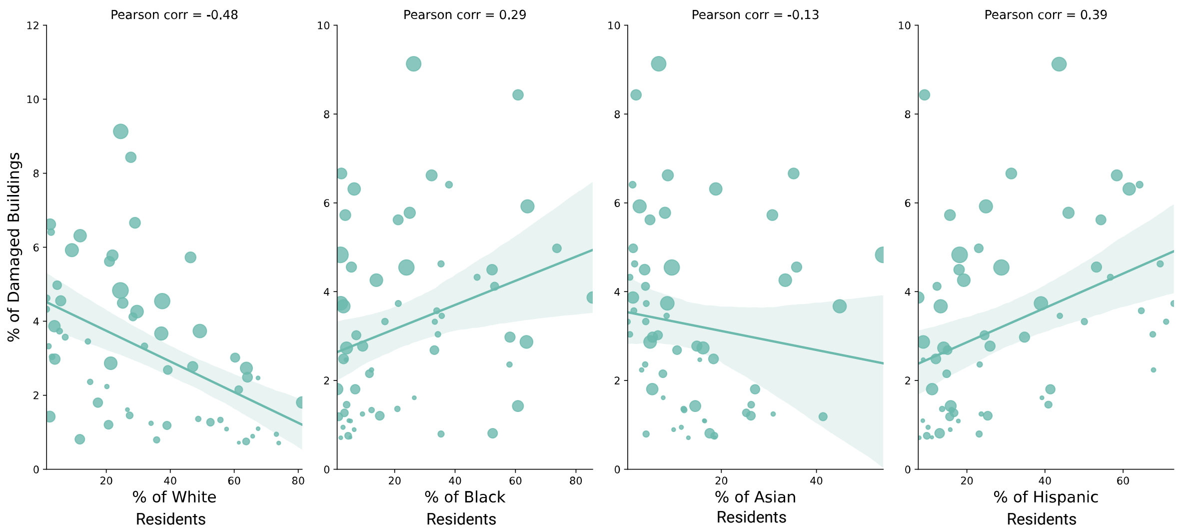


Figure 42: Correlation of Damage Rates and Race and Ethnicity
Source: NYCEM, Census Bureau

LANGUAGES SPOKEN AT HOME

Most of the community districts with the highest rates of damage speak languages other than English at home. Figure 43 presents the languages spoken at home for the ten most and least impacted community districts (by rate of damage).

Spanish is spoken at home at much greater rates in the most damaged neighborhoods, reflecting the racial and ethnic composition of these neighborhoods. Several of these communities also have notable rates of “Other European” and “Other” language speakers. Other European languages include Indo-European languages like Urdu, Hindi, Punjabi, Bengali, and Nepali. “Other” consists of a range of unrelated languages, including Somali, Jamaican Creole, and several Western African languages. In contrast, in communities with the lowest damage rates, English is the majority language spoken at home.

Figure 44 displays the correlation between the rate of damage and the rate of select languages. There is moderate positive correlation between the rate of damage and the rate of Spanish spoken at home and moderate to low negative correlation between the rate of damage and the rate of English spoken at home.

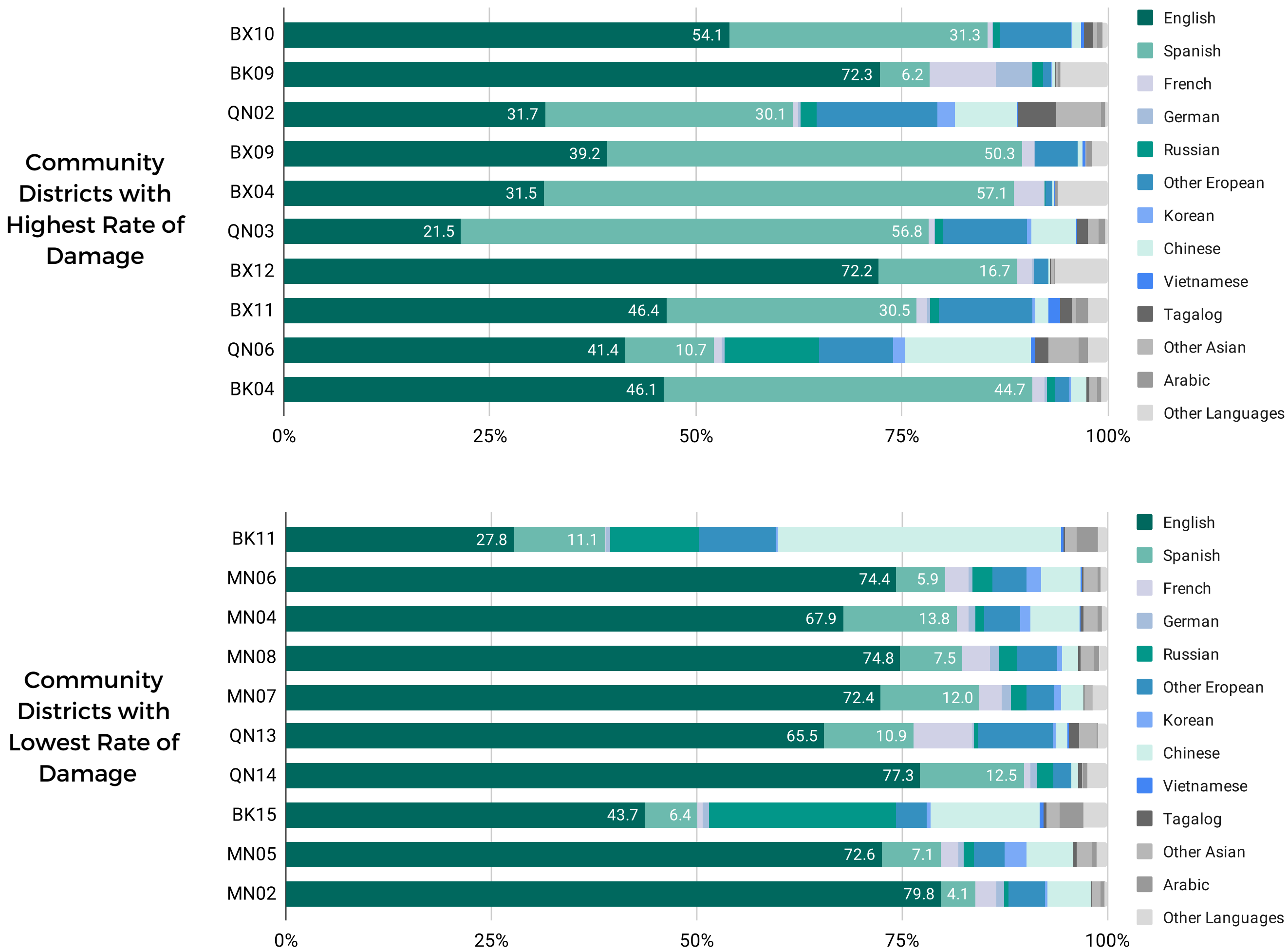


Figure 43: Languages Spoken at Home by CDTA
Source: NYCEM, Census Bureau

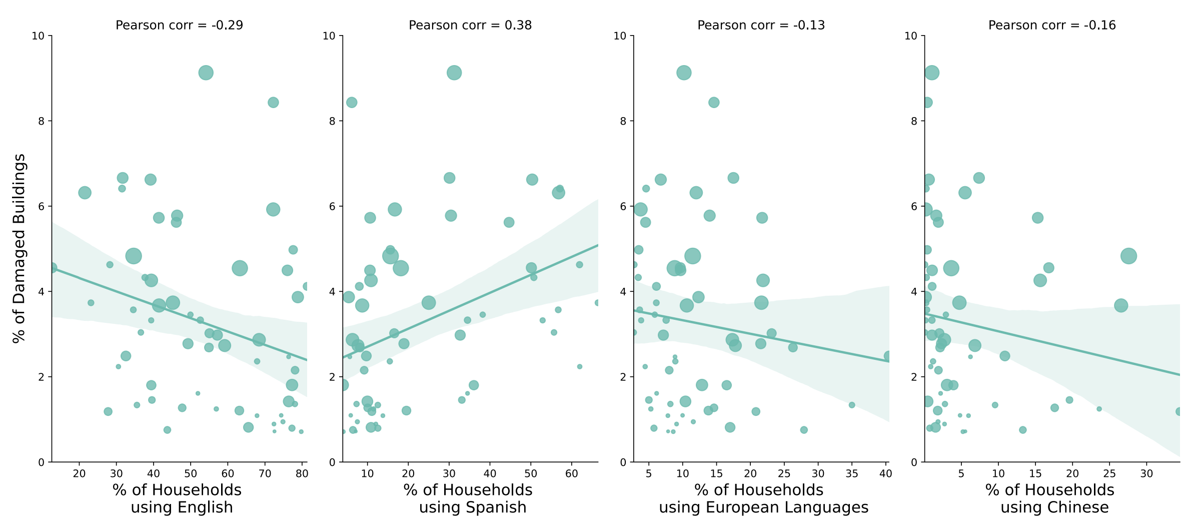


Figure 44: Correlation of the Rate of Damage and Language Spoken at Home by CDTA
Source: NYCEM, Census Bureau

INCOME

Though the SVI socioeconomic theme includes household income as a factor in the ranking, the analysis explored income separately considering the high cost of living and repairs in New York. For context, NYC median household income is ~$67,000, while estimated costs for minimal habitability repairs on damaged one-to-two family homes averaged ~$40,000.

Of the neighborhoods with the highest rate of damage, six out of the top ten have a median household income less than the NYC median (See Figure 46). Figure 45 shows a moderate negative correlation between income and the rate of damage, suggesting that higher-income neighborhoods had less physical damage in their communities while lower-income neighborhoods had more physical damage in their community.

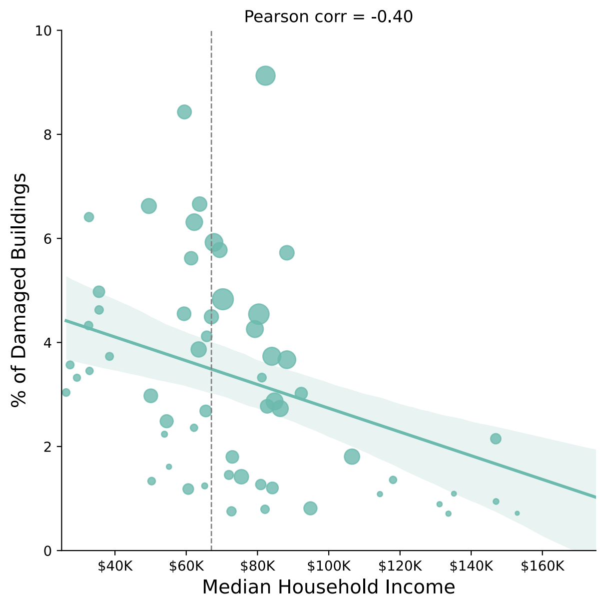


Figure 45: Correlation of Community Damage Rate and Median Household Income by CDTA
Source: NYCEM, Census Bureau

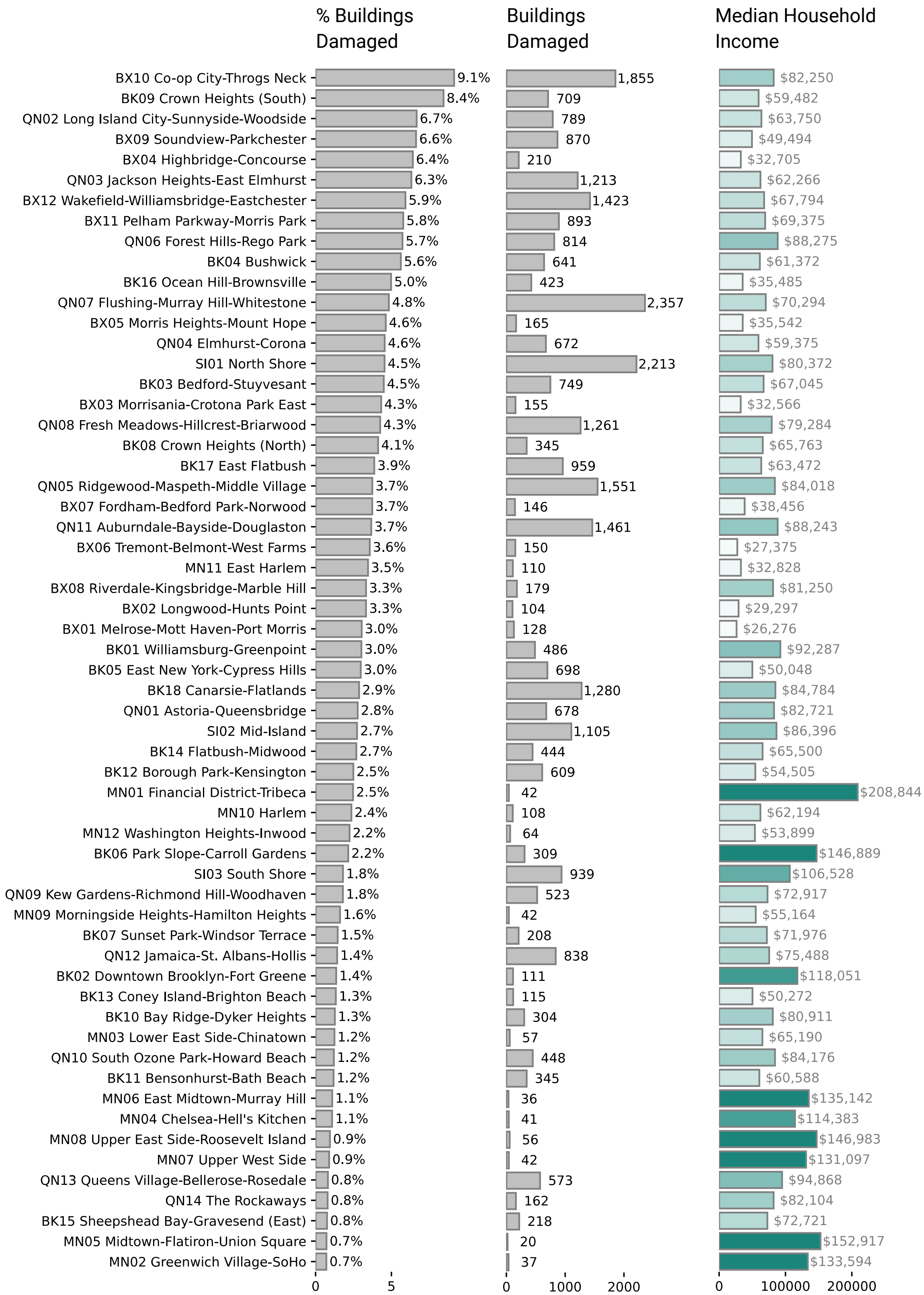


Figure 46: Damage Rates and Median Household Income by CDTA

Source: NYCEM, Census Bureau

Conclusion

The intensity of rainfall during PTC Ida caused widespread flooding throughout New York City, impacting an estimated ~33,500 buildings and ~839,000 New Yorkers. As climate forecasts warn of more frequent rain and more intense rainfall, data-based analysis and models are central to emergency management and resiliency planning. While this report provides an expansive view of PTC Ida's impact, it can inform a deeper exploration of flooding and stormwater risks specific to New York City.

Since PTC Ida, agencies on the local, state, and federal level have conducted a variety of studies, projects, and initiatives to help combat future risks of flash flooding for vulnerable New Yorkers.

Combating Flash Flooding in NYC

- **Rainfall Ready NYC:** In 2022, the City released Rainfall Ready NYC, which outlines the shared responsibilities New Yorkers and City government can do to combat intense storms, together, today.
  - Learn more at https://www.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page

- **Rainproof NYC:** To address increased heavy rainfall in New York City, the Mayor's Office of Climate & Environmental Justice (MOCEJ), the NYC Department of Environmental Protection (DEP), and NYC Housing Recovery Operations (HRO), along with Rebuild by Design and One Architecture & Urbanism, "Rainproof NYC," is a collaborative initiative that brings together government agencies, non-profits, and an array of stakeholders to further develop innovative policies and programs aimed at addressing the challenges New York City faces as climate change causes increased heavy rain events.
  - Learn more at https://climate.cityofnewyork.us/initiatives/rainproof-nyc/

- **DEP/NYCHA Clinton Houses Cloudburst Stormwater Resiliency:** The Clinton Houses Cloudburst Stormwater Resiliency project will develop and implement stormwater flood control measures at the NYCHA Clinton Houses campus in East Harlem. Through the use of green infrastructure and nature-based solutions, cloudburst management stormwater techniques will be applied to store and infiltrate runoff during high intensity rainfall and flash flooding events.

- **DEP Kissena Corridor Cloudburst Hub:** The Kissena Corridor Cloudburst Hub project will turn the Kissena Corridor's outdoor public spaces and surfaces into layers that can absorb, capture, or divert precipitation through green and grey infrastructure, reducing the impacts of local flooding. This neighborhood scale hub will apply cloudburst stormwater management techniques such as porous pavement, conveyances, and onsite storage.

- **Backwater Valves Installation Scoping Study:** The Backwater Valves Study and Report will evaluate the benefits of installing backwater valves for mitigating damage from backflow during severe weather events. The study will inform the creation of a program to support property owners in installing backwater valves, subject to available program funding.

- **Expansion of FloodNet Sensors:** FloodNet is a cooperative of communities, researchers, and New York City government agencies working to better understand the frequency, severity, and impacts of flooding in New York City. Through a network of sensors placed throughout the five boroughs, the collected data can be used to help identify highly impacted communities in real-time. The damage data from this report was used to help inform new locations for these sensors.

- **FEMA Hurricane Ida New York City Mitigation Assessment Team Technical Reports:** As part of the Federal Emergency Management Agency response to significant urban flooding and damage resulting from Hurricane Ida, the FEMA Building Science Disaster Support program deployed a Mitigation Assessment Team (MAT) to assess damage. FEMA publishes reports to document what MATs observe and recommend.
    - The full report can be found here: https://www.fema.gov/emergency-managers/risk-management/building-science/disaster-support

- **USGS High-Water Marks Survey :** The U.S. Geological Survey (USGS) conducted a survey between September 7 and November 23, 2021 across the five boroughs, and is based on observations of mud, debris, and seed lines left by the flooding. Real time and static GNSS surveying as well as available lidar data were used to determine high-water mark elevations at 83 locations.
    - The full report can be found here: https://www.usgs.gov/data/high-water-marks-five-boroughs-new-york-city-flash-flooding-caused-remnants-hurricane-ida

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Credits

NYC Emergency Management's Risk Analysis and Recovery Unit developed this report in collaboration with Far Out Ventures Inc. It draws heavily on the expertise and partnership of teams across agencies, working together to respond and recover from emergency events, reduce hazard risks, and increase the resiliency of NYC communities. Many thanks to all data providers and partners for their contributions and continued work towards a safe, healthy, and equitable NYC.

PROJECT TEAM

New York City Emergency Management helps New Yorkers before, during, and after emergencies through preparedness, education, and response. The Risk Analysis & Recovery unit leads planning and analysis to recover and mitigate risks from all hazards, advances the city's mitigation and recovery capacities, develops tools that enhance risk awareness, and integrates risk and resiliency into emergency planning efforts.

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Far Out Ventures advises leaders on the strategic use of data and technology to improve organizations and systems. They partner with clients in government, technology, and philanthropy to serve local communities with more insight, transparency, and purpose.

Far Out Ventures is a NYC-certified Women-owned Business Enterprise (WBE).

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NYC Mayor's Office of Climate & Environmental Justice
NYC Mayor's Office of Housing Recovery Operations
NYC Mayor's Office of Management and Budget

Appendix

APPENDIX A: GLOSSARY

ACRONYM	NAME
ACS	American Community Survey
CDC	Center for Disease Control and Prevention
CDTA	Community District Tabulation Area
DCAS	NYC Department of Citywide Administrative Services
DCP	NYC Department of City Planning
DEP	NYC Department of Environmental Protection
DOB	NYC Department of Buildings
DOE	NYC Department of Education
DOHMH	NYC Department of Health and Mental Hygiene
DOITT	NYC Department of Information Technology & Telecommunications
DPR	NYC Department of Parks and Recreation
DSNY	NYC Department of Sanitation
FDNY	NYC Fire Department
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
HPD	NYC Department of Housing Preservation & Development
IA	Individual Assistance Program
MOCEJ	Mayor's Office of Climate and Environmental Justice
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration

ACRONYM	NAME
NPCC	New York City Panel on Climate Change
NYPL	New York Public Library
NYCEM	New York City Emergency Management
NYCHA	New York City Housing Authority
NYPD	NYC Police Department
PA	Public Assistance Program
PEU	NYC Mayor's Public Engagement Unit
SBS	NYC Department of Small Business
SVI	Social Vulnerability Index

APPENDIX B: DATA SOURCES

THEME	TOPIC	TOPIC DETAIL	SOURCE	DATASET NAME
Weather	Rainfall	Rainfall	NYCEM	NYCEM Hazard History Event Weather
		Flood Sensors	MOCEJ, FloodNet	FloodNet
Damage Indicators	Severe Building Damage	Structural Damage	DOB via NYC Open Data	DOB Complaints Received
	Emergency Response Requests, Canvassing, and Assessments	Requests and Field Work	Various, including NYCEM Damage Assessment Tool, DOB Assessments, and City Cleanup Corps	Master Tracker
		DOE Flood Report	DOE	Flood Report
		Generators	DEP	Generator Requests
		Dewatering	DEP	Dewatering Requests
		Sewer Backup Flood Complaints	DEP	Sewer Backup Flood Complaints
		Canvassing	Mayor's Public Engagement Unit, NYPD	Master Tracker
	Utility	Gas Outage	National Grid	Bronx Ida Flood Tickets Gas
		Electric Outage	Con Edison	Ida B-Service Off
	Service Requests	311 Complaints	311 via NYC Open Data	Service Requests
Physical Infrastructure	Buildings	Building Size	DCP	Primary Land Use Tax Lot Output (PLUTO)
		Building Age	DCP	Primary Land Use Tax Lot Output (PLUTO)
		Building Type	DCP	Primary Land Use Tax Lot Output (PLUTO)
		Vacates (Historical)	DOB via NYC Open Data	DOB Complaints Received
			HPD via NYC Open Data	Order to Repair/ Vacate Order
				Housing Maintenance Code Violations
		Subgrade Space	DCP via NYC Open Data	Building Elevation & Subgrade
	Sewer	Sewer Type	DEP via NYC Open Data	Municipal Separate Storm Sewer System
			TBD	Combined Sewer Storm Sewer System
	Flood Risk	Coastal Flood	FEMA / NYCPCC	Climate Risk Information
		Stormwater Flood	MOCEJ	New York City Stormwater Resiliency Plan

THEME	TOPIC	TOPIC DETAIL	SOURCE	DATASET NAME
Geography and Environment	Topography	Low Lying Area	DOITT	Building Footprint
	Land Cover	Open Space	DCP	Primary Land Use Tax Lot Output (PLUTO)
		Imperviousness	DEP	Citywide Parcel-Based Impervious Area
	Administrative District	Tabulation Area	DCP	Community District Tabulation Areas
Financial	City Investment	Affordable Housing	NYU Furman Center	Subsidized Housing Database (BBL Analysis)
	Property Value	Property Value	DOF via NYC Open Data	Property Valuation and Assessment Data
	Distress	Distress	DOF via NYC Open Data	Tax Lien Sale List
	Disaster Aid and Awards	Aid/Awards	FEMA	Individual Assistance
			FEMA	Public Assistance
			FEMA	National Flood Insurance Program
Demographics	Neighborhood Characteristics	Social Vulnerability	CDC	Social Vulnerability Index
		Race/Ethnicity	US Census Bureau	ACS 2020 5-year estimate

APPENDIX C: INDICATOR DETAILS

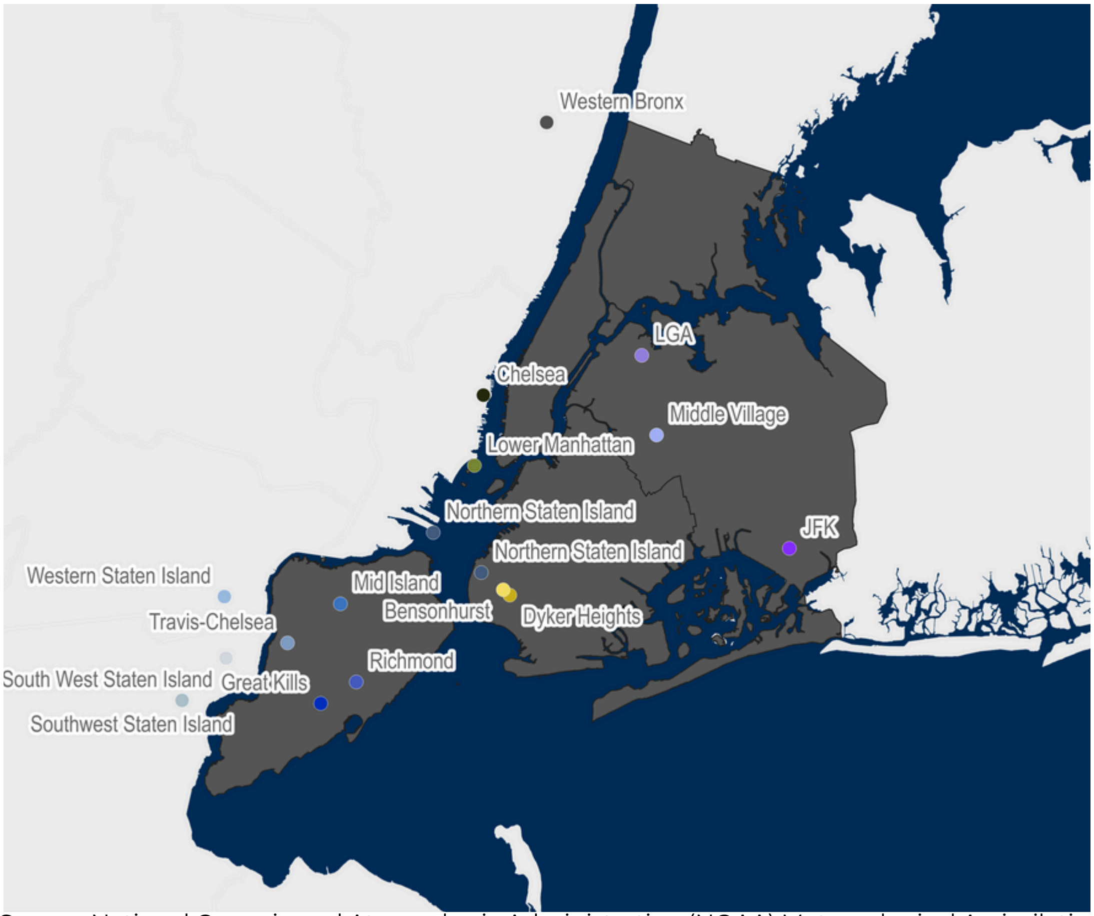
Damage Indicators

TYPE	INDICATOR	VERIFIED OR SELF-REPORTED	SOURCE	PARAMETERS
Health and Housing	Debris Removal Assistance	Self-reported	NYCEM - Damage Assessment Tool	Self reported condition via Damage Assessment Tool.
	Flooring Issues	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Stairway and floor-related complaints received by 311 and assigned to HPD between 9/1/2021 to 9/7/2021. Complaint types include "FLOORING/STAIRS". To minimize the likelihood of counting buildings that were not impacted by Ida but reported housing issues of Paint/Plaster or Flooring/Stairs during and immediately after the event, this is only selected when there is at least one other indicator of damage associated with a building.
	Mold	Self-reported	NYCEM - Damage Assessment Tool	Self reported condition via Damage Assessment Tool.
	Mold	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Mold complaints received by 311 and assigned to DOHMH and/or HPD between 9/1/2021 to 10/13/2021. Complaint types include "Mold" and "MOLD".
	Paint and Plaster Issues	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Paint or plaster-related complaints received by 311 and assigned to HPD between 9/1/2021 to 9/7/2021. Complaint type includes "PAINT/PLASTER". To minimize the likelihood of counting buildings that were not impacted by Ida but reported housing issues of Paint/Plaster or Flooring/Stairs during and immediately after the event, this is only selected when there is at least one other indicator of damage associated with a building.
	Potential Mold Condition	Self-reported	NYCEM Damage Assessment Tool	Self reported condition via Damage Assessment Tool.
	Repair Assistance	Self-reported	NYCEM Damage Assessment Tool	Repair assistance needed. Self reported condition via Damage Assessment Tool.

TYPE	INDICATOR	VERIFIED OR SELF-REPORTED	SOURCE	PARAMETERS
Water and Flooding	Indoor Sewage	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Indoor sewage complaints received by 311 and assigned to DOHMH between 9/1/2021 to 9/7/2021. Complaint type includes "Indoor Sewage".
	Plumbing Issues	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Plumbing-related complaints received by 311 and assigned to HPD and/or DOB between 9/1/2021 to 9/7/2021.Complaint types include "Plumbing", and "PLUMBING".
	Sewer Backup	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Complaints received by 311 and assigned to DEP between 9/1/2021 to 9/7/2021 with a descriptor "Sewer Backup (use Comments) (SA)" .
	Water Leak	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Water leak complaints received by 311 and assigned to HPD between 9/1/2021 to 9/7/2021. Complaint types include "WATER LEAK" with descriptor "Sewer Backup (use Comments) (SA)".
Utility Disruption	Electric Outage	Verified	ConEd	Electric service shutoff verified by ConEd.
	Electric Outage	Self-reported	NYC Open Data - 311 Service Requests from 2010 to Present	Electrical-related complaints received by 311 and assigned to HPD and/or DOB between 9/1/2021 to 9/7/2021. Complaint types include "Electric", "ELECTRIC", and "Electrical".
	Gas Outage	Verified	National Grid	Gas service shutoff or outage reported by NatGrid.
Claims and Awards	Individual Assistance Award	Verified	FEMA	Individual Assistance awards administered to households by building.
	National Flood Insurance Program Claim	Verified	MOCEJ - NYC Ida Claims	National Flood Insurance Program claim.
	Public Assistance Grants	Verified	NYC OMB	Public Assistance grants associated with a building.

APPENDIX D: SUPPLEMENTAL INFORMATION

NYC Weather Station Locations



Source: National Oceanic and Atmospheric Administration (NOAA) Meteorological Assimilation Data Ingest System (MADIS) via NYCEM

Impacted Buildings by Borough

BOROUGH	TOTAL BUILDINGS	IMPACTED BUILDINGS	% OF TOTAL BUILDINGS	% OF TOTAL NYC IMPACTED BUILDINGS
Manhattan	45,541	659	1.4%	2.0%
Bronx	104,698	6,277	6.0%	18.7%
Brooklyn	331,207	8,963	2.7%	26.7%
Queens	461,466	13,369	2.9%	39.9%
Staten Island	141,760	4,264	3.0%	12.7%
Total NYC	1,084,672	33,532	3.1%	100.0%

Source: NYCEM

Buildings Impacted by Community District Tabulation Area

RANK	CDTA	CDTA NAME	TOTAL BUILDINGS	IMPACTED BUILDINGS	% CDTA BUILDINGS IMPACTED
1	QN07	Flushing-Murray Hill-Whitestone	48,793	2,357	4.8%
2	SI01	North Shore	48,694	2,213	4.5%
3	BX10	Co-op City-Throgs Neck	20,318	1,855	9.1%
4	QN05	Ridgewood-Maspeth-Middle Village	41,496	1,551	3.7%
5	QN11	Auburndale-Bayside-Douglaston	39,801	1,461	3.7%
6	BX12	Wakefield-Williamsbridge-Eastchester	24,029	1,423	5.9%
7	BK18	Canarsie-Flatlands	44,629	1,280	2.9%
8	QN08	Fresh Meadows-Hillcrest-Briarwood	29,609	1,261	4.3%
9	QN03	Jackson Heights-East Elmhurst	19,212	1,213	6.3%
10	SI02	Mid-Island	40,437	1,105	2.7%
11	BK17	East Flatbush	24,792	959	3.9%
12	SI03	South Shore	52,010	939	1.8%
13	BX11	Pelham Parkway-Morris Park	15,458	893	5.8%
14	BX09	Soundview-Parkchester	13,139	870	6.6%
15	QN12	Jamaica-St. Albans-Hollis	58,900	838	1.4%
16	QN06	Forest Hills-Rego Park	14,215	814	5.7%
17	QN02	Long Island City-Sunnyside-Woodside	11,846	789	6.7%
18	BK03	Bedford-Stuyvesant	16,666	749	4.5%
19	BK09	Crown Heights (South)	8,409	709	8.4%
20	BK05	East New York-Cypress Hills	23,446	698	3.0%
21	QN01	Astoria-Queensbridge	24,444	678	2.8%
22	QN04	Elmhurst-Corona	14,759	672	4.6%
23	BK04	Bushwick	11,408	641	5.6%
24	BK12	Borough Park-Kensington	24,484	609	2.5%
25	QN13	Queens Village-Bellerose-Rosedale	70,618	573	0.8%
26	QN09	Kew Gardens-Richmond Hill-Woodhaven	29,031	523	1.8%
27	BK01	Williamsburg-Greenpoint	16,101	486	3.0%
28	QN10	South Ozone Park-Howard Beach	37,164	448	1.2%
29	BK14	Flatbush-Midwood	16,535	444	2.7%
30	BK16	Ocean Hill-Brownsville	8,501	423	5.0%
31	BK08	Crown Heights (North)	8,373	345	4.1%
32	BK11	Bensonhurst-Bath Beach	29,126	345	1.2%
33	BK06	Park Slope-Carroll Gardens	14,358	309	2.2%
34	BK10	Bay Ridge-Dyker Heights	23,909	304	1.3%

RANK	CDTA	CDTA NAME	TOTAL BUILDINGS	IMPACTED BUILDINGS	% CDTA BUILDINGS IMPACTED
35	BK15	Sheepshead Bay-Gravesend (East)	28,916	218	0.8%
36	BX04	Highbridge-Concourse	3,276	210	6.4%
37	BK07	Sunset Park-Windsor Terrace	14,286	208	1.5%
38	BX08	Riverdale-Kingsbridge-Marble Hill	5,382	179	3.3%
39	BX05	Morris Heights-Mount Hope	3,567	165	4.6%
40	QN14	The Rockaways	20,423	162	0.8%
41	BX03	Morrisania-Crotona Park East	3,584	155	4.3%
42	BX06	Tremont-Belmont-West Farms	4,200	150	3.6%
43	BX07	Fordham-Bedford Park-Norwood	3,910	146	3.7%
44	BX01	Melrose-Mott Haven-Port Morris	4,210	128	3.0%
45	BK13	Coney Island-Brighton Beach	8,621	115	1.3%
46	BK02	Downtown Brooklyn-Fort Greene	8,164	111	1.4%
47	MN11	East Harlem	3,184	110	3.5%
48	MN10	Harlem	4,575	108	2.4%
49	BX02	Longwood-Hunts Point	3,129	104	3.3%
50	MN12	Washington Heights-Inwood	2,860	64	2.2%
51	MN03	Lower East Side-Chinatown	4,584	57	1.2%
52	MN08	Upper East Side-Roosevelt Island	5,916	56	1.0%
53	MN01	Financial District-Tribeca	1,701	42	2.5%
54	MN09	Morningside Heights-Hamilton Heights	2,605	42	1.6%
55	MN07	Upper West Side	4,707	42	0.9%
56	MN04	Chelsea-Hell's Kitchen	3,769	41	1.1%
57	MN02	Greenwich Village-SoHo	5,208	37	0.7%
58	MN06	East Midtown-Murray Hill	3,283	36	1.1%
59	MN05	Midtown-Flatiron-Union Square	2,781	20	0.7%
60	QN81	Flushing Meadows-Corona Park	151	3	2.0%
61	BX27	Bronx Park	228	2	0.9%
62	BK55	Prospect Park	65	1	1.5%
63	QN83	JFK International Airport	282	0	0.0%
64	SI95	Great Kills Park-Fort Wadsworth	184	0	0.0%
65	QN84	Jamaica Bay (East)	168	0	0.0%
66	BX28	Pelham Bay Park	121	0	0.0%
67	BK56	Jamaica Bay (West)	95	0	0.0%
68	BX26	Van Cortlandt Park	60	0	0.0%
69	MN64	Central Park	60	0	0.0%
70	QN80	LaGuardia Airport	49	0	0.0%
71	QN82	Forest Park	36	0	0.0%

Source: NYCEM

Count of Damage Indicators

CATEGORY	DAMAGE INDICATOR	DATA SOURCE	TYPE OF SOURCE	# OF BUILDINGS	
Health and Housing	DOB vacate order	DOB	Assessed/verified	62	6,036
	Repair	Damage assessment tool	Resident-reported (Ida)	3,905	
	Debris removal	Damage assessment tool	Resident-reported (Ida)	2,091	
	Mold	Damage assessment tool	Resident-reported (Ida)	1,193	
	Potential mold	Damage assessment tool	Resident-reported (Ida)	1,040	
	Mold	311	Resident-reported (non-event specific)	90	
	Plumbing	311	Resident-reported (non-event specific)	1,014	
	Paint/Plaster	311	Resident-reported (non-event specific)	367	
	Flooring/Stairs	311	Resident-reported (non-event specific)	409	
Water and Flooding	Flooding	DOE flood report	Assessed/verified	169	6,177
	Indoor sewage	311	Resident-reported (non-event specific)	47	
	Sewer	311	Resident-reported (non-event specific)	5,530	
	Water leak	311	Resident-reported (non-event specific)	409	
	Dewatering	Generator request	Resident-reported (Ida)	11	
	Dewatering	Basement generator request	Resident-reported (Ida)	55	
Utility Disruption	Gas outage	National Grid	Assessed/verified	239	582
	Electrical outage	Con Ed	Assessed/verified	6	
	Electrical outage	311	Resident-report (non-event specific)	343	
Claims and Awards	IA	FEMA	Assessed/verified	23,781	25,032
	PA	FEMA	Assessed/verified	328	
	NFIP	NFIP	Assessed/verified	1,059	

Damage by Building Class

BUILDING CLASS	DAMAGED BUILDINGS	% DAMAGED BUILDINGS
A: One Family	12,578	37.5%
B: Two Family	11,398	33.4%
C: Walk up apartment	5,947	17.7%
D: Elevator apartment	1,548	4.6%
S: Residence - multiple use	592	1.8%
R: Condominium	482	1.4%
W: Education facility	248	0.7%
K: Store buildings	158	0.5%
Y: Government installations	121	0.4%
O: Office buildings	69	0.2%
M: Religious facilities	52	0.2%
E: Warehouses	49	0.2%
I: Hospitals	47	0.1%

Source: DCP, NYCEM

Damaged Buildings by City Agency

AGENCY	TOTAL BUILDINGS	DAMAGED BUILDINGS	% OF DAMAGED BUILDINGS
NYCHA	2,971	230	7.7 %
DOE	1,350	153	11.3 %
NYPD	144	56	38.9 %
DPR	2,324	52	2.2 %
FDNY	425	35	8.2 %
DSNY	226	25	11.1 %
DCAS	253	24	9.5 %
NYPL	68	13	19.1 %
H+H	119	10	8.4 %
HPD	271	8	3.0 %
DEP	430	4	0.9 %
SBS	342	4	1.2 %
SCA	70	4	5.7 %
DOHMH	26	3	11.5 %
DHS	74	2	2.7 %
QPL	56	2	3.6 %
DDC	28	1	3.6 %
DCA	54	1	1.9 %
DOC	204	1	0.5 %

Source: DCP, NYCEM

Impacted Buildings, Units, and Residents

	RESIDENTIAL BUILDING	MIXED BUILDING	COMMERCIAL BUILDING	TOTAL
NYC BUILDINGS	940,377	67,739	61,278	1,084,672
DAMAGED BUILDINGS	30,879	1,704	803	33,532
IMPACTED RESIDENTIAL UNITS	145,306	72,253	N/A	217,559
IMPACTED POPULATION	383,309	170,994	N/A	554,303

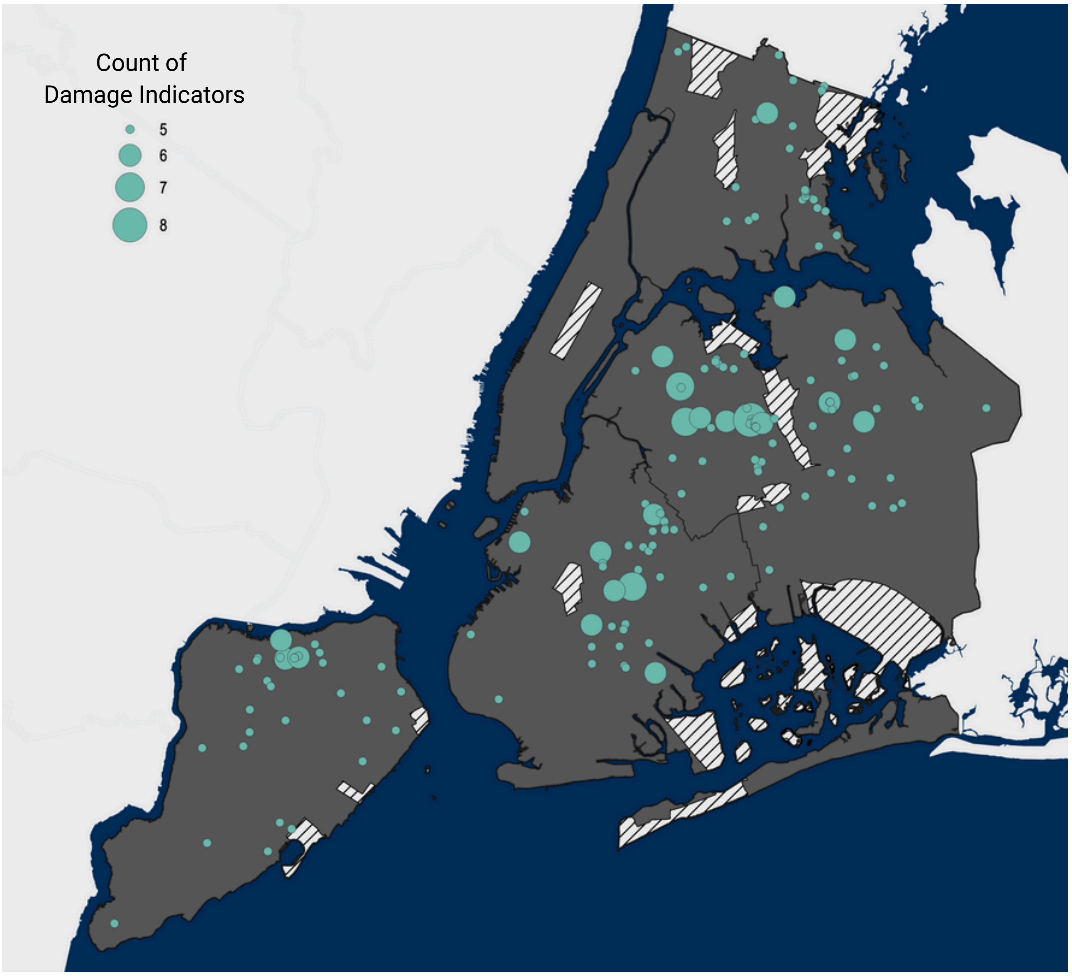
Source: DCP, NYCEM, Census Bureau

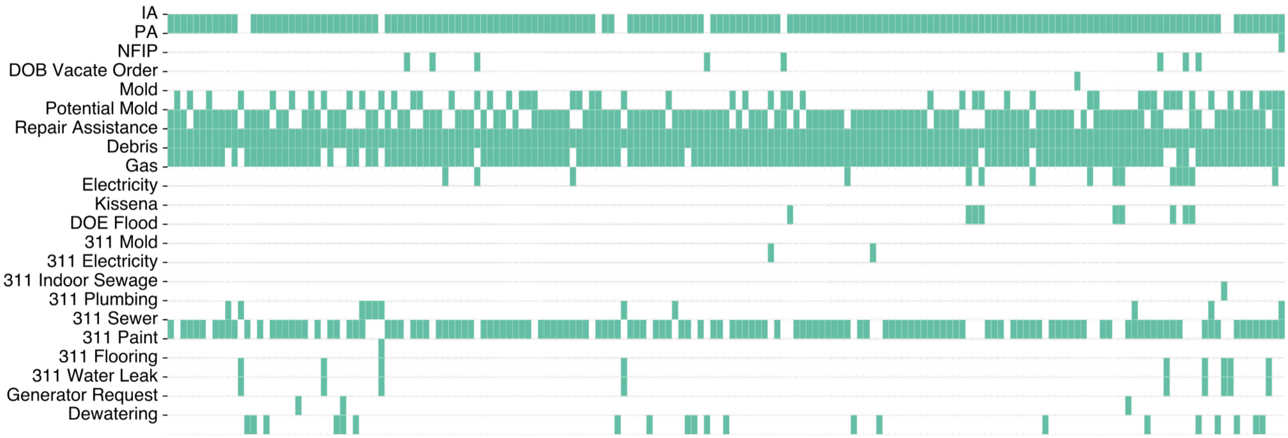
Impacted Buildings, Units, and Residents by Flood Scenario

	TOTAL BUILDINGS	DAMAGED BUILDINGS IN THE SCENARIO	DAMAGED BUILDINGS OUT OF THE SCENARIO	TOTAL HOUSING UNITS	IMPACTED UNITS IN THE SCENARIO	IMPACTED UNITS OUT OF THE SCENARIO	TOTAL POPULATION	IMPACTED POPULATION IN THE SCENARIO	IMPACTED POPULATION OUT OF THE SCENARIO
FEMA 100 YEAR	90,810	2,305	31,227	341,312	27,421	190,138	815,326	488,669	65,636
FEMA 500 YEAR	148,634	4,591	28,941	548,680	46,117	171,442	1,321,321	443,168	111,136
MODERATE STORMWATER	40,943	3,598	29,934	175,024	19,565	197,995	431,236	502,779	51,525
EXTREME STORMWATER	219,286	14,331	19,201	861,275	81,764	135,796	2,161,874	342,584	211,720

Source: DCP, NYCEM, Census Bureau, MOCEJ

Buildings with Five or More Indicators of Damage





Source: NYCEM, FEMA, NFIP, 311, PEU, HRO, DOB,