RESILIENT NJ
NORTHEASTERN NEW JERSEY

FLOOD IMPACT ASSESSMENT

JUNE 2022

Image Source: accarrino

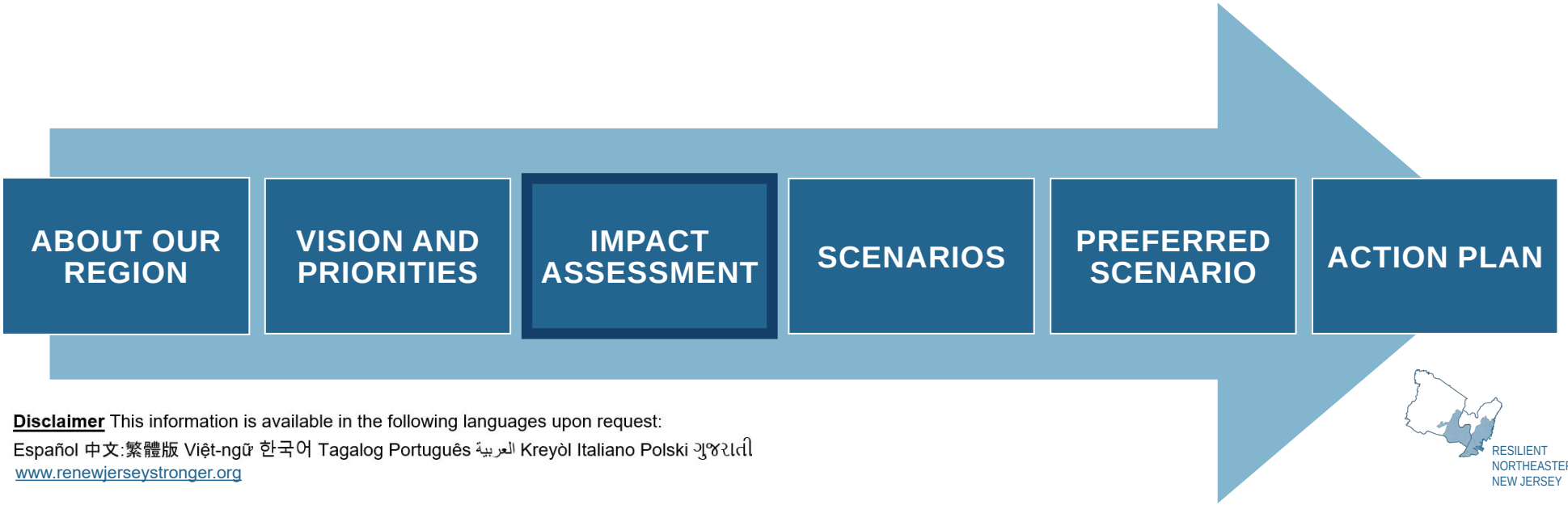
SHARE YOUR FEEDBACK

Resilient Northeastern NJ is always seeking your feedback to guide the program and ensure it is reflective of perspectives and priorities from across the region. Please continue to share your feedback on the program and get in touch with us through either of the options below:

- BY EMAIL: ResilientNENJ@gmail.com
- BY SOCIAL MEDIA: @ResilientNENJ on Twitter & Facebook, @resilient_nenj on Instagram

Please visit our website at www.resilient.nj.gov/nenj to learn more about the program and what we've done so far.

The About Our Region report (released April 2021) shared the planning context, while the Vision and Priorities report (released October 2021) summarized what we had heard from the community so far. **The Impact Assessment describes what might happen under certain storm and tide conditions if nothing is done to protect the region from current and future climate threats.** This assessment summarizes flood impacts, while the full Climate Hazards Assessment report (released separately) provides insight on other climate threats, such as extreme heat, groundwater rise, and decreased air quality, and will include the executive summary of flood impacts.



Disclaimer This information is available in the following languages upon request:
Español 中文:繁體版 Việt-ngữ 한국어 Tagalog Português العربية Kreyòl Italiano Polski ગુજરાતી
www.renewjerseystronger.org

RESILIENT NORTHEASTERN NEW JERSEY

REGION TEAM
Steering Committee Members

JERSEY CITY
Tye Waggoner, Lyndsey Scofield, Kate Lawrence, Lindsey Sigmund, and Carolina Ramos

NEWARK
Nathaly Agosto Filión, Robert Thomas, and Juba Dowdell

HOBOKEN
Caleb Stratton, Jennifer Gonzalez, Ann Holtzman and Yasmine Pessar

BAYONNE
Suzanne Mack and Andrew Raichle

HUDSON COUNTY
Kevin Force and Francesca Giarratana

HOPES CAP
Evelyn Mercado and Barbara Reyes

IRONBOUND COMMUNITY CORPORATION
Drew Curtis and Maria Lopez Nuñez

CONSULTANTS

ARCADIS

INGROUP

SCAPE LANDSCAPE ARCHITECTURE

ONE ARCHITECTURE & URBANISM

IRYS

SAM SCHWARTZ ENGINEERING

HGA

RESILIENT NJ
NORTHEASTERN NEW JERSEY

FLOOD IMPACT ASSESSMENT

JUNE 2022

CONTENTS

EXECUTIVE SUMMARY 6

ACRONYMS & DEFINITIONS 10

01 - INTRODUCTION 15

About This Report 16
Our Relationship with Water 18
Sources of Flooding 23
Who and What are at Risk? 24
People and Places 24
Social Vulnerability and Risk 26
Assets at Risk 30
New Flood Models 36
Measuring Impacts 42
Considerations and Limitations 43

02 - REGIONAL FLOOD IMPACTS 45

Regional Critical Asset Exposure 46
Rainfall Flooding Impacts 50
Tidal Flooding Impacts 56
Storm Surge Impacts 58
Comparison of Results 60
Breakdown of Impacts 61

03 - CITY AND STUDY AREA FLOOD IMPACTS 65

Jersey City 66
East Jersey City 70
West Jersey City 74
North Jersey City 78
Newark 82
Doremus - East Ironbound 86
Dayton - Airport 90
Ironbound 94
Downtown Newark 98
Branch Brook Park 102
Ivy Hill & Vailsburg 106
Clinton Hill, Weequahic & West Side 110
Hoboken 114
Bayonne 120
East Bayonne 124
Central & West Bayonne 128

04 - NEXT STEPS 133

APPENDICES 137

REFERENCES 139

RESILIENT
NORTHEASTERN
NEW JERSEY

EXECUTIVE SUMMARY

Administered by New Jersey's Department of Environmental Protection (NJDEP), Resilient New Jersey brings together resilience experts, local leaders, community organizations, residents, and regional agencies to discuss risk and resilience-related issues and develop effective solutions. The New Jersey program is undertaking detailed resilience studies in coordination with four pilot regions: Northeastern New Jersey, Raritan River and Bay Communities, Long Beach Island, and the Atlantic County Coastal Region.

This report summarizes findings from the Flood Impact Assessment for Resilient Northeastern New Jersey (NENJ), a pilot region encompassing Jersey City, Newark, Hoboken, and Bayonne. Resilient NENJ is a partnership between the municipalities, Hudson County, Ironbound Community Corporation, and HOPES CAP, Inc. The report describes what will likely happen under certain storm and tide conditions if nothing is done to protect the region from current and future climate-related threats.

Northeastern New Jersey has been shaped by its relationship with water. Large portions of the region used to be a marsh that could absorb rainfall from storm events, but as the land was settled, the wetlands drained, and the urban landscape developed, flood risk has increased. Much of the region is covered with impervious surfaces, such as concrete, which accelerate the rate at which water moves across the ground. **Heavy rainfall, coastal storms, and tidal flooding all impact the region today and this risk is evolving with climate change.**

NENJ is a vibrant, densely populated, and constantly evolving region that around 700,000 people call home. The people of this region represent a wide range of social backgrounds, values, opportunities, and challenges, including many neighborhoods classified by the Center for Disease Control as amongst the highest-ranking socially vulnerable census tracts in the country, which means the region's people are especially at risk from the impacts of climate change. While NENJ is part of the New York City metropolitan area and deeply intertwined with New York City's economy, the region also stands alone as a community with treasured waterfront, county and neighborhood parks, retail and restaurant corridors, small businesses, festivals, arts and recreational centers, and many other important community places. Impacts to this region can reverberate across the larger metropolitan area, state, and nation due to the presence of several public transportation hubs, interstate and state highways, and the critical port and airport infrastructure, as well as energy, waste, water, and wastewater infrastructure of regional and statewide importance.

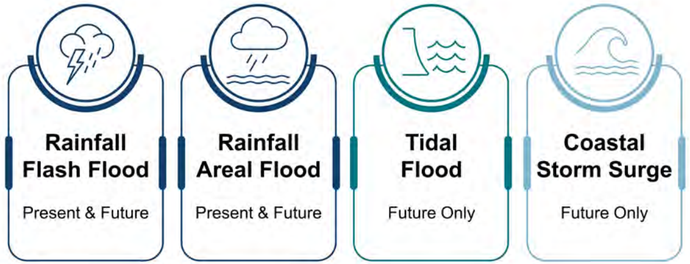
This assessment uses an extensive inventory of buildings and critical assets, built from the best available data. The inventory includes:

- 3,000 critical assets across approximately 50 unique asset types,
- 2,200 acres of parks and public open space,
- 1,300 miles of linear assets, such as roads, bridges, and transmission lines, and
- 43,000 buildings, such as residences, businesses, industrial sites, religious spaces, or public services.

NJDEP developed models of flooding for large storms that may affect the region. These models estimate the depths of flooding even in areas where historical flood data are not available, making them useful in highlighting potential flood-prone areas, comparing possible flood mitigation options, and prioritizing action. The models are for rainfall and storm surge events similar to those that have occurred in the past and add sea level rise.

Resilient NENJ modeled two distinct types of rainfall-based flood events to help clarify where and how bad flooding might occur during different types of major rainstorms: Flash Flooding and Areal Flooding. Flash floods occur when there is a significant amount of rainfall over a short period of time (the model uses two hours). Areal floods occur when flooding develops more gradually and comes from sustained rainfall over a longer period of time (the model uses 24 hours). Ida (2021) is an example of what can happen during a flash flood event, as significant rainfall fell over a relatively brief period; Newark saw almost four inches of rain in one hour. Irene (2011), on the other hand, is an example of an areal flood event. Irene had a longer build up with 10 inches falling during August 27 and 28.

MODELED FLOOD EVENTS



All flood scenarios simulate tidal peaks at Mean Higher High Water, which represents the average of the higher of the two daily high tides. Resilient NENJ modeled an extreme coastal storm surge event by taking the observed high-water marks experienced during Hurricane Sandy and projecting them into 2070, assuming 2.4 feet of sea level rise.

TYPES OF IMPACTS QUANTIFIED

With a baseline understanding of flood hazards, along with the people, places, and things throughout the region that may be impacted, the Resilient NENJ team quantified the range of impacts flooding has on our region using a variety of metrics. The team used methodologies developed by the Federal Emergency Management Agency (FEMA) and the United States Army Corps of Engineers (USACE) to quantify four types of impacts to buildings and the people, businesses, and services they house: direct physical damage, human impacts, business and fiscal impacts, and loss of function. Results from this assessment are summarized as Total Direct Losses, or the sum of these four types of damage for all buildings within the reporting area. In cases where Total Direct Losses were either unavailable or inappropriate indicators, additional exposure metrics quantify impacts, including Population Counts, Asset Counts, Building and Contents Values, and Land Values. In addition to the quantified losses, the Resilient NENJ team also looked at qualitative impacts of flooding, such as areas where significant flooding overlaps with concentrations of socially vulnerable people and ways that damages to infrastructure can reverberate across the region.

Resilient NENJ categorized critical assets based on their relationship to the people they serve. Keeping with this approach, the team prioritized community assets within each category based on the breadth of impact – how wide-reaching losses of the asset might be felt – as well as the magnitude of impact, approximated as the depth of flooding experienced across all the evaluated flood events. The following list represents exposed critical assets with regional importance, while prioritized assets for each city are summarized later in this report.

INFRASTRUCTURE

- **Newark Liberty International Airport (EWR)** is currently exposed to both modeled rainfall and storm surge flooding.
- Most of **New Jersey Transit's rail lines**, which are also used by Amtrak trains, run through the region, and all PATH stations are in the region.
- **Ferry terminals** in NENJ, including the Hoboken, Warren Street, and Liberty Harbor terminals, serve nine ferry services to downtown Manhattan that carry approximately 15,000 people daily.
- Without action, areas of **Port Newark** could expect 14 feet of flooding during a future extreme storm surge event.
- **Roadways, bridges, and tunnels** will be impacted under rainfall and storm surge events, including the Holland Tunnel along with surface streets, impacting accessibility throughout the region.
- All eight of the **active power generation facilities**, together contributing more than 2,700 megawatts of power to the electrical grid, have at least some portion of their facilities exposed to all of the modeled flood events.
- Two of the region's **Wastewater Treatment Plants (WWTPs)** are likely to be exposed to future rainfall and storm surge flooding: The North Hudson Sewerage Authority Adams Street Plant and the site of the Passaic Valley Sewerage Commission (PVSC) WWTP (which has received significant flood mitigation in the wake of Hurricane Sandy.)

EMERGENCY RESPONSE

- **Hoboken University Medical Center** is expected to be exposed to future extreme storm surge events.
- Flood mitigation measures under construction at **Jersey City Medical Center** should effectively protect against the flood scenarios modeled, as long as all measures that require emergency action are deployed effectively (e.g., deployable barriers).
- The region is home to approximately **50 hurricane evacuation routes**, 40 miles of which may be exposed to at least 6 inches of flooding in the modeled future storm surge flood event. Six inches of flooding on a road is enough to damage vehicles, make routes impassable, and potentially pose serious threats to life safety.

PUBLIC HEALTH

- The **Northern State Prison** in Newark, which houses 2,600 people, is at risk to both rainfall and coastal flooding events.
- **Columbus Hospital** in Newark is expected to be exposed to flooding due to both present and future major rainfall events.[1]
- **Combined sewer outfalls and known contaminated sites** are widespread through the region and flooding at these assets would negatively impact the community.

QUALITY OF LIFE

- **Liberty State Park** is expected to experience flooding during the future rainfall and extreme storm surge events, which will disrupt its use by the community and potentially cause ecological harm.

ECOSYSTEM HEALTH

- There remains approximately 200 acres of sensitive **wetland habitats** in the region, mostly in the Meadowlands area of Jersey City. Eighty percent of these wetlands are expected to be inundated by high tides with sea level rise.

[1]*Note that some hospitals fall into emergency response related assets and others are public health related assets. The difference is that hospitals with emergency departments are classified as emergency response, and hospitals without are classified as public health for this assessment.*

Community degradation from repeat and unmitigated flooding is formidable. The risk is here, now. Coastal and rainfall flooding are already widespread in the region. **A present-day flash flood event has the potential to cause $2.7 billion in losses, while a present-day areal flood event is expected to cause $5.2 billion in losses.**

Areas with the biggest risk from rainfall flooding, including **East Jersey City, Hoboken, and the Ironbound neighborhood of Newark, are each expected to incur more than $500 million in losses in a future rainfall event if no mitigation action is taken.** These same areas, as well as the Dayton-Airport area in Newark, are also expected to have the highest losses in a future storm surge event, with **losses in each study area expected to be more than $3.5 billion.** These loss estimates represent direct impacts to buildings and residents and do not consider reverberating economic losses, impacts to mobility, or the disproportionate effects these losses may have on under-resourced communities.

Flooding regionwide is significant and is the product of a combination of factors, including elimination of natural flow pathways over recent centuries, expanding impervious surfaces, and outdated drainage infrastructure. Coupled with climate change and other quality of life concerns in the region, this culminates in **$6 billion of potential losses in a future areal rainfall event and $31 billion in a future extreme storm surge event.**

Overall, 280,000 residents are expected to have their homes exposed to either rainfall or coastal storm surge flooding, representing over 40 percent of the population in the region at large. Of these residents, **half live in areas of high social vulnerability.**[2] In other terms, about a third of the residents in these most highly socially vulnerable areas are exposed to flooding.

Areas that are expected to have the deepest flooding with no action (based on the modeled rainfall events) include Vailsburg, Upper Roseville, South Ironbound, the western coasts of Jersey City and Bayonne, Liberty State Park and areas to its west, and Southwest Hoboken. These areas could also be expected to flood first during a rainfall event. Upper Roseville, South Ironbound, and Southwest Hoboken have higher proportions of socially vulnerable people based on the Centers for Disease Control and Prevention's (CDC's) Social Vulnerability Index and, therefore, should be prioritized in scenario development.

Various actions are already underway across the region to help address storm surge flooding. For example, the Resilient NENJ team estimates, based on new flood modeling, that the Rebuild by Design-Hudson River and Newark Flanking Plan projects combined could reduce risk to areas that could experience $11 billion in losses across 2,300 buildings and impact 69,000 residents in a future extreme storm surge event.

No matter the solutions, a fair amount of risk is likely to remain, particularly from rainfall flooding. As such, investment will need to consider both the community's ability to respond and recover from flooding and how to reduce its impacts.

[2] *as defined as an SVI score over 0.75.*

ACRONYMS

BRIC – FEMA's Building Resilient Infrastructure and Communities program
CDC – Centers for Disease Control and Prevention
CSO – Combined Sewar Outfall
EWR – Newark International Airport
FEMA – Federal Emergency Management Agency
GCT – Global Container Terminals
HUD – U.S. Department of Housing and Urban Development
IMTT – International-Matex Tank Terminals
KCS – Known Contaminated Sites
LTCP – Long-Term Control Plan
MHHW – Mean Higher High Water
MHW – Mean High Water
MLLW – Mean Lower Low Water
MLW – Mean Low Water
MOTBY – Military Ocean Terminal at Bayonne
MSL – Mean Sea Level
NAVD88 – North American Vertical Datum of 1988
NENJ – Northeastern New Jersey
NFIP – National Flood Insurance Program
NJDEP – New Jersey Department of Environmental Protection
NJDOT – New Jersey Department of Transportation
NJIT – New Jersey Institute of Technology
NJOEM – New Jersey Office of Emergency Management
NWS – National Weather Service
PANYNJ – Port Authority of New York and New Jersey
PATH – Port Authority Trans-Hudson
PVSC – Passaic Valley Sewerage Commission
SLR - Sea Level Rise
SVI – Social Vulnerability Index
USACE – United States Army Corps of Engineers
WWTP – Wastewater Treatment Plant

HOW TO USE THIS REPORT

Since the flood impact assessment addressed risk at multiple scales, the report summarizes impacts starting at the highest, regional level before drilling down into results for each city and their corresponding study areas. Colored headers are used to help differentiate these different scales:

- Background information is presented in **blue** sections,
- Regional results are explained in **orange** sections,
- City impacts are described in **purple** sections, and
- Study Area results are found in **gold** sections

At each scale, impacts are summarized with infographics showing monetized expected losses along with counts of impacted buildings and exposed residents, with:

- Rainfall Flooding impacts in **dark blue** graphics,
- Tidal Flooding impacts in **teal** graphics and
- Coastal Storm Surge impacts in **light blue** graphics

DEFINITIONS

Flooding Terminology

100-year Flood – A commonly used term often referring to a 1 percent annual chance event. This terminology is misleading, as it implies that a sized event should only happen once every 100 years, which is not the case. Today's 1 percent annual chance event has nearly a 40 percent chance of occurring at least once in the next 50 years.

Annual Exceedance Probability – The annual exceedance probability is the probability that a flood or rainfall event of a given size might be met or exceeded in any given year. It is based on long-term statistics of observed storms in the area.

Areal Flooding – Areal floods occur when flooding develops more gradually and comes from sustained rainfall over a longer period. The Resilient NENJ models use around 8 to 9 inches over 24 hours, which is similar to Ido or Irene, depending on the area.

Flash Flooding – Flash floods occur when there is a significant amount of rainfall over a short period of time. The Resilient NENJ models use around 3.5 inches over two hours, which is a little worse than Floyd (1999), Irene (2011), and Henri (2021) in most places and not nearly as heavy as the worst of Ida in 2021.[3]

Future Flooding – In this assessment, future flooding represents potential conditions in 2070; however, due to changing understanding of the rate of climate change, this may occur sooner. These future flooding models for rainfall incorporate 2.4 feet of sea level rise and a 10-percent increase in rainfall. The future coastal flood model adds 2.4 feet onto high water marks from Hurricane Sandy in 2012.

Mean Higher High Water – The rainfall flood models use mean higher high water as the high tide elevation. High tides happen twice a day, and one is usually higher than the other. Mean higher high water is the average height of the daily highest tide.

Present Day Flooding – In this assessment, the present day is represented by rainfall models without sea level rise. This assessment does not include present day flooding models for coastal flooding.

Stormwater Flooding – Flooding that occurs when rainfall overwhelms drainage systems.

Impact-related Terminology

Critical Asset – Critical assets are essential for a community to thrive. They include buildings, infrastructure, or spaces that host community events. Assets can include places where people gather, build relationships, and enjoy themselves.

Present Day Conditions – All models are imposed upon present day conditions, which include 2020 population, building inventory, critical assets, land use types, assessed values, and replacement costs.

Prioritized Asset – Prioritized assets are critical assets exposed to flooding which rank higher than other assets of a similar type. A high ranking indicates more exposure to flooding or a larger impact on the community if flooded.

Other Terminology

Adaptation – The process of modifying behaviors, policy, or the built and natural environment to adjust to risk.

Community Resilience – The capacity and capability of communities to respond, adapt, and transform in response to natural hazards and climate change.

Hazard Mitigation – The act of reducing risk. This can be done through a variety of different strategies and types of actions, which are discussed in more detail in the Resilient NENJ Scenario Development report.

[3] *In actuality, rainfall does not fall evenly over a large area. Localized rainfall amounts may have been higher away from the official observation sites. Further, the amount of flooding from an actual rainfall event will differ based on the conditions of an area (e.g., how much concrete there is or whether storm drains are clogged by leaves that day) and atmospheric conditions leading into the event. For example, Ida and Henri in 2021 were on the heels of a very moisture rich summer.*

Historic Fill – Materials that were brought in from offsite to raise land elevation or displace areas of water. Historic fill was often a combination of soil and other materials such as construction debris, and often contains contamination that requires it to be remediated or cleaned up.

Impervious Surface – Hard surfaces, like asphalt or concrete, that prevent infiltration of water into the soil beneath, which means that more water stays on the ground as runoff and can contribute to flooding. Permeable surfaces are those that allow more infiltration, such as grass or planted areas with soil.

Resilient New Jersey – A regional planning program that brings together resilience experts, local leaders, community organizations, and residents to discuss storm and flood-related issues and develop effective solutions to reduce flood risk and build resilience. The program is administered by the New Jersey Department of Environmental Protection (NJDEP) and supported by a grant from the U.S. Department of Housing and Urban Development (HUD) awarded through the National Disaster Resilience Competition. Resilient New Jersey encompasses four regions: Northeastern New Jersey, Raritan River and Bay Communities, Long Beach Island, and the Atlantic County Coastal Region.

Resilient Northeastern New Jersey – The collaborative partnership dedicated to enacting the Resilient New Jersey program for the region encompassing Jersey City, Newark, Hoboken, and Bayonne. Partners include representatives from each municipality, Hudson County, HOPES Community Action Partnership, and the Ironbound Community Corporation, as well as a team of consultants to aid with community outreach, stakeholder engagement, risk analysis, design and evaluation of mitigation strategies, and the development of the action plan.

Risk, At Risk, Vulnerability – Terms to describe when something is exposed to danger. Risk can also be used in the terms "risk assessment" and "risk probability" where it implies calculations combining how likely something is to happen with some measure of the impact (i.e., How bad is the risk?). Risk and at risk are used in this assessment to indicate exposure to danger.

Social Vulnerability – The degree to which a community's people are challenged when faced with significant disruptions, such as natural disasters or disease. The term is imperfect because it does not acknowledge the systems and circumstances, such as historical discriminatory housing practices, that have contributed to factors such as income that contribute to social vulnerability. Nonetheless, social vulnerability, which is represented in this report using the CDC's Social Vulnerability Index, is a helpful measure for identifying and prioritizing people who have been historically underrepresented or marginalized.

Study Area – Subdivisions of the region identified to support technical assessment and implementation planning. The study areas are based on a combination of flood pathways and watersheds, as well as natural neighborhood and infrastructure boundaries.

Watershed – A watershed can most easily be thought of as an area within which, wherever water falls, it will all eventually flow to the same place. Watershed can cross municipal and state boundaries, which can present a challenge when planning for flooding and risk reduction.

HOBOKEN FLOODING

An ambulance sits stranded at a flooded intersection in Hoboken.

Image Source: *accarrino*

01 - INTRODUCTION

ABOUT THIS REPORT

RESILIENT NORTHEASTERN NEW JERSEY MISSION STATEMENT

Resilient NENJ will provide a clear vision and roadmap for reducing flood risk through collaboration between local and state governments and community-based organizations along with valuable input from the public and other stakeholders. The plan will leave a legacy of regional investment, information, and resource sharing to help our people and places thrive in the decades to come. The plan will be driven by best available data, technical evaluation, and inclusive and equitable engagement. It will leverage best practices to create social, environmental, and economic benefits and bring value to those who live in the region now and for future generations.

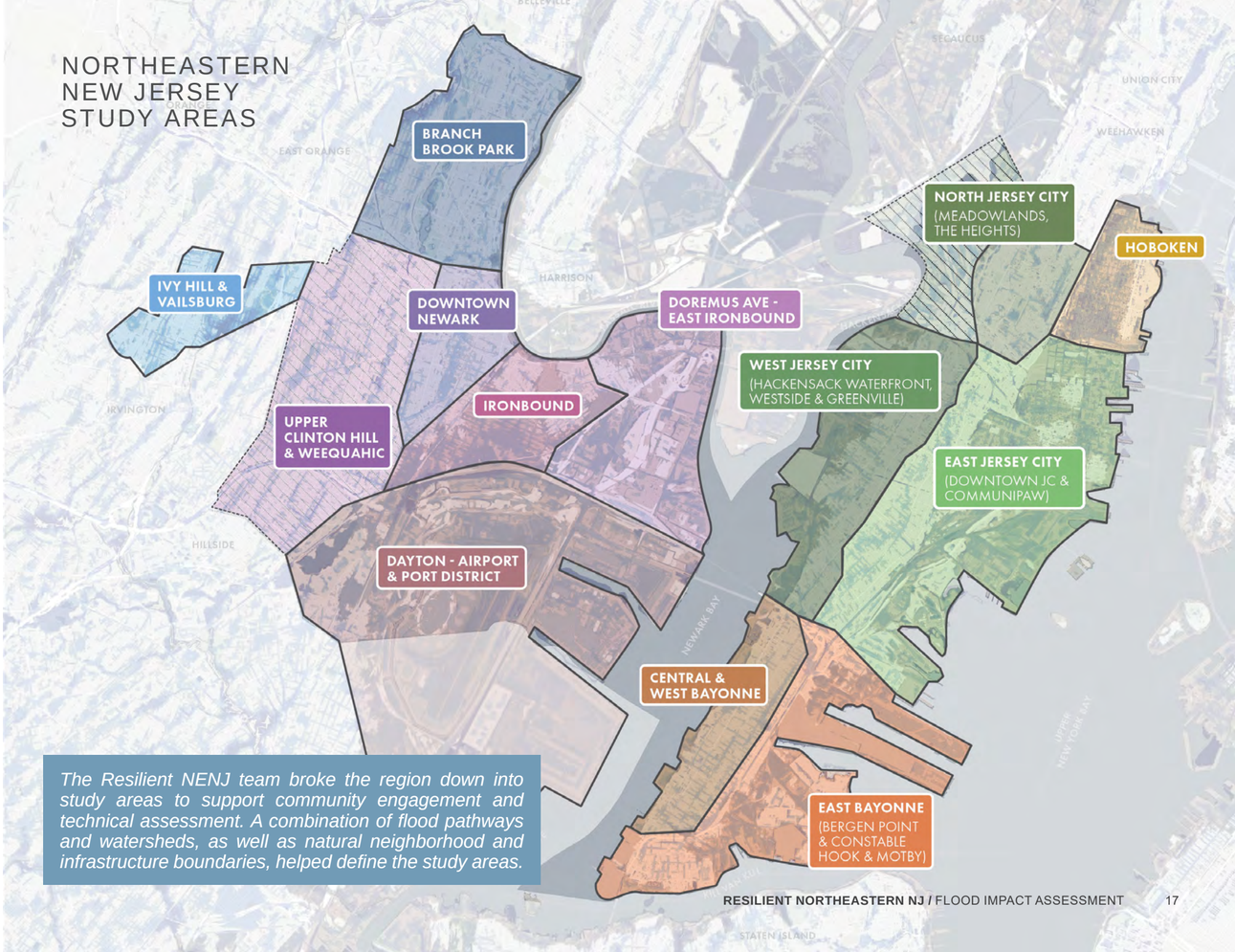
Resilient New Jersey (Resilient NJ) is a regional planning program that brings together resilience experts, local leaders, community organizations, residents, and regional agencies to discuss storm and flood-related issues and develop effective solutions to reduce flood risk and build resilience. The program is administered by the New Jersey Department of Environmental Protection (NJDEP) and funded by the U.S. Department of Housing and Urban Development (HUD). The Resilient Northeastern New Jersey (Resilient NENJ) team addresses these goals in the region covering Jersey City, Newark, Hoboken, and Bayonne.

Resilient NENJ will develop actions to address current and future flooding that build toward long-term social, economic, and physical resilience. To do so, the Resilient NENJ team, community members, agencies, and others who live and work in the region must understand where flooding does and will occur, how bad it is, and how bad it could get in the future.

This report summarizes findings from the Flood Impact Assessment to explain what will likely happen under certain storm and tide conditions if nothing is done to protect the region from current and future climate-related threats. This assessment is based on modeled flooding and engagement to date to achieve the following:

- **Identify who and what** is in the region
- Evaluate their **exposure** to present and future flooding
- **Measure impacts** of flooding experienced by the community in both qualitative and quantitative methods
- Clarify **implications** of those results
- Outline clear **next steps** for developing solutions to reduce flood impacts in the community.

This report should inform action development at different scales – from neighborhoods, to cities, to the region at large. The report starts by summarizing findings at the regional scale before focusing on city- and neighborhood-level consequences of flooding.



The Resilient NENJ team broke the region down into study areas to support community engagement and technical assessment. A combination of flood pathways and watersheds, as well as natural neighborhood and infrastructure boundaries, helped define the study areas.

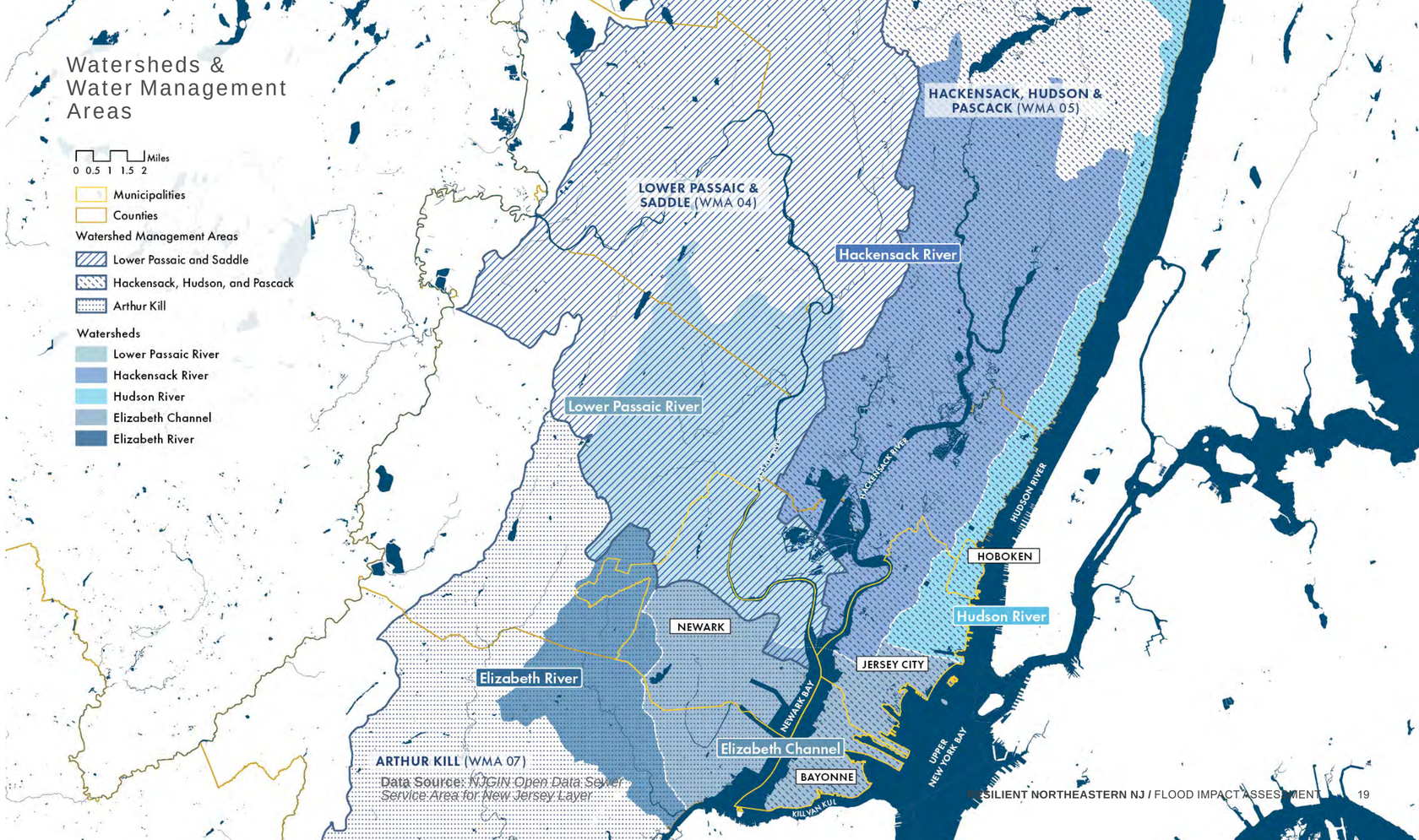
OUR RELATIONSHIP WITH WATER

Northeastern New Jersey has been shaped by its relationship with water. Hoboken is bounded by the Hudson River to the east, while Jersey City has the Hudson River and Upper New York Bay to the east and the Hackensack River to the west. Bayonne is a peninsula surrounded by the Upper New York Bay to the east, the Kill Van Kull to the south, and the Newark Bay to the west. Newark's northeastern and eastern boundaries are surrounded by the Passaic River and Newark Bay.

Much of NENJ used to be a marsh that could absorb rainfall from storm events, but as the land was settled and the wetlands were drained and developed, flood risks increased throughout the region.

At the time of European settlement in the 1600s, the region was home to the Lenape people, and tidal wetlands occupied large areas around the coast. Hoboken was previously a marshy island that the Lenape people inhabited seasonally. Settlers developed these wetlands over time. Wetlands previously known as Newark Meadows are now Port Newark, Newark Liberty International Airport, and the New Jersey Turnpike. Settlers initially drained the Meadowlands using dikes to create farmland. Later, beginning in the late 1800s, dredging the Passaic and Hackensack Rivers and the diversion of water upstream for drinking water increased the saltiness of the freshwater Meadowlands, leading to the displacement of plant species that had once populated the area. The presence of the high elevation Palisades outcrop in this region is also notable, creating dramatic contrast in the area's topography between the low-lying former marsh areas and the higher points, such as the Jersey City Heights, that are part of the Palisades formation. While the higher elevation reduces storm surge exposure to areas such as the Jersey City Heights, they can still experience flooding from rainfall.

The About our Region[4] report provides more on NENJ's history.



[4] *About Our Region Report*, https://tinyurl.com/NENJAboutOurRegion.

Historical Fill

Scale 1:85,000

0 0.5 1 1.5 2 Miles

- Municipalities
- Counties
- Current Coastline
- Historic Fill

Beginning in the 1900s, people added fill to further displace wetlands, add land, or elevate existing land for development. Today, more than 12,000 acres of former wetlands or open water in NENJ has been built up with artificial fill. Fill material covers more than 30 percent of the land areas of Newark, Bayonne, and Jersey City, and more than 60 percent of the land area of Hoboken. Much of the fill was a mix of dredging material from nearby rivers, construction debris, and even garbage. Historically, this fill was not placed many feet above the high tide mark.

Fill takes up space that could have been used to store water or creates land that is low lying and more likely to flood.

HOBOKEN
501 ACRES OF FILL (62% OF HOBOKEN'S LAND AREA)

NEWARK
5,540 ACRES OF FILL (36% OF NEWARK'S LAND AREA)

JERSEY CITY
4,530 ACRES OF FILL (48% OF JERSEY CITY'S LAND AREA)

BAYONNE
1,450 ACRES OF FILL (39% OF BAYONNE'S LAND AREA)

Data Source: *NJGIN Open Data Historic Fill in New Jersey Layer; Library of Congress Topographical Map (1882)*

Impervious Surfaces

Most of the region is also covered in impervious surfaces. Impervious surfaces are non-porous, hard surfaces that do not allow rain water to infiltrate the earth, such as concrete, roads, or buildings. During rain events, impervious surfaces accelerate the rate at which water moves across the ground.

Scale 1:85,000

0 0.5 1 1.5 2 Miles

- Municipalities
- Publicly Owned Impervious Surfaces
- Other Impervious Surfaces

Heavy rainfall, coastal storms, and tidal flooding all impact the region today. These impacts are exacerbated by combined sewer systems and limited drainage capacity. The region's aging drainage systems also contribute to waterway pollution during storm events. The system backs up when the outfalls are blocked by high tides or when sewer lift stations fail due to power outages. These outfalls are spread regionwide, and community members from across the region have reported this flooding from these outfalls.

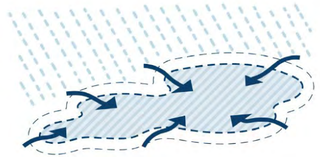
Data Source: *Parcels and MOD-IV Composite of NJ; Impervious Surface of New Jersey from Land Use/Land Cover (2012)*

THE HUDSON RIVER WATERFRONT WALKWAY

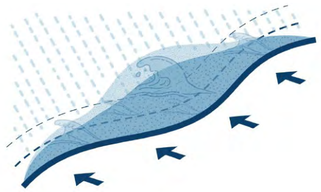
As pictured here in Hoboken, portions of the walkway are already threatened by rising sea levels.

Image Source: *Carter Craft/Outside New York*

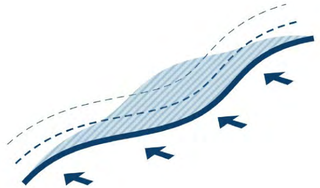
SOURCES OF FLOODING



RAINFALL FLOODING



COASTAL STORM SURGE



TIDAL FLOODING

Quantifying flood impacts will help Resilient NENJ develop a clear action plan for reducing future flood risk. Resilient NENJ is looking at flooding from rainfall, high tides, and coastal storm surge (also described in the Vision and Priorities Report[5]).

Rainfall Flooding: Inches of rain can fall in a few hours during the peak of a storm, causing flooding in low lying areas. These areas might be along waterways (riverine flooding) or inland where rainfall overwhelms storm drains (stormwater flooding). Rainfall flooding affects the entire region today. Bayonne, Hoboken, Jersey City, and Newark all experience flooding during heavy rainstorms, including several times during the summer of 2021 alone.

Tidal Flooding: Tidal flooding is the temporary inundation of low-lying areas due to high tides, which occur regardless of the weather. Sea level rise will cause tides to be higher than they are today, and some areas will flood daily. Future high tides will likely flood places along the Hudson, Hackensack, and Passaic Rivers, as well as along Newark Bay and Upper New York Bay.

Coastal Storm Surge: Tropical storms, hurricanes, and nor'easters can raise water levels along the coast. Storm surge affects areas along the Hudson, Hackensack, and Passaic Rivers, as well as along Newark Bay and Upper New York Bay. Hurricane Sandy is an example of an event with significant storm surge.

The National Flood Insurance Program (NFIP), managed by FEMA, maps riverine flooding and coastal storm surge. FEMA flood maps do not include stormwater flooding, the impacts of climate change, or combined flooding from more than one flood type. Resilient NJ is working to fill these gaps by modeling a range of present and future flood events from each of these three flooding sources.

NWS WARNING DEFINITIONS

The flood events described in this report mirror three types of flood warnings that the **National Weather Service (NWS)** may issue in the region when it is likely that a significant weather event will pose a risk to life and property.

- **Flash Flood Warnings** are issued when heavy rainfall is or is about to cause dangerous small stream or urban stormwater flooding within the next 6-hours, like what may occur during a short duration rainfall event
- **Areal Flood Warnings** are issued when widespread general flooding is or is about to occur, like the flooding associated with a longer duration rainfall event
- **Storm Surge Warnings** are issued when rising ocean water moves inland from the shoreline, typically in association with a tropical storm or Nor'easter whose path directly hits the area.[6]

[5] *Vision and Priorities,* https://tinyurl.com/NENJVisionReport; [6] *NWS New York, NY Watching Warning Advisory Definitions Page,* https://www.weather.gov/okx/wwa_definitions

WHO AND WHAT ARE AT RISK?

Flooding can impact a community in many unique ways. The consequences of flooding are reflected by the people, places, and things in harm's way and their relative resilience against short and long term flood impacts.

USEFUL DEFINITIONS

"Risk" or **"at risk"** are commonly used terms to describe when something is exposed to danger. Another term commonly used to describe when something is exposed to danger is the term **"vulnerability."** Risk can also be used in the terms "risk assessment" and "risk probability" where it implies calculations combining how likely something is to happen with some measure of the impact (i.e., How bad is the risk?). This report uses both risk and at risk to indicate exposure to danger.

Community resilience is the capacity and capability of communities to respond, adapt, and transform in response to natural hazards and climate change. **Hazard mitigation** is the act of reducing risk. **Adaptation** is the process of modifying behaviors, policy, or the built and natural environment to adjust to risk.

PEOPLE AND PLACES

NENJ is a vibrant, densely populated, and constantly evolving region that approximately 700,000 people call home. The region's diversity is valued by its residents, with people speaking a variety of languages and having different ethnic and cultural backgrounds. While NENJ is part of the New York City metropolitan area and deeply intertwined with New York City's economy, the region also stands alone as a community with a treasured waterfront, county and neighborhood parks, retail and restaurant corridors, small businesses, festivals, arts and recreational centers, and many other important community places. As described in later sections of this report, many of these important places have already flooded in recent history or could flood in the future.

Impacts to this region reverberate across the larger metropolitan area due to the area's several public transportation hubs, interstate and state highways, and the critical port and airport infrastructure. As described below, many of the region's residents have historically been left out of the benefits from these economic centers, and the proximity of neighborhoods to this infrastructure also leads to environmental justice concerns because of exposure to pollutants, poor air quality, and subsurface contamination. These additional challenges compound the impacts of flooding for the people of this region. Additional background about the region can be found in the About Our Region report, and information about important community places is included in the Vision and Priorities report.

(top) Man 'fishing' in flood waters in the Ironbound from July 17th thunderstorms.; Man walking through flood waters in the Ironbound from July 17th thunderstorms.; Emergency response team on Vesey Street in the aftermath of Tropical Storm Henri. Source: Kenny Lin

(bottom) Discussion session at a NENJ virtual community meeting. Source: Resilient NENJ

JULY 17 THUNDERSTORMS

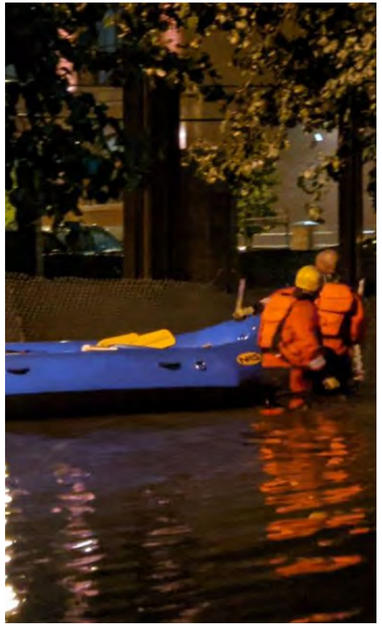
A resident in floodwaters during summer of 2021.

Image Source: Kenny Lin

WADING THROUGH THE IRONBOUND

Waist-deep flooding in the Ironbound neighborhood of Newark during severe thunderstorms on July 17th.

Image Source: Kenny Lin



TROPICAL STORM HENRI

An emergency response team in a flooded Vesey Street in Newark on August 22nd in the aftermath of Tropical Storm Henri.

Image Source: Kenny Lin

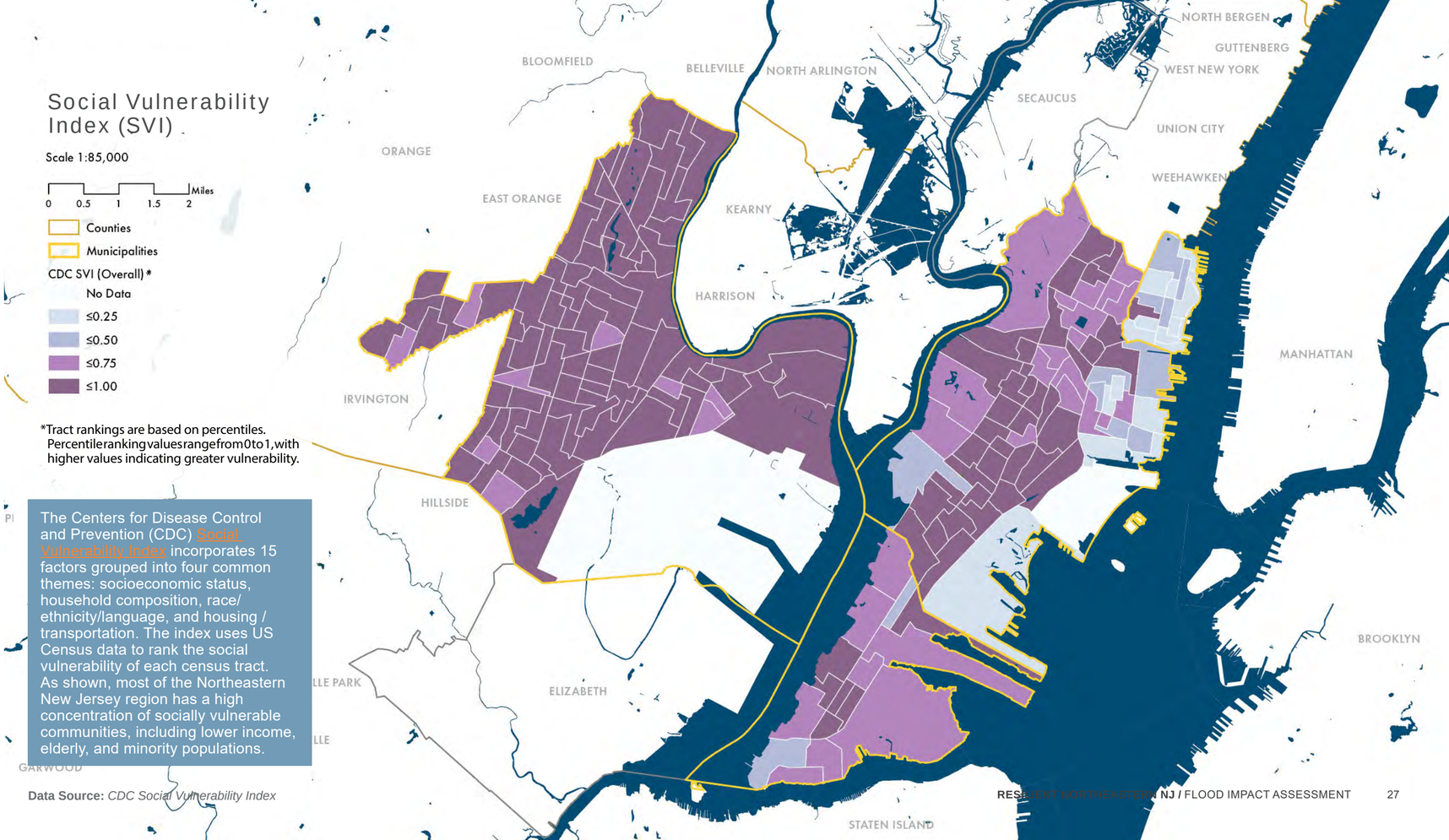
SOCIAL VULNERABILITY AND RISK

SOCIAL VULNERABILITY

Social vulnerability refers to the degree to which a community's people are challenged when faced with significant disruptions, such as natural disasters or disease. A variety of socio-economic factors, in most cases tracing their roots to historical injustices and racially discriminatory practices (such as redlining of neighborhoods), play a pivotal role in understanding the degree of impact a community or household may experience because of flooding. For example, lower income households have fewer resources to adapt to changing and dangerous circumstances – whether by moving to areas or homes less exposed to risk, by retrofitting their homes or securing appropriate flood insurance to withstand severe events, by having access to transportation to seek shelter in an emergency, or to financially recover from a destructive flooding event. Historical exclusion and a lineage of policies that have inequitably distributed resources have tended to make communities within certain demographic categories – such as, Black and Latinx communities, low-income populations, households with low English-speaking proficiency, and people with disabilities – especially susceptible to the most severe impacts of flooding.

The people of this region represent a wide range of social backgrounds, values, opportunities, and challenges. This region – especially Newark and Jersey City – has a notable history of racially discriminatory housing practices from the early- to mid-twentieth century called redlining, whose effects can still be felt today. Most neighborhoods in Newark, Jersey City, Bayonne, and Hoboken were designated as Third and Fourth Grade residential security areas – neighborhoods subject to the most extreme forms of exclusionary planning and zoning practices. Today, many of these same neighborhoods are classified by the CDC as amongst the highest-ranking socially vulnerable census tracts in the country. The CDC's social vulnerability index (SVI) is based on 15 factors, including the following :

- Poverty level
- Unemployment
- Income
- High school diploma
- Aged 65 and older
- Aged 17 or younger
- Disability prevalence
- Single-parent households
- Minority status
- English proficiency
- Multi-unit housing
- Mobile homes
- Crowding
- Vehicle ownership
- Group quarters



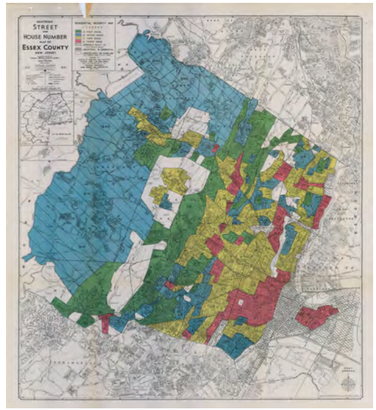
Data Source: *CDC Social Vulnerability Index*

The CDC index shows very high rates of social vulnerability concentrated in Newark, central Jersey City, Bayonne, and southwest Hoboken. Low income, minority residents are spread across Newark, including in the South Ironbound, East Ironbound, Woodside, and Vailsburg. Newark has significant populations of Spanish and Portuguese speaking residents, as well as Haitian Creole and several West African languages, including Yoruba, Igbo, and Akan. Communipaw, Bergen-Lafayette, Greenville, and parts of the Heights are some of the areas in Jersey City with the highest CDC social vulnerability index, and Jersey City is also known for its Little India and Little Manila in the Journal Square and Downtown areas, where Hindi and Gujarati and Tagalog are often spoken, respectively. Bayonne has a notable Polish-speaking population as well as a tight-knit Coptic Christian, Arabic-speaking community. Hoboken's low-income and minority populations, mostly Spanish speaking, are primarily concentrated in the Hoboken Housing Authority properties and surrounding streets in Southwest Hoboken. Overall, 430,000 residents in the region (65 percent) live in areas designated with an SVI over 0.75.

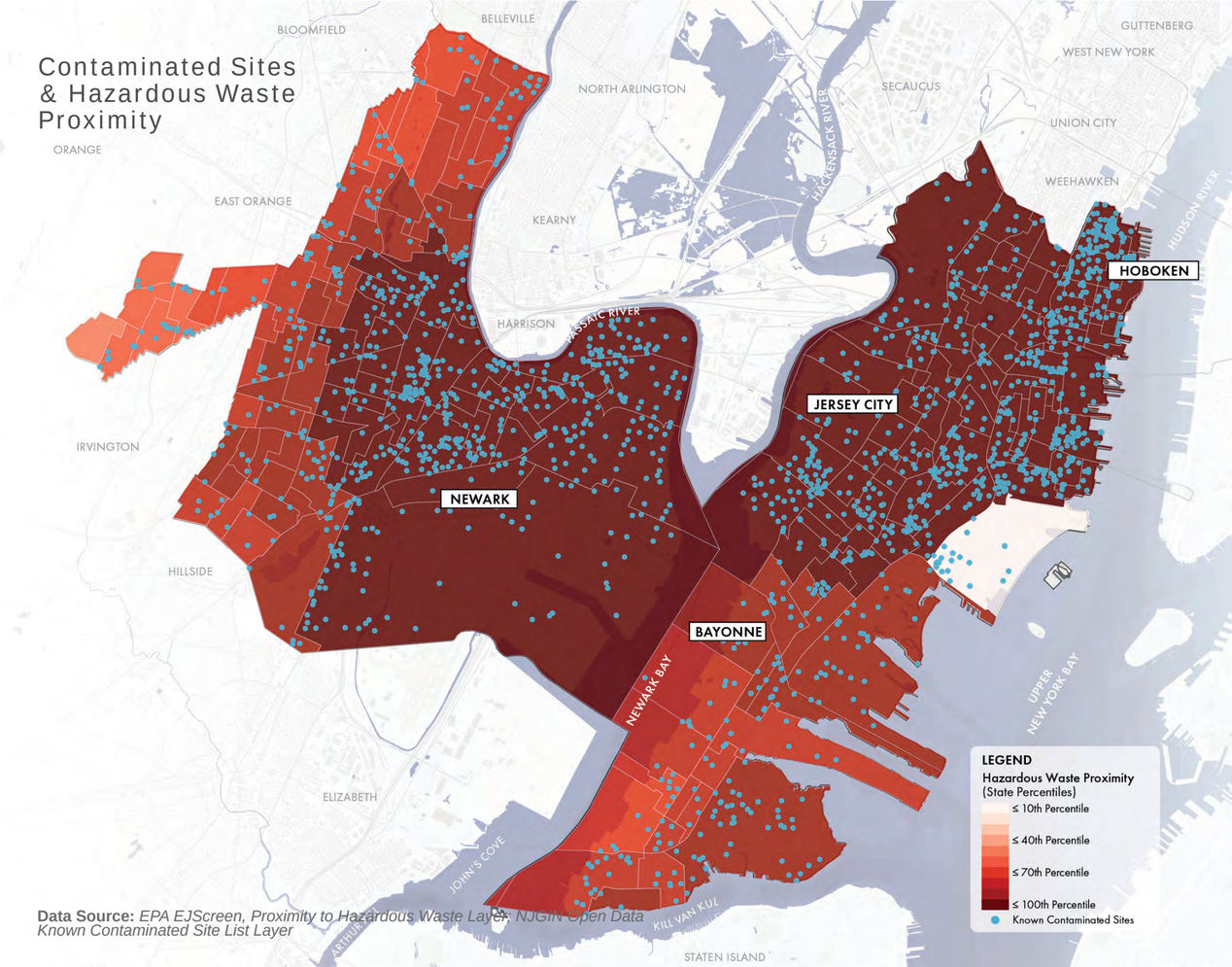
Higher index values point to the higher relative stakes of a flood event for historically excluded or under-resourced communities. For example, flooding and downtime of a neighborhood grocery store has much more drastic consequences for a low-income neighborhood with minimal access to affordable food than for a higher-income neighborhood with high rates of car ownership and/or access to multiple alternative options.

In addition to the social and demographic factors directly correlated with higher consequences of flood hazard, the geographic locations of these communities can also figure significantly into the higher overall risk they face. For example, in NENJ, neighborhoods with high social vulnerability index scores overlap significantly with high concentrations of contaminated sites and overall proximity to hazardous waste. Residents in or near contaminated sites may face additional health risks that depend on the contaminants present but may include long-term illness, adverse pregnancy outcomes, risk of premature death from exposure to toxicity, and associated psychological stress. For example, in some cases floodwaters may disrupt sources of pollution, including contaminated sites and active industrial sites, and spread the hazard away from the site. More research on the water quality of floodwaters and processes is needed to fully understand the impacts and risk.

These geographic factors are no coincidence and can also trace their roots back to historical injustices, as marginalized and minority communities were previously forced to settle in areas facing chronic disinvestment and high industrial activity, even as the surrounding region came to depend on these areas as key economic and transportation hubs.



1939 Redlining Maps of Essex County (top) and Hudson County (bottom) (University of Richmond, Mapping Inequality: Redlining in New Deal America)



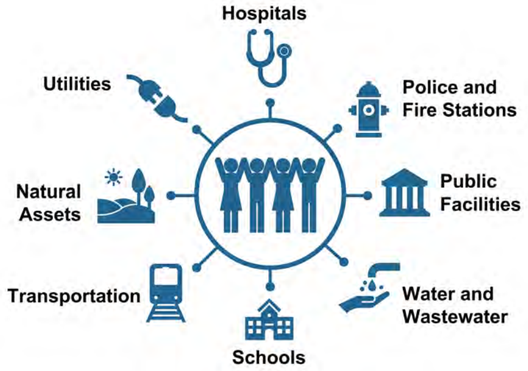
Data Source: *EPA EJScreen, Proximity to Hazardous Waste Layer; NJGIN Open Data Known Contaminated Site List Layer*

ASSETS AT RISK

Assets are anything that affect or have value to the community – from homes where people live, to the businesses where they work, to the parks where they play, and the roads and utilities that connect these places. Critical assets are those that are most essential for a community to thrive. These could be buildings (like schools, hospitals, or fire stations), infrastructure (like roads, bridges, and pipelines), or even less tangible things like traffic or community events. Assets can be of region-wide importance or specific to a community, and include places in time where people gather, connect, build relationships, and enjoy themselves.

Assets, like schools or hospitals, are often the focus of risk assessments. This report looks at many non-traditional community assets, such as shared gardens or street festivals, that are just as important to providing community cohesion, character, and quality of life. Critical community assets are of special importance in areas with high social vulnerability metrics, as the services tied to the assets can be critical to recovering from flood events for these populations. Assets can be positive or negative in their value contributions. For example, contaminated sites are an example of a negative critical asset because of their possible health and environmental impacts.

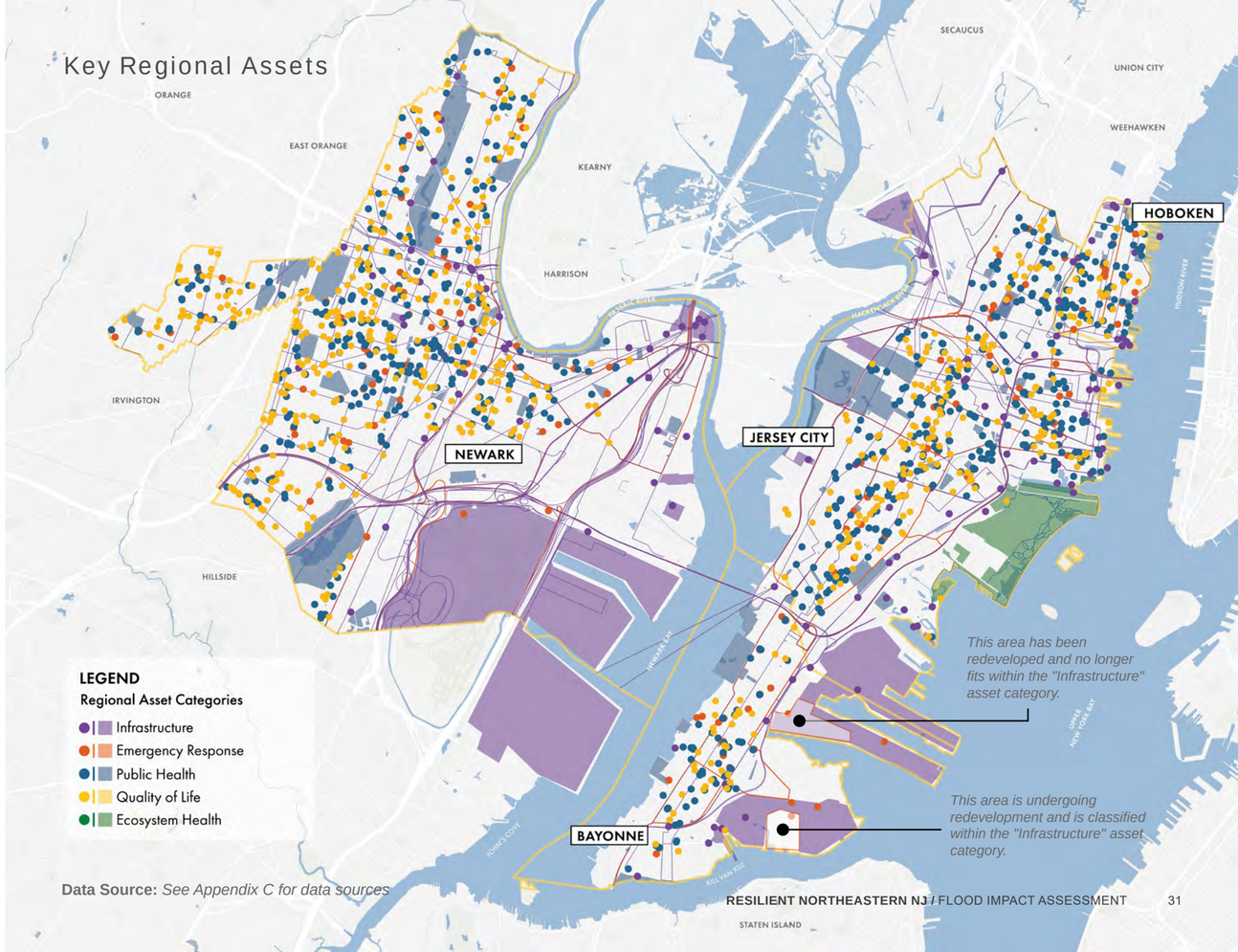
ASSETS TRADITIONALLY IDENTIFIED AS CRITICAL



ADDITIONAL CRITICAL ASSETS

(top) Critical assets traditionally included in risk assessments; (bottom) Additional assets critical to a community included in the Resilient NENJ flood impact assessment

Key Regional Assets

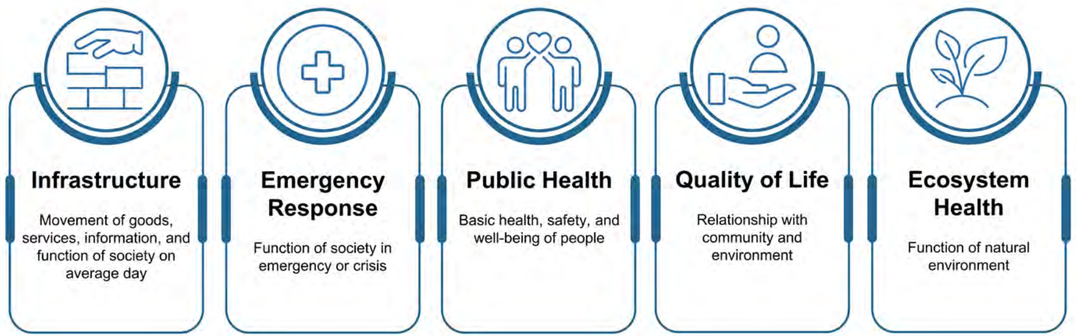


Data Source: *See Appendix C for data sources*

WHAT CRITICAL ASSETS ARE WE TALKING ABOUT?

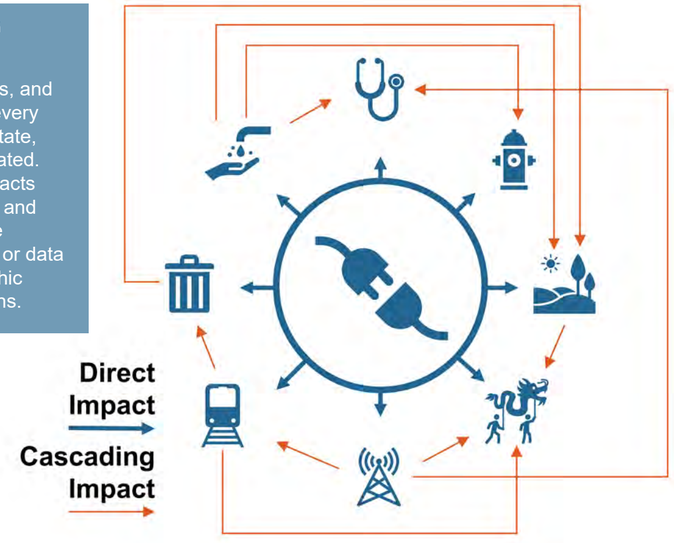
Understanding the impacts of exposed critical assets involves defining how each asset impacts the human experience. Assets may fit in one or many of following five benefit categories that consider the different ways that the community interacts with assets and the how the assets affect their lives:

- **Infrastructure**: Assets that ensure or impact movement of goods, services, information, and function of society on an average day, including ***Transportation*** assets that enable the movement of people and goods and ***Utility*** assets that impact the movement of essential resources, services, and information. Examples include roads, bus routes, wastewater treatment plants, and electrical substations.
- **Emergency Response**: Specific infrastructure or other assets that ensure or impact the functioning of society in an emergency or time of crisis. Examples include emergency shelters, fire stations, and hospitals with emergency rooms.
- **Public Health:** Additional assets that ensure or impact basic health, safety, and the well-being of people that are not specifically identified as infrastructure or emergency response assets, including groups of ***Vulnerable Populations*** or specific areas that provide housing and shelter for the elderly, unhoused, or other economically disadvantaged populations as well as educational institutions, such as K-12 schools. Additional examples include prisons, childcare centers, local parks, and municipal buildings. Contaminated sites also fall into this category.
- **Quality of Life:** Assets that ensure or impact people's positive relationships with themselves, one another, their community, and their environment. Examples include libraries, places of worship, and local festivals.
- **Ecosystem and Environmental Health:** Assets that ensure or impact the functioning of the natural environment. Examples of those that benefit the natural environment include state parks and wetlands. Parks have many benefits including improving well-being, quality of life, and being critical to ecosystem health. For this assessment, we've grouped local parks into **Public Health** due to their role in community health and wellness, and the significantly larger Liberty State Park with **Ecosystem Health** because of the significant concentration of wildlife habitats that support ecosystems, although many parks serve these multiple functions. Meanwhile, landfills and combined sewer outfalls are stressors to the natural environment.



INTERDEPENDENCIES AND CASCADING IMPACTS

NENJ's influence on the movement of people, goods, and services regionally and nationally is staggering. At every scale – from the neighborhood level to the region, state, and beyond – critical community assets are not isolated. Impacts to one asset could generate cascading impacts to many others. Interdependencies may exist within and between different types of assets. They may include functional or operational dependencies, information or data dependencies, additional disruption due to geographic proximity, and management and financial implications.



WHAT TYPES OF BUILDINGS ARE WE TALKING ABOUT?

Understanding how buildings are used is a key part of understanding how flooding currently impacts and will impact the region. Risk to various building types sheds light on the ability of a community to function, recover, and thrive over time. The Resilient NENJ team categorized buildings in the region with the following use types:

- **Commercial:** Structures providing economic services or goods, such as grocery stores, shopping centers, and offices
- **Education:** Structures providing any form of education, from preschool to universities
- **Emergency Services:** Emergency medical or social services such as EMS, Fire and Police Stations, and Hospitals
- **Government:** Judicial, municipal, and other government service buildings
- **Industrial:** Warehouses or buildings within manufacturing campuses or facilities
- **Religious:** Places of worship
- **Residential:** Structures that house community members
- **Transportation:** Structures supporting transportation infrastructure, such as railway stations and ferry terminals

INVENTORY STATISTICS

The Resilient NENJ Flood Impact Assessment is based on an extensive inventory of existing, present day buildings and critical assets. This inventory was built from the best available geospatial datasets as of 2020 and includes the following:

- 3,000 critical assets across approximately 50 unique asset types
- 2,200 acres of parks and public open space
- 1,300 miles of linear assets, such as roads, bridges, and transmission lines
- 43,000 buildings, such as residences, businesses, industrial sites, religious spaces, or public services

For more information about how assets were identified and prioritized, see Appendices C and D, which include a full list of assets for each city in the region.

COMMERCIAL

Hudson Riverfront
Jersey City

Downtown CBD
Newark

EDUCATION

University Heights
Newark

Public Middle School
Jersey City

INDUSTRIAL

Constable Hook Industrial Zone
Bayonne

Doremus Ave Industrial Zone
Newark

RESIDENTIAL

Fifth Ward
Hoboken

Droyer's Point Complex
Jersey City

TRANSPORTATION

Journal Square Transportation Center
Jersey City

Newark- Penn Station
Newark

NEW FLOOD MODELS

NJDEP developed models of flooding for large storms that affect the region. These models estimate the depths of flooding even in areas where historical flood data are not available, making them useful in highlighting potential flood-prone areas, comparing possible flood mitigation options, and prioritizing action. Appendices A and B share more detail on the development of these models.

The new models estimate flood risk from both rainfall and coastal storm surge.

RAINFALL FLOODING

Resilient NENJ modeled two distinct types of rainfall-based flood events to help clarify the locations and severity of flooding during different types of major rainstorms. The project team also cross-referenced the model data with flood locations reported by municipalities and community members to help confirm the findings.

- **Flash Flooding** occurs when there is a significant amount of rainfall over a short period of time. Water is quick to rise, but may also quickly fall. The Resilient NENJ models use around 3.5 inches over two hours, which is more intense than what fell in the same amount of time during Floyd (1999), Irene (2011), and Henri (2021) in most places and not nearly as heavy as the worst of Ida in 2021. This short duration, high intensity rain event is likely to temporarily overload storm sewers and cause flooding, but waters recede as the storm ends, limiting long-term impacts. Nevertheless, such a short storm may occur suddenly, providing little time for preparation or evacuation.
- **Areal Flooding** occurs when flooding develops more gradually and comes from sustained rainfall over a longer period. The Resilient NENJ models use around 8 to 9 inches over 24 hours, which is similar to Ida or Irene, depending on the area. In fact, Ida was really a flash flood event, but the duration and expanse turned it into an areal flood, as well. Areal flooding is typically regional in nature, while flash flooding is typically more localized.
- Longer duration events may not drain for a longer period. Storms of this size are also likely to overwhelm any available drainage networks and, therefore, tell us where significant damage and disruption likely does and could occur. The term *areal flooding* comes from the NWS Hazardous Weather Warning System to represent inland flooding over widespread extents of low-lying areas.

NJDEP provided two different rainfall models for each type of rainfall. The two models for both flash and areal flooding vary depending on two factors:

- Rainfall amounts – One of the models is 10-percent more rainfall than the other.
- Sea level – One of the models includes 2.4 feet of sea level rise, while the other uses year 2000 sea levels. High tide can impede drainage from land, so it is important to understand how flooding might change with sea level rise.

MODEL NAME	RAINFALL AMOUNT	TIME PERIOD	SEA LEVEL RISE
Present Day Flash Flooding	3.3 inches	2 hours	None (Year 2000)
Future Flash Flooding	3.7 inches	2 hours	2.4 feet (Year 2070)
Present Day Areal Flooding	8.3 inches	24 hours	None (Year 2000)
Future Areal Flooding	9.2 inches	24 hours	2.4 feet (Year 2070)

2070 CLIMATE ASSUMPTIONS

Rutgers University provided projections of expected increases given various assumptions about government intervention in the *New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel.*[7] NJDEP used Rutgers University's high emissions or "business as usual" scenario for 2070, assuming decisions that we make now about our infrastructure and communities will affect life in 50 years and beyond. Fifty years is also thought to be the timeframe within which projections should be relatively accurate if nothing changes. Should the effects of climate change occur slower or faster than projected, the timeframe the models represent will change, but the region must still plan for the risk the models represent.

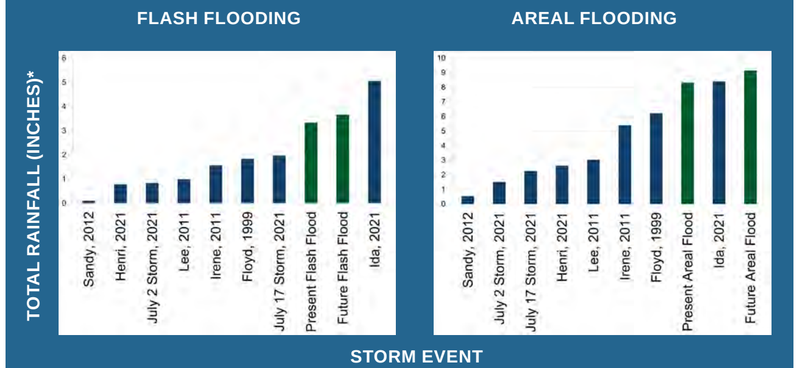
- **10 percent increase in rainfall** – It is widely believed that precipitation amounts will increase within the next century. To account for the uncertainty in the exact rate, NJDEP chose a 10 percent increase for these models as an estimate of increased rainfall on the same type of event in 2070.
- **2.4 feet of sea level rise** – This increase represents the central estimate for sea level rise by 2070 based on the "business as usual" emissions scenario.

HOW DO THE RAINFALL MODELS COMPARE TO EVENTS IN OUR COMMUNITIES?

The graphs below provide a comparison of the models to other events as they've been experienced in the region. The Resilient NENJ flash flooding models use 3.3 and 3.7 inches over two hours, which is a little worse than Floyd (1999), Irene (2011), and Henri (2021) in most places and not nearly as heavy as the worst of Ida in 2021. The Resilient NENJ areal flooding models use 8.3 and 9.2 inches over 24 hours, which is similar to Ida, Floyd, or Irene, depending on the area.

The graph provides the location of the rainfall gathered for the past events because real rainfall does not fall evenly over a large area (whereas the models provide uniform rainfall across the region). Localized rainfall amounts for past events may have been higher or lower away from the official observation sites.

Additionally, the amount of flooding from an actual rainfall event will differ based on the atmospheric conditions leading into the event. For example, Ida and Henri in 2021 were on the heels of a very moisture rich summer.



**Rainfall amounts for past events drawn from gages at Newark airport. Rainfall amounts for modeled events apply regionwide.*

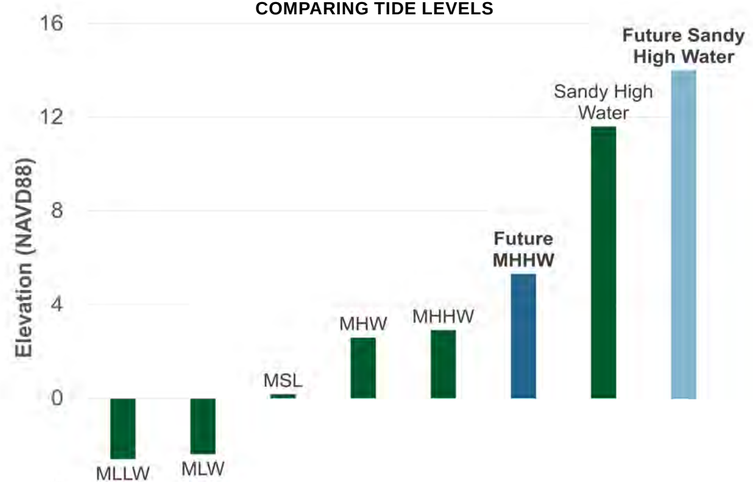
[7] *New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel,* https://climatechange.rutgers.edu/

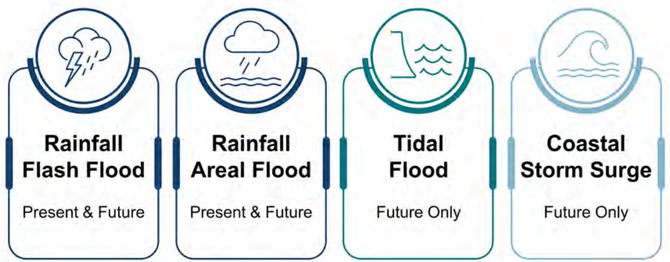
TIDAL STATE

All flood scenarios simulate tidal peaks at Mean Higher High Water (MHHW), based on elevations reported at nearby tide gauges.[8] The MHHW metric represents the average of the higher of the two daily high tides, as opposed to Mean High Water (MHW), which represents the average of all high tides at a given location.[9] Because Mean Sea Level (MSL) varies from place to place, a common datum – the North American Vertical Datum of 1988, or NAVD88, is used to standardize sea level measurements across the United States, Canada, and Mexico.

The MHHW elevation at the Bergen Point tide gauge in the Kill Van Kull just south of Bayonne, for example, is about 3 feet NAVD88, whereas MSL is a little more than 2 inches NAVD88. The modeled future rainfall and tidal flooding events add 2.4 feet to the spatially varying MHHW for the NENJ region.

COMPARING TIDE LEVELS





COASTAL STORM SURGE

Flooding from coastal storms is destructive due to high flood depths caused by storm surge and forceful waves. As climate change progresses, warmer oceans will likely contribute to more frequent and more intense storms. Sea level rise will make the impacts of storm surge even greater, leading to substantial flooding.

Resilient NENJ modeled an extreme coastal storm surge event that was developed by taking the observed high-water marks experienced during Hurricane Sandy[10] and projecting them into 2070, assuming 2.4 feet of sea level rise. Storm surge from Hurricane Sandy in 2012 represented the highest water levels ever measured at the Bergen Point tide gauge, with elevations nearly 9 feet higher than MHHW.

[8] *Additional information on the applied tidal cycle is found in Appendix B, Attachment A;* [9] *Mean Lower Low Water (MLLW) and Mean Low Water (MLW) are defined similarly. Tidal Datums,* https://tidesandcurrents.noaa.gov/;
[10] *USGS Flood Event Viewer,* https://stn.wim.usgs.gov/FEV/#Sandy, *accessed July 2021*

WHY AREN'T WE TALKING ABOUT ANNUAL EXCEEDANCE PROBABILITY? WHAT IS ANNUAL EXCEEDANCE PROBABILITY, ANYWAY?

*Starting with the second question first, the **annual exceedance probability** is the probability that a flood or rainfall event of a given size might be met or exceeded in any given year. It is based on long-term statistics of observed storms in the area. For example, a rainfall total with a 1 percent annual exceedance probability has a 1 percent chance of occurring or being exceeded each year, while a 2 percent storm is twice as likely to occur. The annual exceedance probability is linked to its return period – a 1 percent event may also be referred to as a 100-year event.*

This terminology is misleading, as it implies that a sized event should only happen once every 100 years. This is not the case. Today's 1 percent annual chance event has a 26 percent chance of occurring at least once in the next 30 years – with climate change and sea level rise the magnitude of a 1-percent event has been changing. Additionally, these probabilities are generally developed using backward looking information.

As our risk context changes, probabilities of occurrence change, and flood mapping efforts do not always keep up. In the last decade, for example, we have had three events – Hurricanes Henri, Ida, and Irene – that were all considered 1 percent annual chance events based on historical data. Henri and Ida both happened in 2021 alone! The 1 percent chance event of the last century is not the same as the 1 percent chance event today, and each is expected to occur more frequently in 2070 than they do today.

In fact, during the writing of this report, NJDEP released findings from a recent study indicating that rainfall rates for the 1-percent annual chance 24 hour storm have increased between 1 and 15-percent between the year 2000 and 2020, depending on the part of the state.[11] Northeastern New Jersey has possibly increased about 9-percent according to this report. Most climate projections do not include data gathered since the year 2000, which means that they are not keeping up with the rate of change.

NEW FLOOD MODELS FOR THE RESILIENT NEW JERSEY PROGRAM

Any model must be suitable for its intended use. The models developed for Resilient NJ are large-scale planning models that compare and prioritize areas across a region. The models include representations of road and railroad crossings, have assumptions to account for existing stormwater drainage systems, and incorporate recently completed large projects to reflect improvements that reduce flooding.

Due to their scale, these models contain an inherent level of uncertainty. The model results are appropriate to examine flooding at regional, municipal, and study area levels, but they were not developed with the intent to evaluate flooding for design purposes at the individual property or structure level.

Appendices A and B describe the program-level model development methodology and refinements special for Resilient NENJ, respectively.

[11] *Changes in Hourly and Daily Extreme Rainfall Amounts in NJ since the Publication of NOAA Atlas 14 Volume,* https://www.nj.gov/dep/dsr/publications/nj-atlas-14.pdf

PLANNING ON OUR FEET

Resilient NENJ submitted four funding applications to FEMA's Building Resilient Infrastructure and Communities (BRIC) program in January 2021 in partnership with the New Jersey Office of Emergency Management (NJOEM) and the regional team. Hoboken submitted a fifth for the expansion of their resilience park. The four projects that were developed through this program, if funded, will protect the lives and property of hundreds of people.

1. In Newark, Resilient NENJ partnered with Newark Public Schools to develop a pilot resilience hub based on feedback received early in the project. A resilience hub is a central gathering point in times of need with access to information and resources, and may double as an emergency shelter. Newark's pilot will take place at Ironbound's Ann Street School. Due to the severity of flood risk in Newark, the pilot location is incorporating subsurface stormwater storage and pervious pavement to mitigate flooding in addition to central air conditioning and power resilience improvements. Ultimately, the Ironbound Resilience Hub will reduce recurrent flooding for 60 homes and 17 businesses and schools. This effort will reduce flood risk to hundreds of people in the Ironbound neighborhood, providing $53 million in expected avoided losses in flood risk alone. It will also provide a cooling center, consistent power supply, and critical resource for community members to go to in times of emergencies.
2. In Jersey City, the McGovern Park Resilience project will leverage existing park and open space to capture stormwater that currently floods approximately 80 homes.
3. In Bayonne, the Cottage Street Flood Mitigation project will mitigate repetitive flooding to 32 structures through both underground storage and increasing the capacity of the stormwater conveyance system.
4. Also in Bayonne, the 63rd Street Pump Station Power Resilience project will stop sewage from entering the homes of elderly people in the community, as it has multiple times this year. There are 59 properties directly benefitting from this project, and at least 177 people will hopefully never again have to deal with the stress of having raw sewage backup into their homes once this project is complete.
5. Hoboken also submitted an application independently to expand the Southwest Resilience Park, a public park that includes green infrastructure components such as rain gardens, porous pavers, rainwater harvesting, and underground storage to manage stormwater and provide green space. The expansion would continue the benefits of the Rebuild by Design–Hudson River project, which includes coastal flood barriers and rainfall flood mitigation components, as described in more detail in the Hoboken section of this report.

DO THE NJDEP RESILIENT NJ MODELS REPLACE FEMA'S FLOOD MAPS?

No. The Resilient NJ flood models and FEMA's flood maps serve different purposes.

FEMA maps riverine and coastal flooding to determine where flood insurance is required through the NFIP and where certain building code requirements apply. FEMA flood models are used to support policy implementation. They generally do not include stormwater flood risk but do include some information about probability of flooding. FEMA models flood risk based on past events only and does not predict how risk will change. FEMA is currently updating the flood maps in our region. Visit the FEMA Coastal Restudy website to learn more.

The flood models developed for Resilient NJ are large-scale planning models that are useful for comparing and prioritizing areas at risk of tidal, stormwater, riverine, and coastal flooding across a region. These models cover more types of flooding than the FEMA maps, while also projecting how risk will change in the future. The Resilient NJ models, however, focus on specific modeled events, rather than providing the probability that any individual structure will flood.

STREET FLOODING

A vehicle drives through flood waters in Hoboken in July 2021.

Image Source: *Carter Craft / Outside New York*

MEASURING IMPACTS

With a baseline understanding of flood hazards, along with the people, places, and things throughout the region that may be impacted, the Resilient NENJ team quantified the range of impacts flooding has on our region using a variety of metrics. The team used methodologies developed by FEMA and the United States Army Corps of Engineers (USACE)[12] to monetize four types of impacts to buildings and the people, businesses, and services they house:

- **Direct Physical Damage:** Replacement and restoration costs for buildings and their contents or inventory that are expected to be damaged by flooding, including retail or wholesale inventory.
- **Human Impacts:** Costs associated with residential displacement, lost productivity, injuries, and mental stress and anxiety treatment for residents in the region as a direct result of impacts to their homes.
- **Direct Business Impacts:** Impacts to tax revenue, economic output, employment, and business relocation as a direct result of impacts to buildings. This only includes losses from businesses expected to be directly impacted by flooding and does not model any indirect economic impacts that might reverberate through the metropolitan area or beyond.
- **Loss of Function:** Expected impacts associated with the time that public and essential services are out of use, approximated as the portion of annual operating costs associated with the downtime experienced from direct impacts of flooding. For this analysis, public and essential services include libraries, schools, fire stations, hospitals, police stations, nursing homes, rail stations, and electric substations.

This report provides **Total Direct Losses**, or the sum of these four types of damage for all buildings within the reporting area. In cases where Total Direct Losses were either unavailable or inappropriate indicators, additional exposure metrics were used to quantify impacts, including **Population Counts, Asset Counts, Building and Contents Values, and Land Values**. Results are complemented by community feedback on the types of flood impacts experienced or are most concerning today and in the future.

The **Total Direct Losses** that are reported are for a **single occurrence** of each of the flood events described in the New Flood Models section of this report. This is different from how we might sometimes see losses reported on an annual basis.

[12] *More information about how the team estimated damage can be found in Appendix C*

CONSIDERATIONS AND LIMITATIONS

DAMAGE METRICS

Some damage metrics were not evaluated in this analysis due to limited data availability or other project constraints, meaning the consequences presented in this report represent conservatively low estimates of the expected losses. For example, the business impacts reported do not include indirect economic impacts on business-to-business purchases in the supply chain or induced (reverberating) economic impacts stemming from changes in household income spending. This report does not quantify impacts to roadways.

Loss of function calculations include cascading impacts from a limited number of essential services. The assessment uses standard FEMA values and methodologies to estimate these losses. Nevertheless, there are plenty of other assets that, if flooded, would cause cascading impacts throughout the community, such as childcare centers (complications for working parents), wastewater treatment plants (damage from sewage backups and environmental impacts from release of partially treated waste), and street festivals (economic and social benefits) that the assessment does not capture. Furthermore, even the metrics themselves may underrepresent potential impacts. Using operating costs as a proxy for loss of function only captures a small portion of the reverberating impacts across the community.

Estimates of building and contents values do not fully capture the complexities of the diverse spaces within the region. Nonetheless, impacts presented in this report represent the best available data for the region, and future analyses should continue to build on these findings and refine loss estimates to support the development of mitigation strategies.

RELATIVE ACCURACY OF RESULTS

The consequence analysis looks at the potential losses for a limited number of hypothetical events and uses high-level, large-scale planning models to evaluate impacts. Though the team used the best available data for the analysis, that does not mean the data are perfect. Modeled flood extents are not the same as a real, lived event. Specific buildings or assets may be miscategorized or even completely missing from the analysis. All results presented are estimates and are best used on a relative basis, which means comparing them to each other or to other values. For example, use the information to compare which type of flood event causes larger losses or affects a larger number of people in each area and by what order of magnitude, rather than focusing on the exact dollar value of the losses for any single event.

RELATIVE PROBABILITIES OF OCCURRENCE

While damage metrics reported in this analysis are calculated based on a single occurrence of each flooding event, the flood conditions evaluated in this report have different expected probabilities of occurrence. For example, a tidal event representing the mean higher high water (MHHW) tide, or the average height of the highest daily tide, indicates permanent inundation, as opposed to occasional or infrequent flooding associated with the rainfall and storm surge models. In other words, tidal flooding could occur once or twice daily, and can thus be considered permanent inundation, while the areal, flash flooding, and coastal flood models *should* generally occur infrequently (possibly one storm in decades, though multiple rainfall events in the last decade have met or exceeded the modeled rainfall amounts in at least some areas).

Nevertheless, the consequences of daily flooding from high tides do not imply that losses would be incurred daily. Rather, assets that face that type of potential flooding will be unusable, and losses are often better represented as the total value of exposed assets. If at the point of daily flooding, these assets may have to be abandoned or their use radically transformed.

TROPICAL STORM HENRI FLOODING IN NEWARK

Flooding along Wilson Ave in summer 2021

Image Source: *Michael Sol Warren*

02 - REGIONAL FLOOD IMPACTS

This section summarizes expected regional-scale flood impacts given new model results. This section begins with a qualitative discussion around the exposure of critical assets, before diving into the quantitative impacts of rainfall flooding, tidal flooding, and storm surge events. These results are then compared through lenses of the timeframes, damage metrics, and building uses evaluated in this report.

REGIONAL CRITICAL ASSET EXPOSURE

As described earlier in this report, Resilient NENJ categorized critical assets based on their relationship to the people they serve. Keeping with this approach, the team ranked community assets within each category based on the breadth of impact – how wide-reaching losses of the asset might be felt – as well as the magnitude of impact, approximated as the depth of flooding experienced across all the evaluated flood events. Because each asset type serves different populations and because there generally isn't a specific count of how many people use every asset, surrogate information is used to estimate the breadth of flood impacts, as described in detail in **Appendix D**.This section summarizes potential flood impacts across a selection of the highest priority region-scale assets identified by the team today. As the region grows and the climate changes, the identity of the area could shift, and new or existing assets could emerge as higher priorities in the event of a flood.

At the city scale, prioritized assets include the highest-ranking asset in each benefit category for each study area within the municipality. These assets represent a wide cross-section of asset types and are intended to highlight the diversity of assets that are exposed to flooding, and are summarized in each city-specific section of this report.

UTILITY MITIGATION UNDERWAY

The Passaic Valley Sewerage Commission (PVSC) has recently constructed various resilience projects at the PVSC WWTP, including a perimeter floodwall, stormwater pumping stations, and a stormwater collection system. As long as all measures that require emergency action are deplolyed effectively (e.g., deployable barriers), these measures may help mitigate some of the $8 million of losses expected at the WWTP in a future areal flood and the $87 million expected in the modeled future extreme storm surge event.

INFRASTRUCTURE

- **Newark Liberty International Airport (EWR)** is currently exposed to both rainfall and storm surge flooding. As one of the three major airports in the New York City metropolitan region, EWR is a national critical asset. In 2019, the airport boarded 46 million passengers on more than 446,000 flights.[13] Any disruption to the airport will have significant impact on regional, national, and international commercial air transit and freight operations based out of the facility.
- Most of **NJ Transit's rail lines**, which are also used by Amtrak trains, run through the region, and all PATH stations are in the region. More than 450 trains with approximately 200,000 passengers per day cross through this section of the northeast corridor.[14] Rail lines are expected to be inundated by flooding throughout the region, which will mean widespread impacts on train operations. In total, 28 stations are expected to be impacted under one or more of the rainfall and coastal events evaluated in this analysis. Newark Penn Station and Hoboken Rail Terminal, two large, regionally significant stations, are expected to be inundated with flooding during both rainfall and coastal events.
  Disruption of public transit systems disproportionately affects people without cars or who cannot afford alternative transportation.
- **Ferry terminals** in NENJ, including the Hoboken, Warren Street, and Liberty Harbor terminals, serve nine ferry services to downtown Manhattan that carry approximately 15,000 people daily.[15] Impacts to the terminals, which are expected under the modeled coastal, tidal, and rainfall events, could interfere with commuters, visitors, and residents' daily lives. Additionally, as ferry terminals are built along the water's edge, they may be especially susceptible to impacts from rising sea levels and associated higher tides. The terminals will have to adapt to continue operating seamlessly through anticipated climate change impacts.
- **Port Newark** facilitates the entry of $200 billion of goods into the United States annually. An estimated 400,000 jobs are associated with the Port alone as of 2018.[16] Without action, areas of Port Newark could expect 14 feet of flooding during a future extreme storm surge event. The Port Authority of New York and New Jersey (PANYNJ) recently embarked on a planning and feasibility study as part of a larger Wharf Replacement Program, which focused on replacing critical port infrastructure at Port Newark and other coastal New Jersey terminals. This effort considered climate change and sea level rise impacts on future capital investments.
- **Roadways, bridges, and tunnels** will be significantly impacted under rainfall and storm surge events. More than 36 million vehicles crossed through the region eastbound into New York City through the Lincoln and Holland Tunnels and over the Bayonne Bridge in 2019.[17] These roadways may be impacted in a flash flood or areal flood event. The Holland Tunnel was significantly impacted during Hurricane Sandy in 2012, but significant planning and improvements have gone into protecting tunnel assets since that time. Additionally, much of the modeled areal and flash flooding collects on surface streets, impacting accessibility in communities throughout the region.
- Two of the region's **Wastewater Treatment Plants (WWTPs)** are likely to be exposed to future flooding. The North Hudson Sewerage Authority Adams Street Plant, serving approximately 200,000 customers in and near Hoboken, may flood during future rainfall and extreme storm surge events. The site of the Passaic Valley Sewerage Commission (PVSC) WWTP, serving 1.5 million customers in 48 municipalities, is expected to flood during a future extreme storm surge event. Nevertheless, significant flood protection investment since Hurricane Sandy should mitigate risk of service disruption.
- All 8 of the **active power generation facilities**, together contributing more than 2,700 megawatts of power to the electrical grid, have at least some portion of their facilities exposed to the modeled flood events. More detailed site-specific vulnerability assessments, where not already complete, would determine a full picture of risk and the cascading impacts that flooding may have to the power needs of the region and beyond.

EMERGENCY RESPONSE

- **Hoboken University Medical Center** is expected to be exposed to future extreme storm surge events. The center houses a 34-bay

WHAT IS ALREADY BEING DONE TO PROTECT OUR REGION'S TRANSPORTATION SYSTEMS?

The Port Authority of New York and New Jersey (PANYNJ) has already implemented a variety of flood mitigation measures to protect their assets, including Port Newark, Holland, and Lincoln Tunnels. At the port, pump stations, substations, administrative buildings, and other critical facilities are equipped with temporary flood barriers. Critical utility systems at these facilities have been elevated, and emergency generators were installed for administrative buildings. PANYNJ has also increased their resilience on other assets, including the airport and PATH trains, through a combination of elevation and flood barriers or shields.

The Jersey City Resiliency Master Plan recommended evaluating the possibility of a street levee around Route 440 and elevating the roadway to maintain it as a safe evacuation route and to protect the Country Village neighborhood. Coordination would be needed between Jersey City and the New Jersey Department of Transportation (NJDOT) to advance this project. This flood protection measure is estimated by the Resilient NENJ team to benefit 2,000 residents and to have a capital cost of $24 million.

New Jersey Transit has several completed or planned flood protection and infrastructure resilience projects across the region, including the Long Slip Fill and Rail Enhancement Project in Jersey City, the Hoboken New Jersey Transit Terminal Accessibility and Resiliency Improvements, the Hoboken Terminal Resilient Signals and Power, the Hudson-Bergen Light Rail Caven Point Facility Resiliency Project in Jersey City, and the New Jersey Transit Grid Traction Power System Project, which will provide electricity to critical transit services benefiting many people within and around Northeastern New Jersey.

[13] https://www.panynj.gov/airports/en/statistics-general-info.html; [14] https://d2g63oyneaimm8.cloudfront.net/sites/default/files/pdfs/rail/Rail_System_Map.pdf (http://www.gatewayprogram.org/about.html)

[15] *2019, NY Waterway Ridership Data;* [16] *2017,* https://www.panynj.gov/port/en/our-port/port-development/port-master-plan.html; [17] https://www.panynj.gov/bridges-tunnels/en/traffic---volume-information---b-t.html

EMERGENCY RESPONSE

Jersey City Medical Center
Jersey City

Hoboken University Medical Center
Hoboken

ECOSYSTEMS & ENVIRONMENT

Richard A. Rutkowski Park
Bayonne

Liberty State Park
Jersey City

INFRASTRUCTURE

Hoboken Transit Terminal
Hoboken

Port Newark
Newark

Newark-Liberty Airport
Newark

Some assets serve the community in more than one way and, therefore, fit into more than one community benefit category. For these assets, the major service they provide was used to define their primary community benefit category; however, the other services they provide are considered in the evaluation of consequences. For example, Hoboken University Medical Center primarily provides emergency services, but it also provides other public health benefits.

emergency room and a dedicated OB-GYN emergency department. It provides services in specialty, general, and surgical medicine.

- Flood mitigation measures under construction at **Jersey City Medical Center** should effectively protect against the flood scenarios modeled, as long as all measures that require emergency action are deployed effectively (e.g., deployable barriers). The Jersey City Medical Center is currently constructing a flood mitigation project around the perimeter of the facility, including vertically deployable flood barriers, concrete floodwalls, reinforced-waterproofed walls, flood doors, flood resistant glazing of glass, and stormwater management systems. These mitigation features are critical to ensure that the hospital can continue to provide emergency services and support to the community
- The region is home to approximately **50 hurricane evacuation routes**, 40 miles of which may be exposed to at least 6 inches of flooding in the modeled future storm surge flood event. Six inches of flooding on a road is enough to damage vehicles, make routes impassable, and potentially pose serious threats to life safety. Evacuation routes often follow major highways (such as Highways I-78 and NJ-440), meaning flooding along these routes could keep other emergency response vehicles, such as ambulances or fire trucks, from accessing communities in need. Additionally, “evacuation route” signage is currently limited, which means residents may not know where to evacuate to, or on the macro level vehicles would not be evacuating according to the roadways and transit lines that are intended for evacuation, leading to reduced evacuation egress. ***Six inches of water can knock over an adult and 1 to 2 feet of water can carry away a vehicle.***

PUBLIC HEALTH

- The **Northern State Prison**, which houses **2,600 people**, is at risk to both rainfall and coastal flooding events. Impacts to this facility could have reverberating effects on the incarceration system, starting from the logistics of securely transporting incarcerated persons to new facilities in the event of an evacuation, to ensuring that there are sufficient resources to support the additional capacity at other locations.
- **Columbus Hospital** in Newark is expected to be exposed to flooding due to both present and future major rainfall events. With 63 long-term hospital beds, this hospital serves those who have not responded to short-term treatment in traditional hospitals. Many patients are ventilator dependent, suffering from organ failure, or experiencing serious ulcerations – representing an **extremely vulnerable population**.

QUALITY OF LIFE

- **Liberty State Park** is located along the Upper New York Bay opposite of Liberty Island and Ellis Island, providing 1,200 acres of public recreational space in Jersey City. This park is expected to experience flooding during the future rainfall and extreme storm surge events, which will disrupt its use by the community and potentially cause ecological harm.

ECOSYSTEM HEALTH

- Though most of the Northeastern New Jersey region is a highly urbanized and developed city landscape, there remains approximately 200 acres of sensitive wetland habitats, mostly in the Meadowlands area of Jersey City. Eighty percent of these wetlands are expected to be impacted by sea level rise (i.e., occur below the future MHHW tidal elevation). Without areas for marsh migration, compounded by already impaired natural accretion processes, the acreage of wetland habitats in this region is expected to decrease with sea level rise. Future permanent inundation of wetland habitats will convert existing vegetated habitats to open water. Other wetland habitats will change plant community composition. Overall, sea level rise will directly reduce the acreage of wetlands in this region as well as impact the ecological services and functions of remaining wetland habitats that are important to wildlife and surrounding communities.
- As identified in the About Our Region report, assets, such as combined sewer outfalls and known contaminated sites, are widespread through the region. While specific outfalls or contaminated sites are not singled out as priority assets, flooding at these assets would negatively impact the community. Overwhelming of the combined sewer system can cause discharge of untreated sewage to water bodies, and system backups can result in overflows in populated areas. Flooding at known contaminated sites can mobilize contaminants and spread them throughout the community. Brownfields present redevelopment opportunities for the community but may be associated with pollutants or hazardous chemicals that may be carried from the site to other locations or local waterways, if flooded. While losses at these sites are not easy to quantify, they are no less important to consider in the action planning process.

RAINFALL FLOODING IMPACTS

We know from past events – like Hurricane Floyd in 1999, Hurricane Irene in 2011, and at least four major storms in 2021 – that heavy rainfall is already flooding homes, businesses, roads, and other critical assets in our communities. Today, flash flooding and areal flooding events have the potential to cause billions of dollars in losses in the form of direct physical damage, disruption, and stress. Resilient NENJ modeled both types of significant rain events to reflect present day and future expected conditions.

While the models show flooding from severe rainfall events, community members frequently tell the project team that flooding from regular rainstorms also disrupts daily life. Many community members reported having anxiety every time it rains because of the possibility of flooding in their homes and streets. Some reported not leaving their homes or going to specific parts of town when it rains. These disruptions were noted across all four cities in the region. Residents reported that insurance rarely covers the full cost to repair losses, and insurance costs are rising. Impacts to public services and daily life include power and water outages, mobility disruptions, and street closures. Neighborhoods, such as Southwest Hoboken and Ironbound, have had longstanding repeat flooding issues, but there are other areas previously not known to flooding that flooded in 2021, such as the Heights in Jersey City.

The map of the modeled present-day flash flood and areal flood events demonstrates that there are few areas in the region unlikely to be exposed to some level of rainfall flooding. **Even the few areas not directly exposed are surrounded by places that are, meaning that power and other utilities, transportation, services, and the ability to evacuate could all be affected. In other words, all people who live, work, and play in the region face some level of flood risk today.**

Rainfall Areal Flood

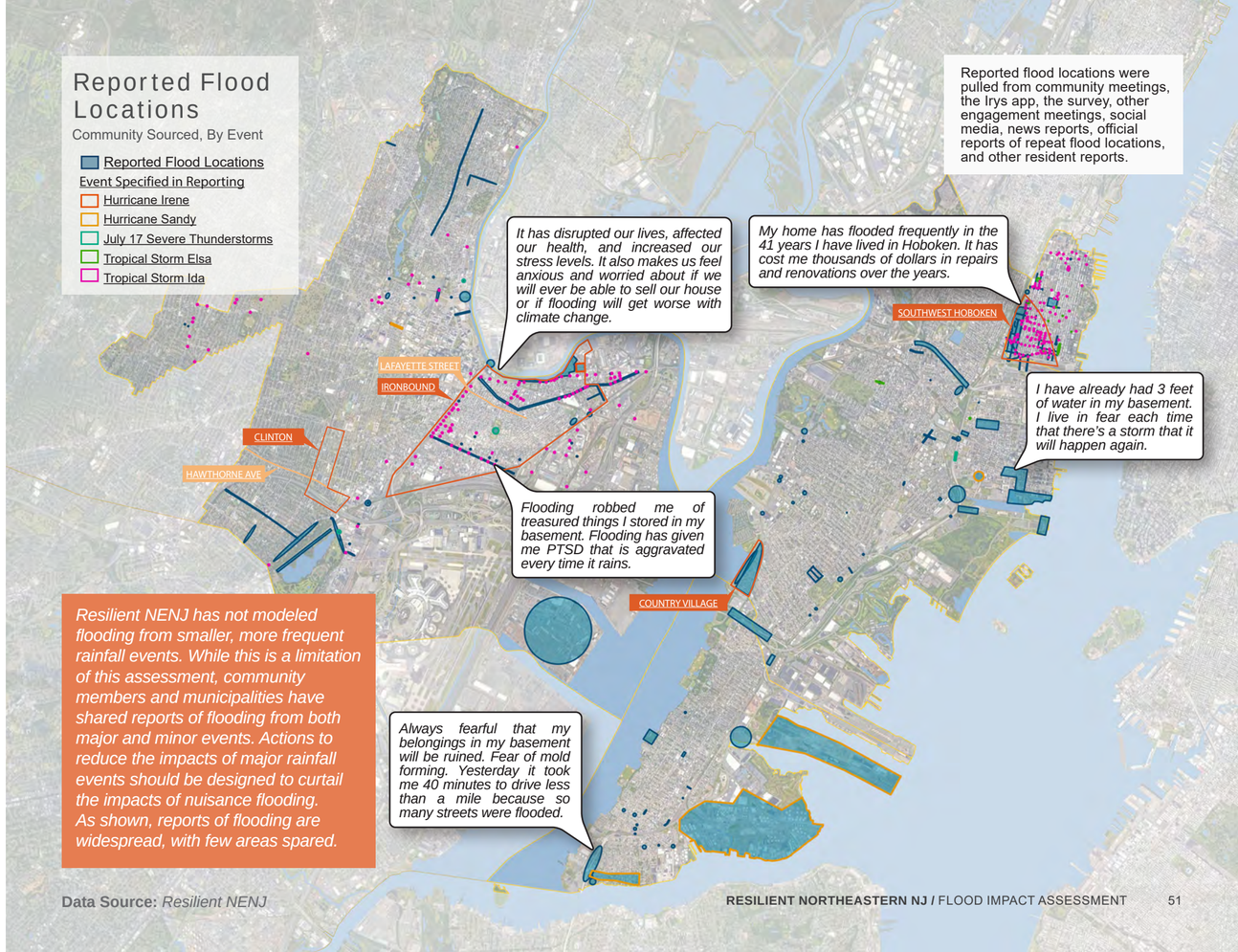
Range indicates change from present to future modeled flood events

$5.2 - $5.9 Billion	11,000 - 12,000 Buildings	210,000 - 220,000 Residents
In expected losses	Impacted out of 42,000 total buildings (29%)	In impacted homes out of 700,000 residents (31%)

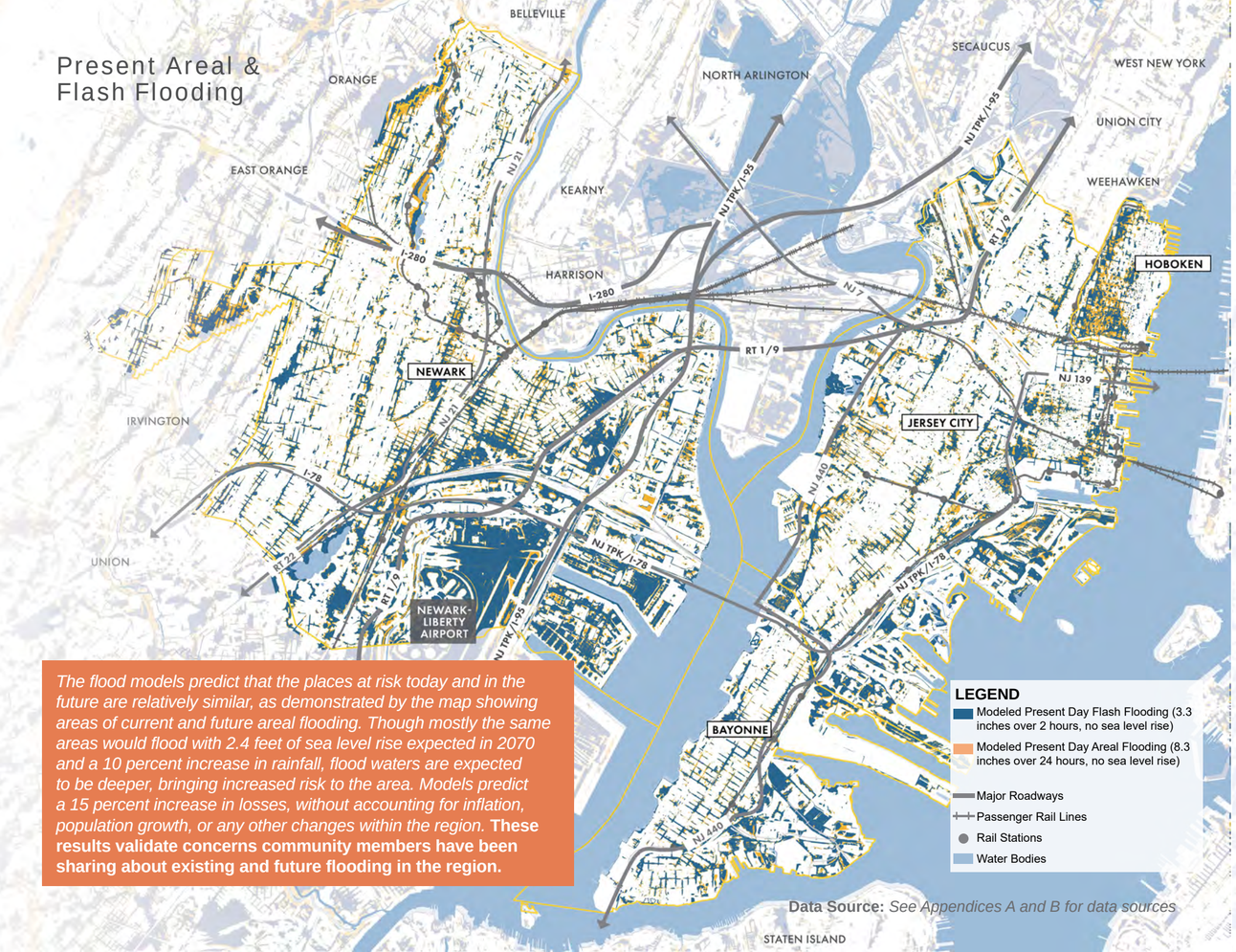
Rainfall Flash Flood

Range indicates change from present to future modeled flood events

$2.7 - $3.1 Billion	7,100 - 7,900 Buildings	150,000 - 160,000 Residents
In expected losses	Impacted out of 42,000 total buildings (17-19%)	In impacted homes out of 700,000 residents (21-23%)

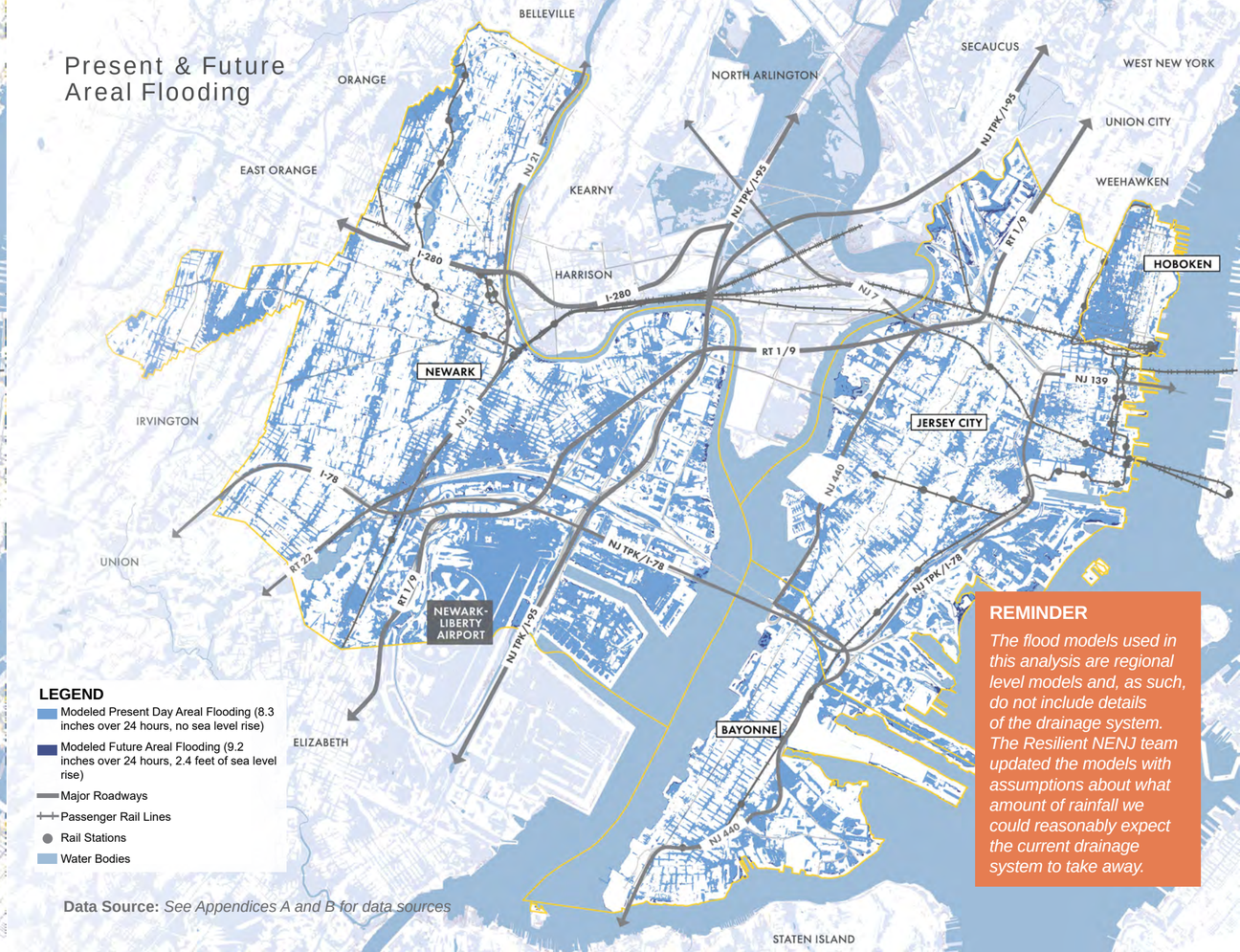


Data Source: *Resilient NENJ*



The flood models predict that the places at risk today and in the future are relatively similar, as demonstrated by the map showing areas of current and future areal flooding. Though mostly the same areas would flood with 2.4 feet of sea level rise expected in 2070 and a 10 percent increase in rainfall, flood waters are expected to be deeper, bringing increased risk to the area. Models predict a 15 percent increase in losses, without accounting for inflation, population growth, or any other changes within the region. **These results validate concerns community members have been sharing about existing and future flooding in the region.**

Data Source: *See Appendices A and B for data sources*



Data Source: *See Appendices A and B for data sources*

REMINDER

The flood models used in this analysis are regional level models and, as such, do not include details of the drainage system. The Resilient NENJ team updated the models with assumptions about what amount of rainfall we could reasonably expect the current drainage system to take away.

INCORPORATING RESIDENT EXPERTISE

Community members have first-hand knowledge of where flooding occurs around them. In addition to the flood reports that community members shared with Resilient NENJ as shown in the map, Responding in response to feedback, each of the Resilient NENJ cities is developing a mapper where residents can report flood locations as they occur. Having this information can help the cities respond to flooding as it happens and to track repeat locations of flooding. Links to the live interactive flood mappers are below:

Newark: https://bit.ly/nwkfloodmapper

Hoboken: https://tinyurl.com/hobokenfloodmap

Jersey City and Bayonne are coming soon.

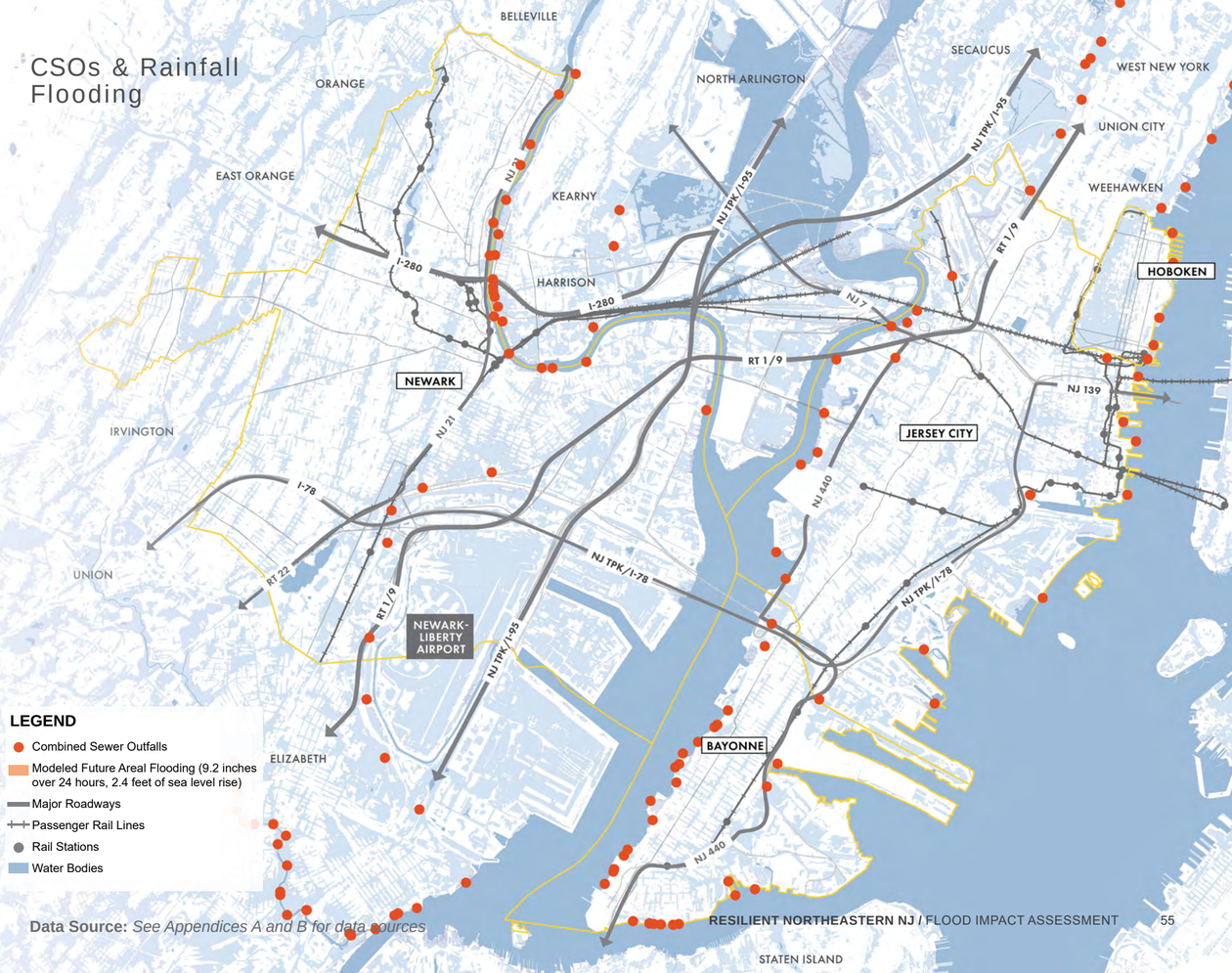
There is also a statewide reporterd used by NJDEP, called New Jersey MyCoast, where residents across the state can report locations of flooding and share pictures of important community places: https://mycoast.org/nj. Another way that residents in the Resilient NENJ region can report flooding is through the Irys App, which is a mobile smart phone engagement app that is available for download from the Apple App Store or Google Play Store.

RAINFALL FLOODING, COMBINED SEWER OUTFALLS, AND THE LONG-TERM CONTROL PLANS

Combined sewer systems serve most areas of NENJ. Combined sewers collect rainwater runoff, sewage, and other wastewater all into the same pipe and then transport the water to a WWTP for cleaning. During times of heavy rainfall, this system can be overloaded. In such cases, the overflow will discharge directly into waterways through combined sewer outfalls. These overflows are a significant and longstanding concern in NENJ, particularly because the overflow contains sewage that pollutes our waterways and is a health risk to our communities. Sea level rise is exacerbating these issues. With high tide, combined sewer outfalls can become blocked. During heavy rainfall, when the system is likely to be overloaded, this can lead to combined sewer backups directly into communities.

System providers and communities, in coordination with NJDEP, recently developed long-term control plans (LTCPs) that aim to improve water quality in surrounding water bodies by reducing sewer overflows into waterways. Though the plans do not currently include specific resilience or flood risk reduction considerations, the plans will provide some flood risk reduction benefit that Resilient NENJ must evaluate as part of solution development.

The expected cost to implement the LTCPs for the region is more than $1.5 billion. In Jersey City alone, the costs will be more than $670 million. The cost burden to municipalities could dampen their ability to invest in flood risk reduction. Although reducing combined sewer overflows is required, there is currently not a legal mandate to address flood risk. As such, Resilient NENJ must find ways to coordinate and maximize flood risk reduction benefits of the LTCPs as they are implemented.



Data Source: *See Appendices A and B for data sources*

TIDAL FLOODING IMPACTS

RISK TOLERANCE

Unaddressed flood risk can lead to long-term disinvestment and unmanaged retreat from an area. How frequent flooding must occur for this to happen is heavily influenced by a market's ***"risk tolerance."*** *Risk tolerance refers to our willingness to accept certain possible outcomes (such as severe flood impacts) in exchange for other benefits (such as staying in the neighborhood we love).*

Risk tolerance is apparent in the form of codes and standards, such as those set by FEMA's NFIP or a municipality's flood damage prevention ordinance. NJDEP has defined the acceptable risk for most types of properties as 1 foot of "freeboard" (a safety factor) over the elevation of the 1-percent annual chance flood event. FEMA's NFIP regulations require only the 1-percent annual chance flood event, though FEMA provides guidance and rewards higher standards, and often requires higher standards for projects funded with federal money. Risk tolerance is often lower in areas that might experience high velocity wave action because waves cause greater levels of destruction.

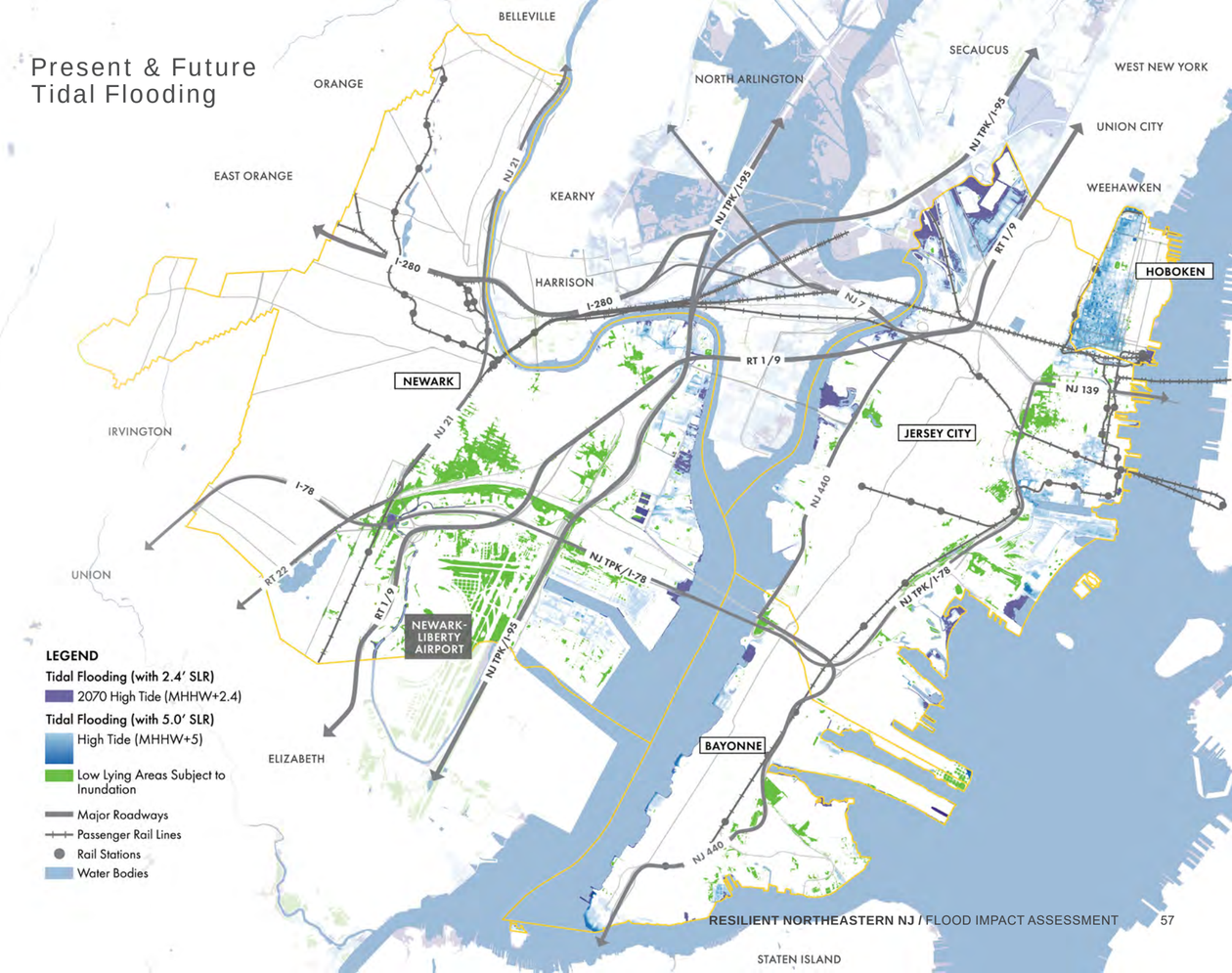
Due to increased risk from climate change, as well as from land use and development changes, many areas are flooding more frequently. As local governments and property owners struggle to reduce risk, the market is forced to react and demonstrate its risk tolerance, leading to community deterioration over time. These market forces can lead to significant inequities, where those who can afford to leave an area that has exceeded their risk tolerance do so, and those who cannot are forced to stay in conditions that continue to decline. Resilient NENJ must consider this reality while developing solutions and targeting public investment.

Tidal Flood
Future modeled flood event

$2.0 Billion	480 Acres	420 Residents
In exposed replacement values	Of land exposed where 55 buildings reside	In impacted homes out of 700,000 residents

Limited areas of NENJ will be inundated regularly during high tides with 2.4 feet of sea level rise, though this area would expand significantly with 5 feet of sea level rise, expected by 2100. Although the extent of impacts is limited, these tidal events occur with a high frequency, resulting in regular flooding – up to twice daily. Areas, access routes, and buildings at risk of high tide will be permanently useless long before this level of inundation. **Depending on the area and uses, infrastructure and buildings may become unusable by the time they experience monthly, yearly, or even less frequent flooding, depending on water depths and the level of disruption.** While roadways can hold out longer, frequent flooding of roadways is extremely disruptive, and areas along them can begin to experience disinvestment.

Rising groundwater levels can impact low lying areas. It is generally expected that within a kilometer of the coast (a bit more than half a mile), groundwater tables will rise at the same rate as sea levels will rise. Though the quantification of groundwater impacts is not evaluated in this analysis, it is important to recognize that rising tides have impacts beyond the extents shown on the map.



Data Source: *See Appendices A and B for data sources*

STORM SURGE IMPACTS

Coastal Storm Surge
Range indicates change from present to future modeled flood events

$17 - $31 Billion
In expected losses

5,300 - 7,200 Buildings
Impacted out of 42,000 total buildings (13-17%)

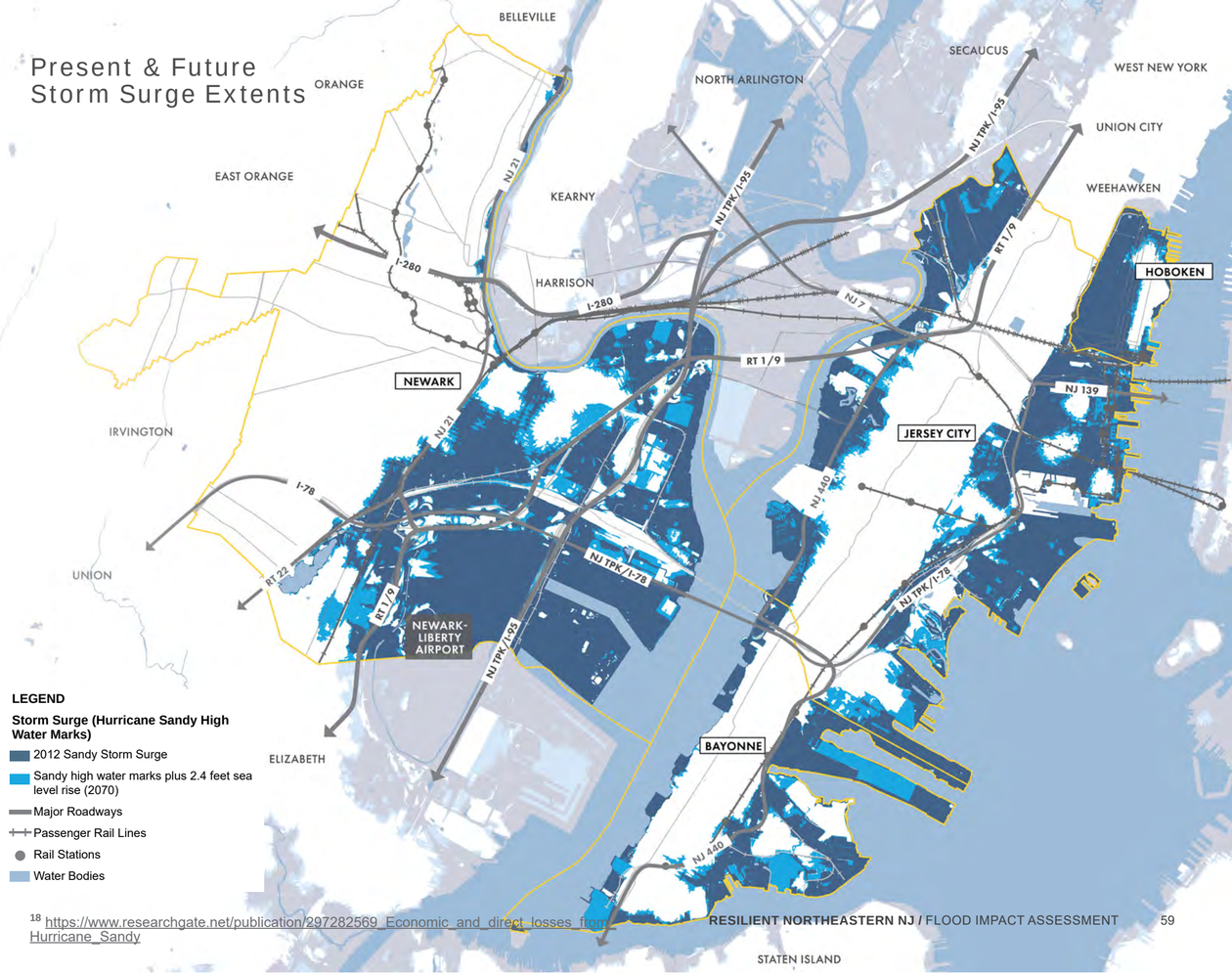
120,000 - 150,000 Residents
In impacted homes out of 700,000 residents (17-21%)

The Present & Future Storm Surge Extents map on page 59 shows extents of flooding (where floodwaters may reach), not depths or areas where the most significant flooding would occur. Modeled depths for the future storm surge event may range from a few inches to over 10 feet. However, even a few inches of flooding could cause significant damage or disruption.

To understand possible future flooding from extreme storm surge, Resilient NENJ modeled a future extreme storm surge event by adding 2.4 feet for sea level rise onto Hurricane Sandy high-water marks. Hurricane Sandy caused extensive flooding to coastal areas in the region in 2012, causing $29 billion of damage across New Jersey.[18] This value includes some of the same damage metrics that this flood impact assessment addresses, such as direct physical damages to personal property and direct business impacts. It also includes other metrics, like impacts to transportation and utilities infrastructure as well as the impact on the state's tourism industry. The Resilient NENJ team estimates that $17 billion of direct losses could be expected in a present-day extreme storm surge event, which falls in a similar order of magnitude to actual losses experienced from Hurricane Sandy in 2012.

A sizable portion of Newark, Port Authority, Doremus, and Ironbound are expected to be impacted by a future extreme storm surge event without action. Flooding is concentrated along the coastal areas of Jersey City and Bayonne and significantly impacts Hoboken. While the map does incorporate changes to properties elevated since Hurricane Sandy, it does not include any projects that are currently planned or ongoing, including Rebuild by Design-Hudson River in Hoboken and the USACE Newark Flanking Plan. **These projects are in progress and should reduce risk to areas that could experience $11 billion in losses across 2,300 buildings and impact 69,000 residents in a future extreme storm surge event.** The Resilient NENJ team estimates that the Rebuild by Design project could reduce the modeled future storm surge impacts to 640 buildings in which 37,000 residents reside, for a total of $6.4 billion in avoided losses. Similarly, the team estimates that the Newark Flanking Plan could reduce impacts to 1,600 buildings in which 32,000 residents live, for a total of $4.6 billion in avoided losses.

Data Source: *See Appendices A and B for data sources*



[18] https://www.researchgate.net/publication/297282569_Economic_and_direct_losses_from_Hurricane_Sandy

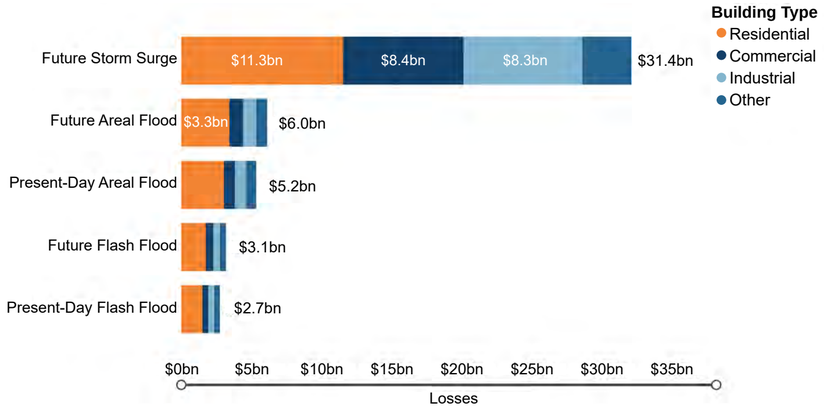
COMPARISON OF RESULTS

When compared to models of future flash flooding or areal flooding events, the extreme storm surge event is expected to cause more losses (nearly five times more!) despite covering a much smaller area. This is because the modeled flood depths in buildings for the future storm surge event (3.5 feet, on average) are quite a bit higher than that for the major rainfall events (0.5 feet, on average), leading to significantly greater direct physical damage. Flood mitigation planning in the region reflects this difference. Many of the ongoing or planned projects in the region, such as the Rebuild by Design-Hudson River project in Hoboken, are targeting coastal flood risk reduction in reaction to the devastation wrought by Hurricane Sandy.

Future extreme storm surge flooding should happen much less often than flash floods or areal floods caused by rainfall events within the region. Though the total rainfall-related impacts presented in this report may be less than the coastal impacts, flash flooding and areal flooding still both have the potential to cause billions of dollars in losses today and cause disruption over a much larger area. Hurricane Irene, for example, caused between $4 and $6 billion of damage in New Jersey. Although this event was a coastal storm, rainfall was the primary driver of flooding in the region, not the storm surge.

Ultimately, an investigation of a wider range of flood frequencies would provide a clearer understanding of relative risk between rainfall and coastal storm events and how that risk will evolve over time. In the meantime, results presented in this report are best understood with the probability of occurrence and source of flooding in mind. As described in the next section of this report, a storm surge event is likely to impact different types of buildings (more industrial and commercial) than a rainfall event. A rainfall event is likely to directly impact more residents (220,000) than a future storm surge event (150,000). Storm surge, flash floods, and areal floods all cause severe losses within the region, but there is presently less investment in addressing stormwater flooding, which may shift the relative importance of one hazard over another. Further, rainfall flooding is already happening on a regular basis, reportedly degrading quality of life in communities across the region.

LOSSES BY FLOOD EVENT TYPE

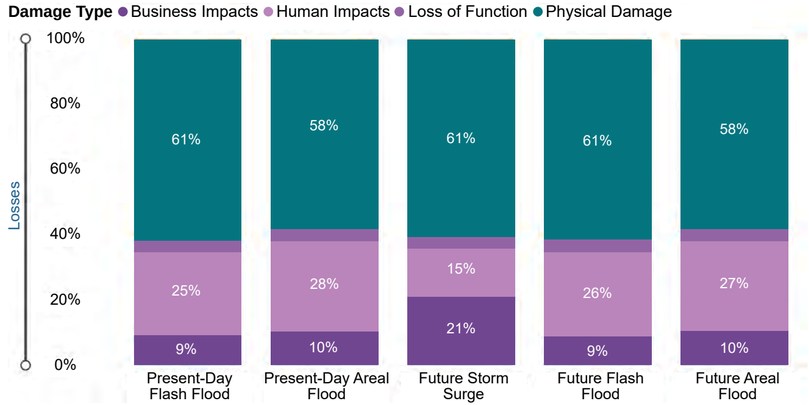


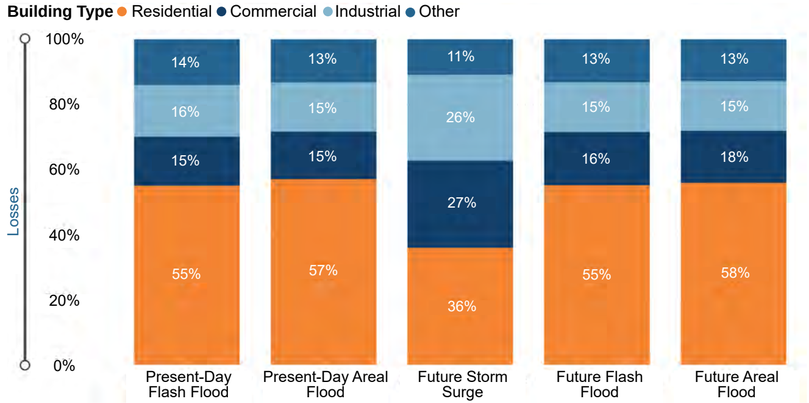
BREAKDOWN OF IMPACTS

- **Direct Physical Damage** is the largest driver of losses calculated in this analysis, contributing to roughly 60 percent of the quantified losses across all rainfall and coastal events modeled for Resilient NENJ. These represent repair and restoration costs that homeowners, business owners, utilities, state agencies, and the federal government may face following a storm event.
- Because **Loss of Function** impacts can be hard to quantify, these values contribute a relatively small (<5 percent) portion of the estimated overall losses to the region. Nevertheless, impacts to public and essential service-related assets can reverberate throughout and beyond the region. For example, a school shut down, as we have seen through the COVID-19 pandemic, can have much broader impacts on the lives and livelihoods of students, parents, and teachers alike – impacts that are not necessarily represented through the operating budget of the school. Loss of function to transportation assets, like ferries, bridges, or tunnels, are also not captured but could have significant impacts to people who live in and travel through the region.
- The largest share of loss calculated comes through expected impacts to **residential buildings** – both because of the sheer number of homes affected in the region and because estimation of losses to these structures are well-established and accepted by industry. These losses include direct physical damage to the homes and their contents, displacement and relocation costs to the residents within, factors accounting for costs due to mental stress, anxiety, and lost productivity of affected people.
- Overall, 280,000 residents are expected to have their homes exposed to either rainfall or coastal storm surge flooding, representing over 40 percent of the population in the region at large. Of these residents, half live in areas of high social vulnerability, as defined as an SVI score over 0.75.

- Future storm surge is likely to have a bigger impact on **commercial and industrial** properties than the flash or areal flood events, because these land uses are generally concentrated along the waterfront, which will be the first area to feel the effects of sea level rise. These areas, particularly along Upper New York Bay and Newark Bay, are the most exposed to storm surge, high wind, and waves. Water levels will also rise along the major rivers based on the storm surge, which are also lined with commercial and industrial properties.
- **Direct business impacts** occupy about 10-percent of losses and only include impacts of businesses that are directly flooded. These calculations do not include the reverberating losses to the economy from these closures, such as lost income and spending from employees. They do not include stress and impacts to employees and visitors who do not live directly within the affected area. This is a recognized limitation of the study, particularly in an area where many of the people who would be affected are commuting to, visiting, or traveling through the area. This large transitory population results in a significant under-count of affected people.

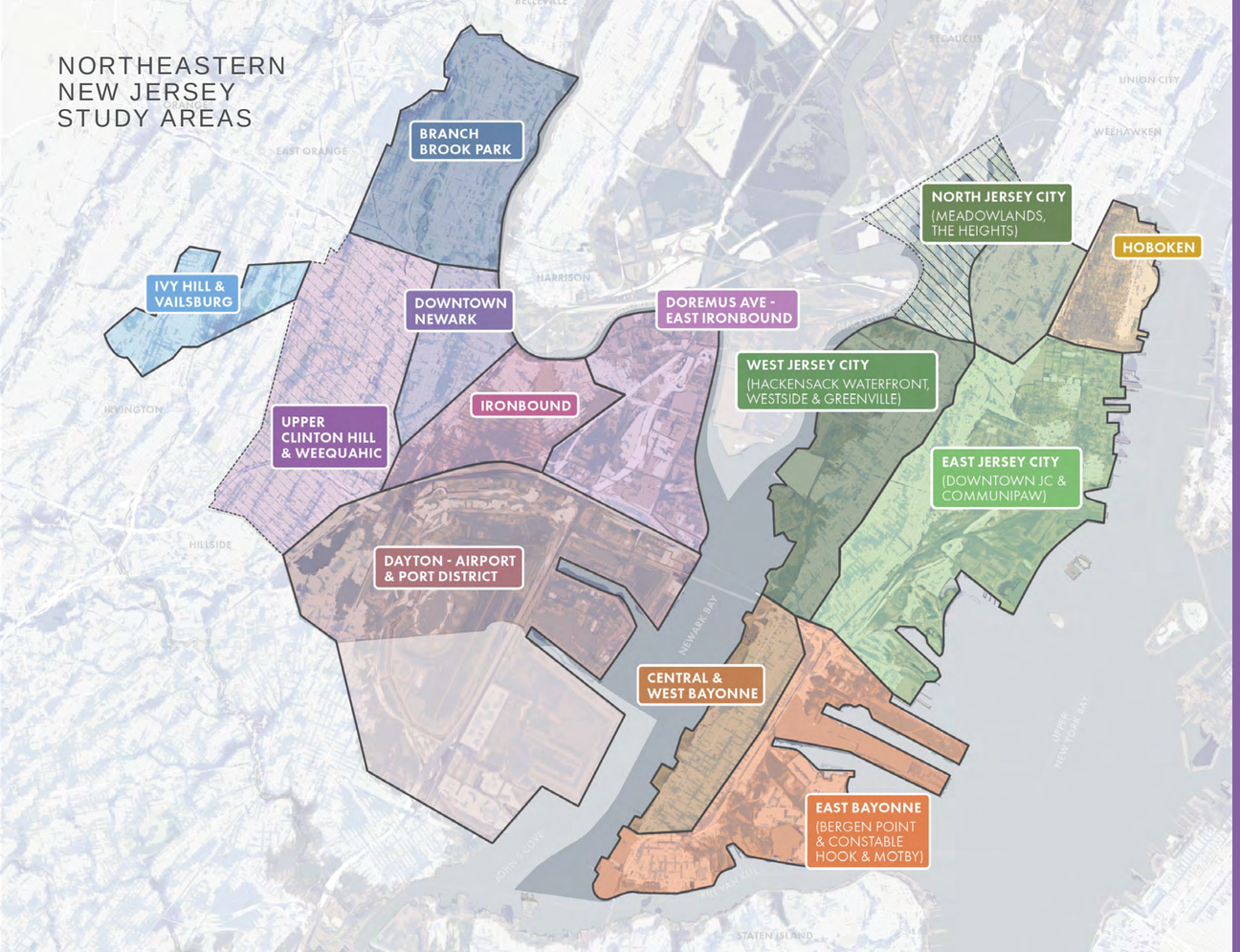
While these breakdowns help to summarize consequences at a regional scale, is it important to remember that each city – each neighborhood – has a unique risk profile and needs. For example, mitigation strategies targeting reduced physical losses to industrial properties may be appropriate in Bayonne, while Hoboken's strategies may focus on reducing human impacts for the large residential population. Specific breakdowns for each city and study area are reported later in this report.





Top: *Share of loss type regionwide by modeled flood event*

Bottom: *Share of overall loss contributed by building use for each modeled event*



03 - CITY AND STUDY AREA FLOOD IMPACTS

This section summarizes flood impacts to cities within the region, then explores the implications to the study areas within each city. Because the extent of flash flooding and areal flooding are similar, this section focuses on the more extreme areal flood event. Impact assessment results with damage breakdowns for each flood event for each study area can be found in Appendix E.

JERSEY CITY

Jersey City is a racially and ethnically diverse city that has been rapidly developing in recent years. The city is home to more than 260,000[19] residents and has population densities ranging from 30,000 to 60,000 residents per square mile. Additionally, about 18 percent of the city's residents are under the poverty line, compared to the national average of 11.4 percent.[20] While many residents commute into New York City, Jersey City itself is also a large employment center and transportation node for the northeastern region.

Rainfall Areal Flood
Range indicates change from present to future modeled flood events

$1.4 - $1.6 Billion	3,200 - 3,400 Buildings	76,000 - 82,000 Residents
In expected losses	Impacted out of 12,000 total buildings	In impacted homes out of 260,000 residents

Coastal Storm Surge
Future modeled flood event

$11 Billion	2,900 Buildings	58,000 Residents
In expected losses	Impacted out of 12,000 total buildings	In impacted homes out of 260,000 residents

Modeled flood impacts are widespread across Jersey City but concentrated along the coasts, even for stormwater. These impacts are due to higher land along the center of the city. Highest losses are expected in downtown Jersey City due to the concentration of people and infrastructure.

For this project, Jersey City was divided into the following study areas: **East, West, and North Jersey City.**

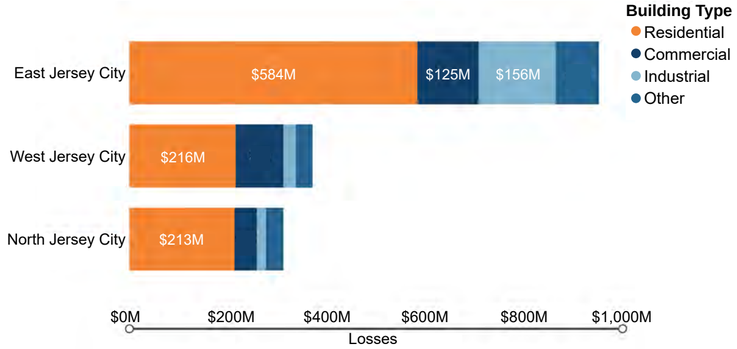
Rainfall Areal Flooding: Present and future rainfall flooding affects coastal areas in Jersey City but also extends into inland areas, particularly along roads and railways. This flooding impacts traffic and movement throughout the city. Segments of critical streets, such as Montgomery Avenue that connects the east and west shorelines and Monticello Avenue that connects north and south Jersey City, may flood up to 1 foot each in some places in the future areal rainfall event (1 percent, 24-hour). Multiple PATH lines – the rapid transit system connecting New Jersey with Lower and Midtown Manhattan – are at risk of disruption from heavy rainfall. The commercial and industrial centers of Jersey City risk inundation, property damage, and business impacts. The warehouses south and west of Liberty State Park and Communipaw as well as many store fronts on the eastern waterfront may incur significant losses. Residential areas, such as sections of Greenville and Country Village, could also have some of the most significant losses from the future areal flood event.

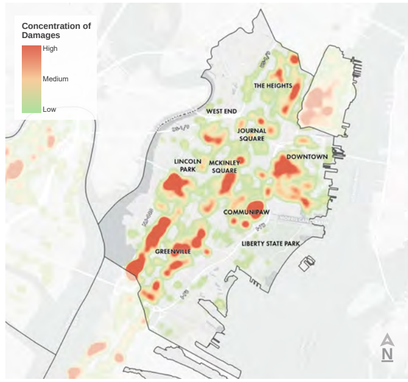
Coastal Storm Surge: As water elevations rise, coastal flood pathways bring floodwaters into Jersey City from the Hudson River and Upper New York Bay on the east as well as from the Hackensack River on the west. The losses expected from the modeled extreme storm surge event are largely attributed to the residential and commercial development along the waterfront, and at least eight public housing complexes are predicted to incur losses. Multiple PATH lines are at risk of disruption, specifically segments at the crossing of the Hackensack River as well as segments along the Hudson River through Downtown Jersey City. Major roadways, including the Holland Tunnel entryway, I-78, and the New Jersey Turnpike, are expected to be flooded, which could impact bus routes, evacuation paths, and overall mobility in and out of the city. The combination of marginalized populations and flooded public transit pathways creates a necessity to act on the coastal risks in Jersey City.

[19] *The most recent 2020 census estimates that the population was more than 290,000, but this analysis is based on population data pulled from 2019 American Community Survey estimates, as the 2020 census data were not available at the time that data analyses were completed. More information on the methodology can be found in Appendix C.*

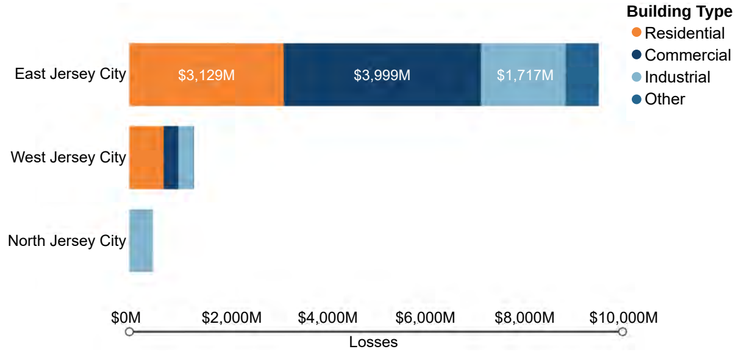
[20] *"Income and Poverty in the United States: 2020," (census.gov)*

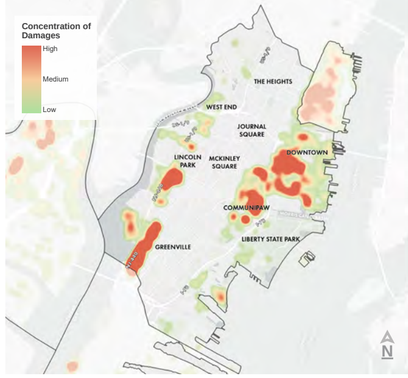
DAMAGES FROM AREAL FLOODING
(MODELED FUTURE AREAL FLOODING)





DAMAGES FROM COASTAL STORM SURGE
(MODELED HURRICANE SANDY PLUS 2.4 FEET)





EXAMPLE PRIORITIZED ASSETS

Category	Type	Name	Tidal Flood	Flash Flood	Areal Flood	Storm Surge
Ecosystem	Community	Estuary & Wetlands	●	●	●	●
Emergency Response	Hurricane Evacuation Route	12th Street		●	●	●
	Fire Stations	Jersey City Fire Department Engine 9		●	●	
	Shelters	Community Center Pershing Field		●	●	
	Shelters	Riverside Assembly of God				●
Infrastructure	Port Facilities	Caven Point Terminal	●	●	●	●
	Rail Stations	Richard St.				●
	Rail Stations	Journal Square		●	●	
	Rail Stations	Newport		●	●	●
	Rail Stations	9th St./Congress St.				●
	Rail Stations	Grove St.			●	●
	Rail Stations	Exchange Pl.		●	●	●
Public Health	Parks	Playground				●
	Schools	Full Will of God Christian Academy		●	●	
	Child Care Centers	Kidz Inn Day Care & Learning Center, Inc		●	●	
	Child Care Centers	Kidz Kingdom Learning Center			●	
Quality of Life	Places of Worship	Vine Development Corporation of Jersey City				●
	Places of Worship	Grace Gospel Chapel			●	
	Colleges	University of Phoenix-New Jersey				●
	Community	Liberty Science Center				●
	Community	Hudson County Community Wellness Center			●	
	Places of Worship	Holy Rosary Roman Catholic Church		●	●	●
	Places of Worship	St Michael Roman Catholic Church		●	●	●
	Community	Country Village Baseball Field				●

This list highlights a selection of prioritized critical assets within the city to demonstrate the variety of impacted asset types. The assets are examples that ranked high during the prioritization process but do not comprise the full list of critical assets in this city. The full asset list along with the prioritization methodology can be found in Appendix D.

EAST JERSEY CITY

East Jersey City includes Downtown, Communipaw, Bergen-Lafayette, and Liberty State Park. The area is loved for its diversity and the abundance of restaurants, shops, and cultural activities. The overall area is a mix of high-density residential, commercial, and industrial, with high rises and commercial properties concentrated along the waterfront and a higher portion of industrial areas in Communipaw and Bergen-Lafayette, mixed in with a high portion of historic or aging buildings.

Community members share an appreciation for the Hudson River Waterfront Walkway, because it provides access to the waterfront, exercise, leisure, and views of Manhattan. In the surrounding neighborhoods, the pedestrian plazas created during COVID have become a valued community asset. The increasing availability of bike lanes Downtown has also made the area more accessible. Access to neighborhood parks, such as Hamilton Park, Van Vorst Park, Lafayette Park, and Berry Lane Park, is essential to the community. Community members describe the larger Liberty State Park as the front yard of their neighborhoods. The park is treasured for its play areas, wildlife, the science center, and other festivals and activities.

Transportation infrastructure is also important in this area for access to other parts of Jersey City and into New York City. This area includes several PATH stations, Hudson Bergen Light Rail stations, ferry terminals, and various bus stops. Downtown and Bergen-Lafayette are concentrated areas of development in the city, and there are various redevelopment plans that guide transformation of these areas.

Rainfall flooding is a more frequent and urgent concern than coastal storm surge flooding in this area. The combined sewer system in the area limits stormwater storage capacity. Modeled areal and flash flooding is widespread and includes streets, such as Grand Avenue, Montgomery Avenue, and Marin Boulevard, and around the downtown New Jersey Turnpike exits, which reflects feedback from community members about flooding in the roads leading to Hoboken and at turnpike exits. Modeled rainfall flooding is also most significant west of the turnpike in Bergen-Lafayette; in and around parks, including Liberty State Park, Lafayette Park, Berry Lane Park, and Bayside Park; in various PATH lines; and in public housing complexes in Communipaw. Though overall damages from rainfall are lower than that of major coastal storms, rainfall flooding is expected to continue to disrupt traffic and transportation and to cause flooding of basements and low-lying first floors in some areas. Of note, community members reported flooding in streets south of Bay View Cemetery, such as along Cator Avenue and Princeton Avenue, which is not reflected in the rainfall models for current or future events.

LAND USE & ASSETS

Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

EAST JERSEY CITY

Coastal flooding in this area can impact a significant amount of people and infrastructure, including many of the highly valued parks and transportation assets. As seen with Hurricane Sandy, though coastal storms are less frequent than rainfall events that cause disruption, they have the potential to cause significant damage. As expected, the modeled future extreme storm surge event has the highest potential to cause significant damage. One of the flood pathways for this area during Hurricane Sandy was the Morris Canal, where waters passed under the turnpike and into the residential areas of Communipaw, including public housing complexes.

Important infrastructure that is at risk from extreme storm surge include City Hall, the Port Authority Police Headquarters, two fire stations, 19 K-12 schools, Warren Street and Liberty Harbor Ferry Terminals, 8 PATH Stations (including the New Jersey Transit – Exchange Place and Paulus Hook Terminal), the Greenville Train Yard, GCT Container Port, and Liberty State Park.

Tidal flooding is expected to impact shops and residential areas in the waterfront area and other low-lying areas, such as southern and western Downtown, Communipaw, and areas within Liberty State Park. Though future tidal flooding has the smallest extent among the modeled flood events, the high frequency of such events would render many of these areas unusable.

Several projects in various stages of the planning process have been proposed within this study area that may help reduce flood impacts to some extent. The Mill Creek Redevelopment Project will raise land in the area for construction of mixed-use spaces and may provide on-site stormwater storage. The PANYNJ Hardening of Exchange Place, Newport, and Grove Street PATH Stations and the Liberty State Park Natural Resource Restoration Project may also provide some co-beneficial flood risk reduction. The Jersey City Resiliency Master Plan proposed several conceptual storm surge protection projects for this area, including a Hudson Riverwalk Boardwalk Levee and Dudley and Washington Street Elevations. There are about 20 structures in East Jersey City that fall within these redevelopment areas and may benefit from these projects.

RISK CONTEXT

Rainfall Areal Flooding

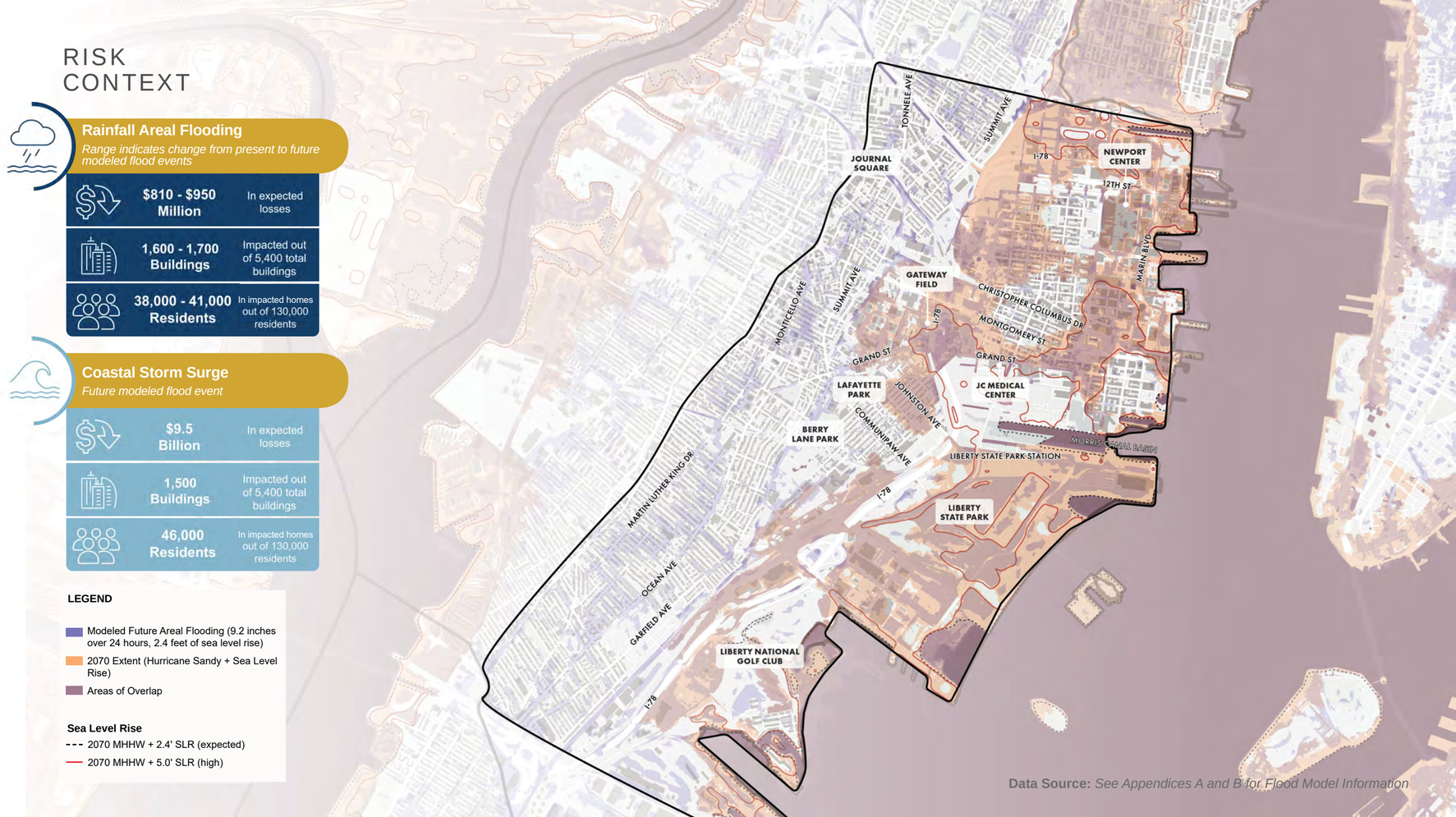
Range indicates change from present to future modeled flood events

$810 - $950 Million	In expected losses
1,600 - 1,700 Buildings	Impacted out of 5,400 total buildings
38,000 - 41,000 Residents	In impacted homes out of 130,000 residents

Coastal Storm Surge

Future modeled flood event

$9.5 Billion	In expected losses
1,500 Buildings	Impacted out of 5,400 total buildings
46,000 Residents	In impacted homes out of 130,000 residents



Data Source: *See Appendices A and B for Flood Model Information*

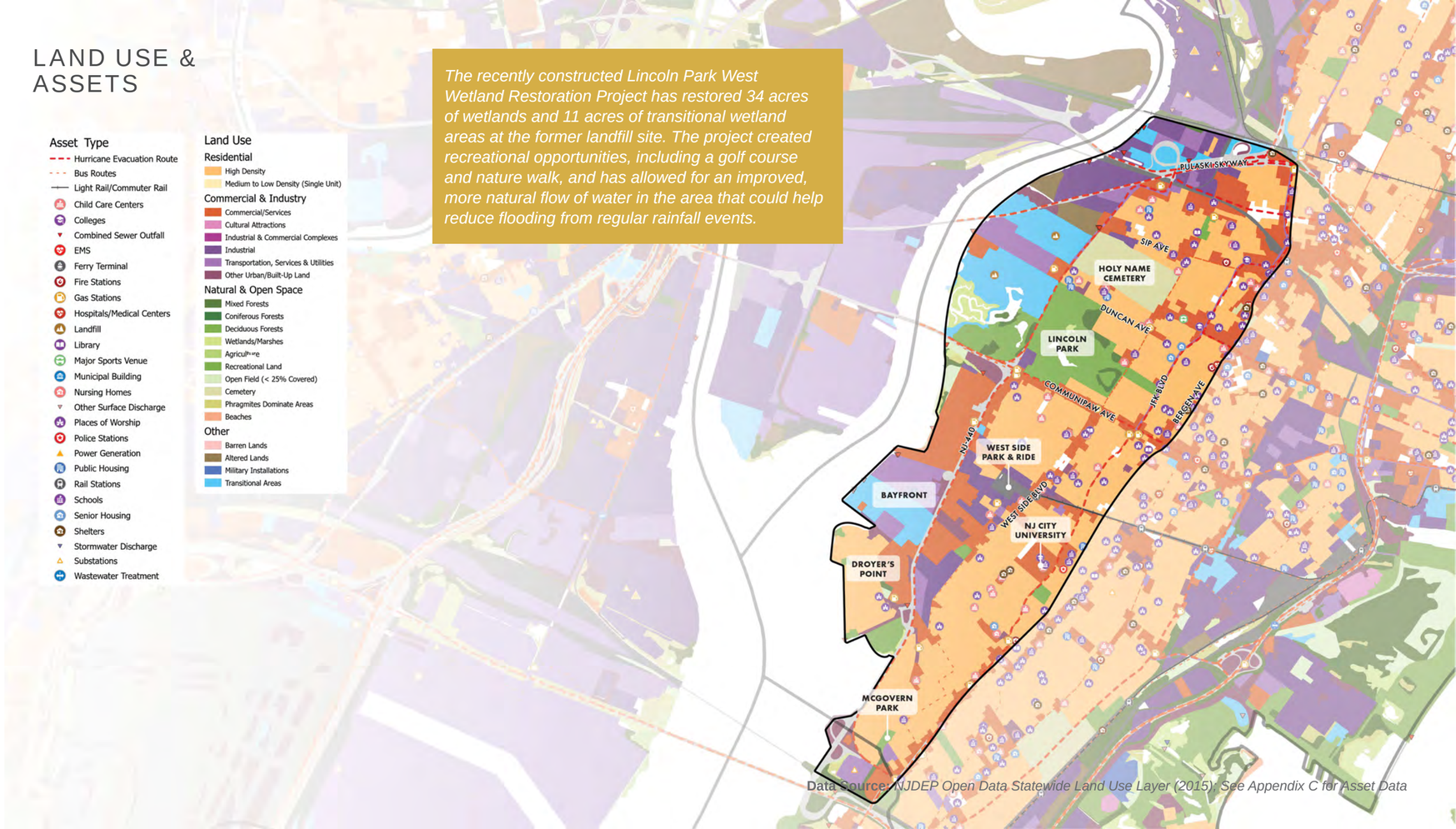
WEST JERSEY CITY

West Jersey City includes the industrial and commercial areas along the Hackensack Waterfront and the inland residential neighborhoods toward the center of the city, spanning from the border with Bayonne to the Pulaski Skyway and the New Jersey Turnpike. Community members in this area value access to the waterfront, the neighborhood pocket parks, and the larger parks, such as Lincoln Park. The community also values the multitude of public transportation options and desires to see improvements in pedestrian and biker experiences in areas where feasible.

Rainfall flooding is a frequent and urgent concern in this area due to the combined sewer system and the limited capacity of the drainage network. Both coastal and rainfall flooding are likely to impact the Country Village neighborhood, Society Hill, Route 440, Route 1-9, New Jersey City University, and the West Side Hudson Mall. The model results mirror reports of repeat flood locations from community members, such as the intersection of West Side Avenue and Sip Avenue, other intersections along West Side Avenue, within and around Route 440, and in Country Village, which is known to have basement flooding issues. Intersections, such as Route 440 at Communipaw Avenue, reportedly flood even during light rain. The Skyway Golf Course, built atop a former landfill, is exposed to both rainfall and coastal flooding. More research is needed to understand the extent to which flooding of this site could release contaminants. Rainfall flooding may extend to areas further to the east but is likely to primarily impact roadways.

LAND USE & ASSETS

The recently constructed Lincoln Park West Wetland Restoration Project has restored 34 acres of wetlands and 11 acres of transitional wetland areas at the former landfill site. The project created recreational opportunities, including a golf course and nature walk, and has allowed for an improved, more natural flow of water in the area that could help reduce flooding from regular rainfall events.



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015). See Appendix C for Asset Data*

WEST JERSEY CITY

The results from this impact assessment show that future coastal events have the highest potential to cause significant damage, though such extreme events are expected to occur less frequently than flash flood or areal flood events. Hurricane Sandy flooded most of the low-lying areas along the Hackensack, including Country Village, Society Hill, and the Hudson Commons. The eastern bounds of future storm surge flooding are roughly Mallory Avenue in the northern portion of this area and Sycamore Road in the southern portion.

The maps show that modeled rainfall or coastal flooding does not impact the Bayfront Redevelopment Area, which is being constructed at a higher elevation to protect from flooding.

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$330 - $370 Million	In expected losses
1,200 - 1,300 Buildings	Impacted out of 4,100 total buildings
22,000 - 23,000 Residents	In impacted homes out of 76,000 residents

Coastal Storm Surge

Future modeled flood event

$1.3 Billion	In expected losses
1,300 Buildings	Impacted out of 4,100 total buildings
12,000 Residents	In impacted homes out of 76,000 residents

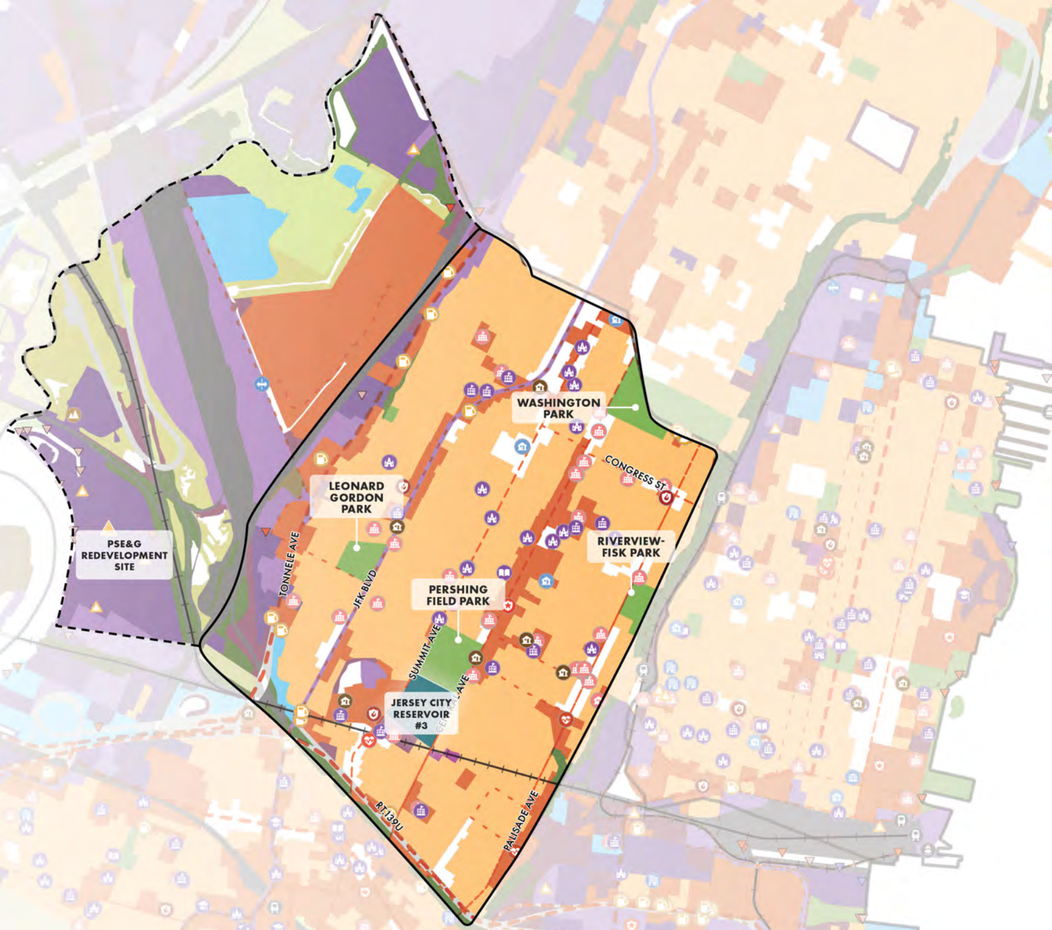
Data Source: *See Appendices A and B for Flood Model Information*

NORTH JERSEY CITY

TThe North Jersey City study area consists of the Heights and the Meadowlands areas, which are under jurisdiction of the New Jersey Sports Exposition Authority. In the growing Heights neighborhood, like in West Jersey City, community members value parks, such as Washington Park and Riverview-Fisk Park, and the variety of shops and restaurants. Growth in the neighborhood may come at a cost. Residents have expressed concerns that development is contributing to flooding and trash and debris in the streets.

The Meadowlands is largely a junction for goods and transportation with multiple rail lines and highways. It is largely centered around the Norfolk Southern (NS Croxton) Intermodal Rail Terminal, where the various shipping ports connect to highways, including I-95, and rail lines that move goods further west. During both heavy rainfall and coastal storm surge events, this critical transportation connection point is at risk of high losses.

LAND USE & ASSETS



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

NORTH JERSEY CITY

Although the Heights is at a higher elevation than other areas of Jersey City and is not expected to flood in a future storm surge event, it is still susceptible to rainfall flooding. The Resilient NENJ team has heard reports of flash floods in streets as well as basement flooding in this area. Residents report that flooding can make it hard to get around and sometimes is associated with bad smells in the streets due to sewer back-ups. The models show that areal flooding is likely significant along Palisade Avenue, Route 1, and in areas east of JFK Boulevard.

RISK CONTEXT

Rainfall Areal Flooding

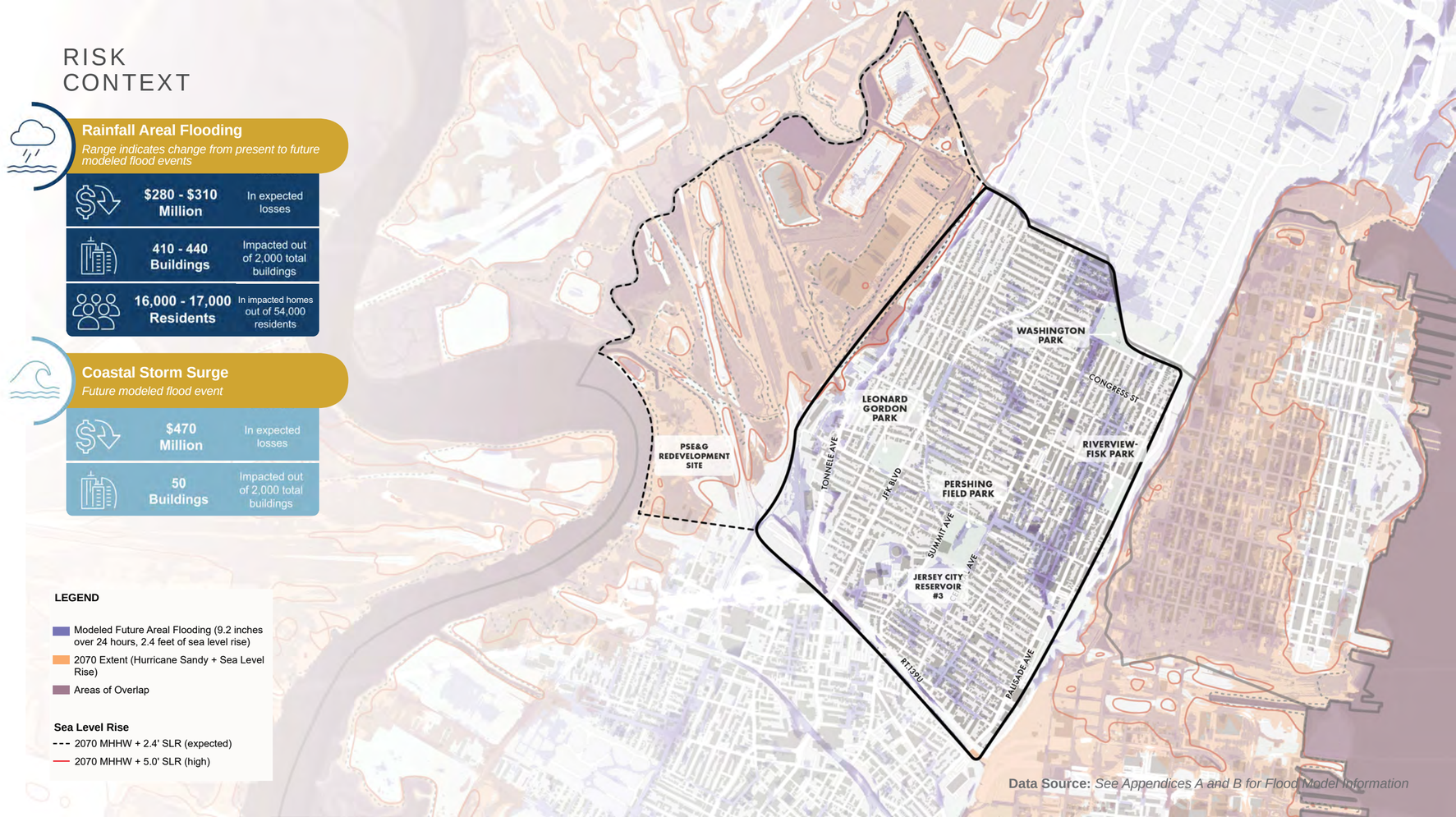
Range indicates change from present to future modeled flood events

$280 - $310 Million	In expected losses
410 - 440 Buildings	Impacted out of 2,000 total buildings
16,000 - 17,000 Residents	In impacted homes out of 54,000 residents

Coastal Storm Surge

Future modeled flood event

$470 Million	In expected losses
50 Buildings	Impacted out of 2,000 total buildings



Data Source: *See Appendices A and B for Flood Model Information*

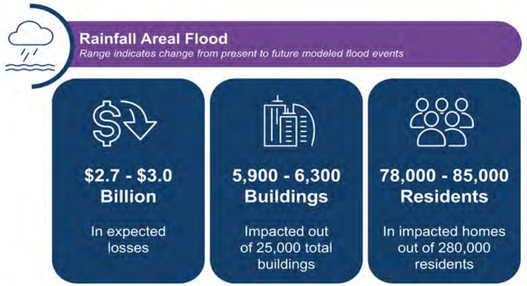
NEWARK

Newark is densely populated and the most populated city in NENJ and the state. It has the largest concentration of populations with high social vulnerability scores and the highest poverty rate of the four municipalities in the region. Before the COVID-19 pandemic, more than 30-percent of the population reportedly lived below poverty level.[21]

Newark is a hub for goods and transportation. Like many of the other cities in the region, several key road and railroad corridors traverse the city. Newark is also home to Newark International Airport and Port Newark, which is the largest port on the east coast. Newark was divided into seven study areas for this project – Doremus Avenue and East Ironbound, Dayton and the Newark Airport/Port District, Ironbound, Downtown Newark, Branch Brook Park, Ivy Hill & Vailsburg, and Upper Clinton Hill.

The flood models reflect what we already know about rainfall flooding in Newark – that it is widespread across the city, with the most significant impacts in Ironbound, Ivy Hill, Vailsburg, and around Branch Brook Park. Coastal storm surge impacts could also be significant but are expected to be concentrated in the areas of Doremus Avenue, the airport, port, and Ironbound. Coastal storm surge is expected to be addressed to some extent by the Newark Flanking Plan, which is under consideration by USACE.

Coastal solutions should consider any areas not directly addressed by the Newark Flanking Plan, most notably the areas around Doremus Avenue that are expected to be heavily impacted by tidal flooding. Stormwater solutions must look to drainage pathways (e.g., Ironbound receives stormwater from other areas in the city). Stormwater solutions should consider the upstream and downstream effects of drainage solutions, bottlenecks in the sewer system, and the presence of contaminated sites, as well as the multiple benefits associated with converting impervious surface to green space wherever possible. The widespread flood risk also points to the need to ensure adequate sheltering or evacuation for life safety.



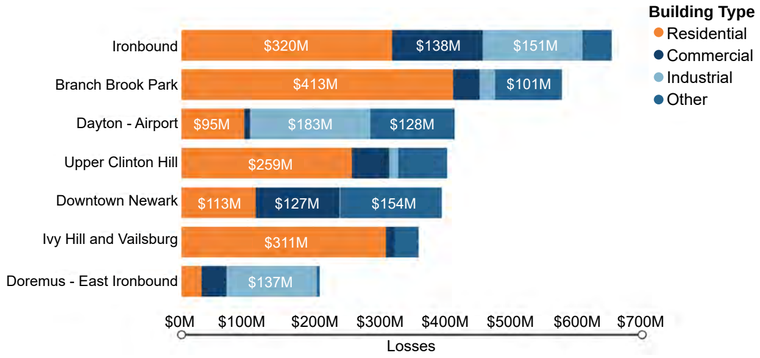
Rainfall Flooding: The flood models show impacts of rainfall flooding across the entire city, and residents echoed similar observations during community meetings and surveys. A heavy rainfall event could impact industry, commercial districts, and residential neighborhoods. Additionally, the models demonstrate risks to roads, highways, and railroad lines, restricting mobility for the city's 280,000 residents and all the people who will move through Newark from other parts of New Jersey, New York City, and Long Island.

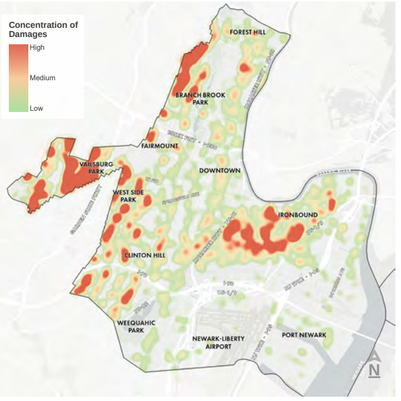
Coastal Storm Surge: Storm surge is expected to cause twice the direct damages as rainfall flooding, entering Newark along Newark Bay and the Passaic River and extending to Route 21 (McCarter Highway) and the Northeast Corridor Railway Line. As occurred during Hurricane Sandy, future flooding would damage the Newark-Elizabeth Marine Terminal, overrun the current floodwall that surrounds Newark Airport, and damage goods held in the warehouses near these hubs. Coastal flooding is also expected to incur losses to the residential areas along the Northeast Corridor Rail Line.

[21] https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html

DAMAGES FROM AREAL FLOODING

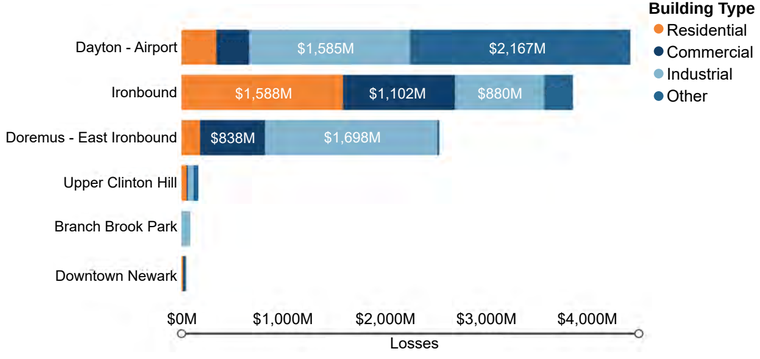
(MODELED FUTURE AREAL FLOODING)

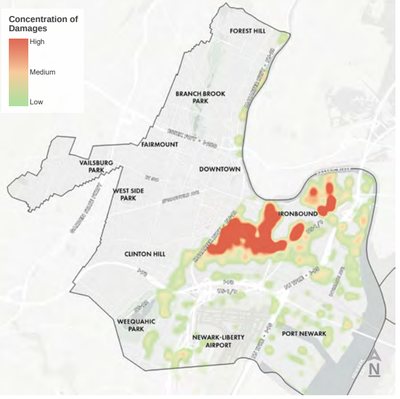




DAMAGES FROM COASTAL STORM SURGE

(MODELED HURRICANE SANDY PLUS 2.4 FEET)





EXAMPLE PRIORITIZED ASSETS

Category	Type	Name	Tidal Flood	Flash Flood	Areal Flood	Storm Surge
Emergency Response	Hurricane Evacuation Route*	New Jersey Turnpike	●	●	●	●
	Police Stations	New Jersey Transit Police Department				●
	Shelters	Newark		●	●	●
	Shelter	Boylan Recreation Center		●	●	
	Shelters	Technology High School		●	●	
	EMS	Inner City Transit Medical Transportation			●	
	EMS	Newark Fire Department Rescue 1			●	
Infrastructure	Light Rail*	AirTrain Newark	●	●	●	●
	Rail Stations	Davenport Ave.		●	●	
	Electrical Substations	Port Street				●
	Electrical Substations	Substation # 133201				●
	Electrical Substations	Substation # 172895			●	
	Electrical Substations	Ironbound				●
	Rail Stations	Washington St.			●	
Public Health	Parks	Weston Park			●	
	Hospitals and Medical Centers	Rainbow Room – Dayton Street School		●	●	
	Hospitals and Medical Centers	Columbus Hospital		●	●	
	Hospitals and Medical Centers	Health Center at Central High School		●	●	
	Child Care Centers	The Chen School, Inc.			●	
	Child Care Centers	Zone Four			●	
	Child Care Centers	Story Hall Daycare Center				●
	Public Housing	Terrell Homes		●	●	●
Quality of Life	Places of Worship	Iglesia De Dios En Espiritu Y En Verdad			●	
	Places of Worship	Igreja Betel Assembleia De Deus Inc				●
	Places of Worship	Light of Rescue			●	
	Places of Worship	Spiritual Assembly of the Bahais of Newark				●
	Places of Worship	House of His Glory Ministries Inc			●	
	Places of Worship	Household of Faith, a NJ Nonprofit Corp		●	●	
	Places of Worship	Promised Land Missionary Baptist Church			●	

This list highlights a selection of prioritized critical assets within the city to demonstrate the variety of impacted asset types. The assets are examples that ranked high during the prioritization process but do not comprise the full list of critical assets in this city. The full asset list along with the prioritization methodology can be found in Appendix D.

DOREMUS - EAST IRONBOUND

In the northeast corner of Newark, the Doremus – East Ironbound study area is largely composed of warehouses, utilities, and large wholesale retailers. Much of this area was historically wetlands and was filled over time to create the industrial and port areas that they are today. As a result of this development, water no longer follows its natural flow patterns, which is an influencing factor in the significant flooding that we see in this area today.

The Doremus area contains critical infrastructure assets like the PVSC WWTP, the Essex Generating Station, and the New Jersey Turnpike, Route 1-9, and railroads that pass through this area. These places are important to the economy of the city and state, but also mean that the area and surrounding areas are exposed to elevated amounts of vehicular pollution and emissions from factories and plants. Industrial properties line the waterfront, blocking off public access to the Passaic River and Newark Bay. Many of these important places already flood regularly during heavy rainfall and flooded during Hurricane Sandy in 2012. Community members have reported flooding along Raymond Boulevard and Avenue P, specifically. Community members have also expressed concerns about the potential for polluted flood waters to impact public health when these industrial areas flood.

LAND USE & ASSETS

The Forward Bound Doremus Plan is a redevelopment plan for this area that is underway and is envisioning the future for this area, including establishing new zoning regulations. Resilient NENJ team has taken steps to ensure that the Forward Bound Doremus Plan and Resilient NENJ Plan aligns with one another.

Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

DOREMUS - EAST IRONBOUND

Future rainfall and coastal storm surge events are expected to cause significant losses on both sides of the New Jersey Turnpike in this area. In addition to warehouses incurring losses, the Essex Generating Station and Newark Energy Center, which both provide regular and peak hour services along Newark Bay, are expected to be exposed to both future rainfall and coastal storm surge flooding. Impacts to these utilities have the potential to cause major, long-term, regional disruptions. There are also multiple transportation connections in the study area that lead to the Pulaski Skyway and I-95. Flooding along these roadways could result in significant traffic disruptions during flood events. The loss numbers reported in this section are based on census data for residents and do not reflect the many workers who spend time in this area at the warehouses and plants.

RISK CONTEXT

Rainfall Areal Flooding

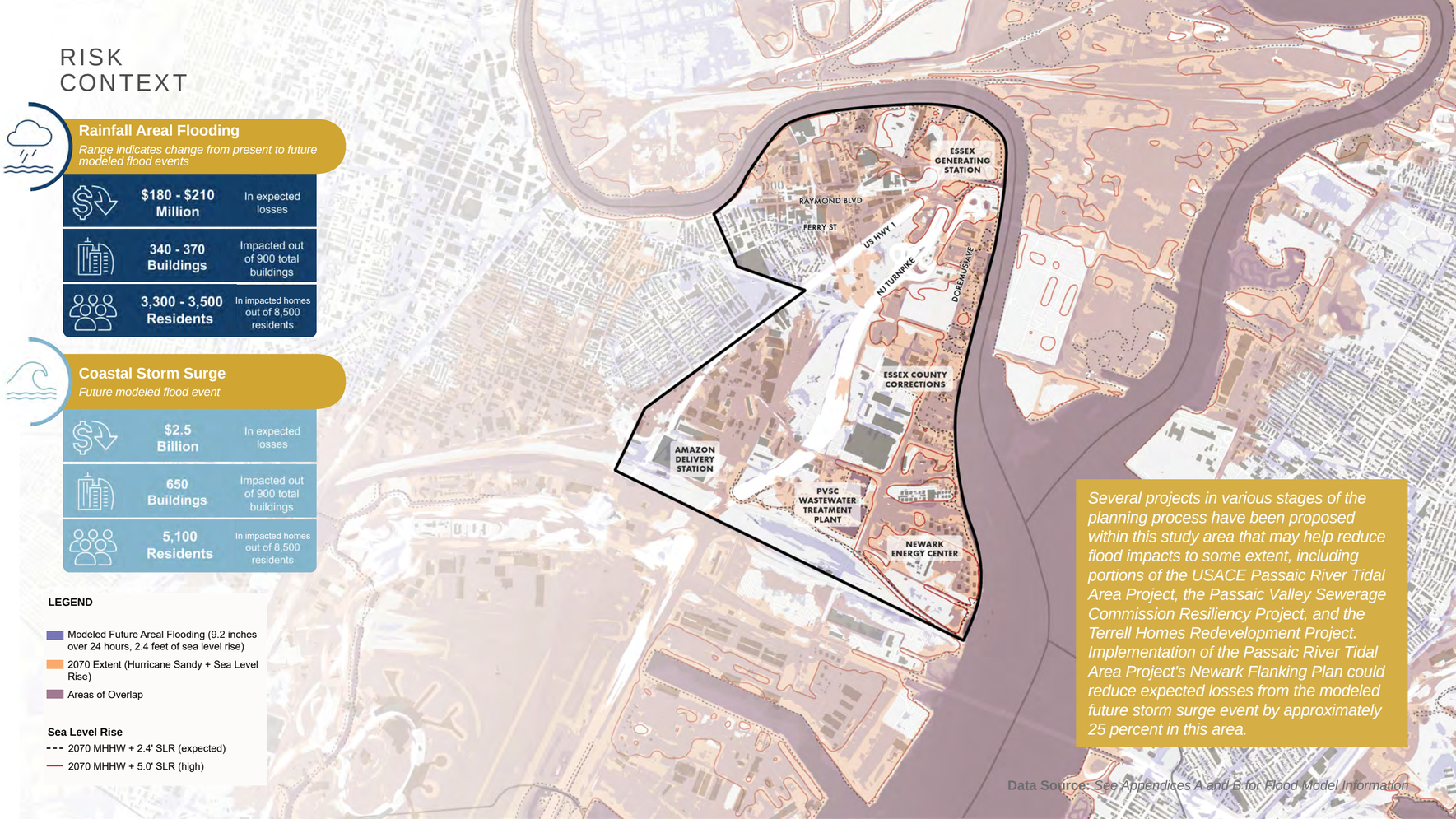
Range indicates change from present to future modeled flood events

$180 - $210 Million	In expected losses
340 - 370 Buildings	Impacted out of 900 total buildings
3,300 - 3,500 Residents	In impacted homes out of 8,500 residents

Coastal Storm Surge

Future modeled flood event

$2.5 Billion	In expected losses
650 Buildings	Impacted out of 900 total buildings
5,100 Residents	In impacted homes out of 8,500 residents



Several projects in various stages of the planning process have been proposed within this study area that may help reduce flood impacts to some extent, including portions of the USACE Passaic River Tidal Area Project, the Passaic Valley Sewerage Commission Resiliency Project, and the Terrell Homes Redevelopment Project. Implementation of the Passaic River Tidal Area Project's Newark Flanking Plan could reduce expected losses from the modeled future storm surge event by approximately 25 percent in this area.

Data Source: *See Appendices A and B for Flood Model Information*

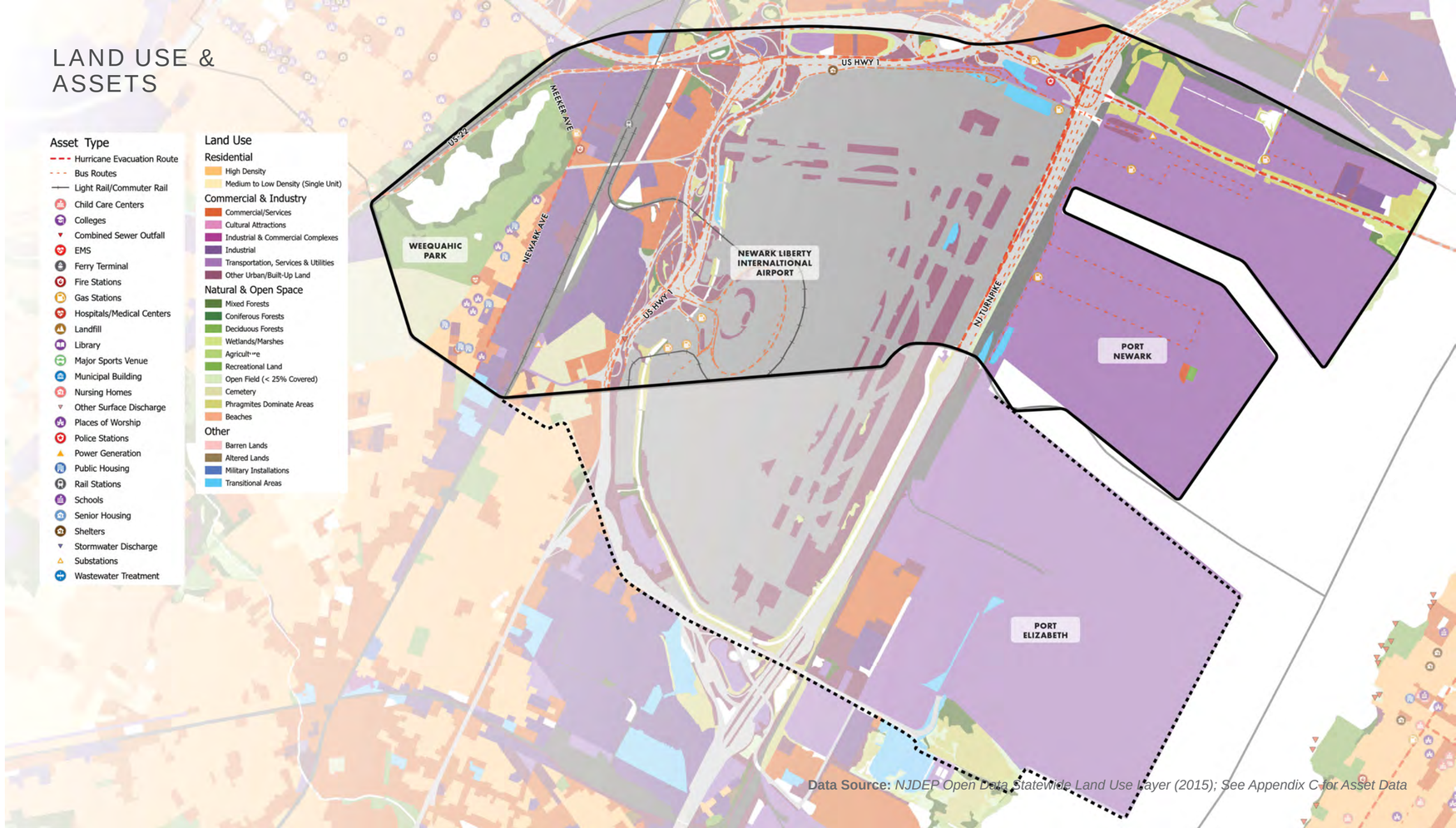
DAYTON - AIRPORT

The Dayton – Airport study area represents a large portion of the future storm surge impacts because of its location along Newark Bay. These areas are within the jurisdiction of the Port Authority of New York and New Jersey that are already working on some solutions to protect their assets in the area, such as elevating critical systems and preparing temporary flood barriers. There are small residential and commercial areas in between the airport and Weequahic Park, which is one of the larger parks in Newark.

Like much of NENJ, many of the important assets in the Dayton – Airport area already flood regularly during heavy rainfall and flooded during Hurricane Sandy in 2012. Project participants have reported flooding along Meeker Avenue, Frelinghuysen Avenue, and areas around Weequahic Park.

The PANYNJ has developed Climate Resilience Design Guidelines that integrate resilience into planned capital projects and has also established a significant resilience planning and implementation program that should mitigate long-term risk to the airport and its assets.

LAND USE & ASSETS



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

DAYTON - AIRPORT

The estimated losses in this area are largely due to inundation of transportation and industrial buildings and infrastructure, including Newark Airport, the Newark-Elizabeth Marine Terminal, I-95, I-78, the New Jersey Turnpike, Highway 1, Highway 9, and the Newark Airport Train Station. The resulting disruptions to the region will be widespread and significant due to the study area's central location and high concentration of critical assets. This study area is also home to the Northern State Prison, which is exposed to both coastal and rainfall flooding, as described in the Regional Critical Asset Exposure section of this report.

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$390 - $410 Million	In expected losses
240 - 260 Buildings	Impacted out of 650 total buildings
3,900* Residents * Present and future	In impacted homes out of 6,700 residents

Coastal Storm Surge

Future modeled flood event

$4.4 Billion	In expected losses
380 Buildings	Impacted out of 650 total buildings
3,800 Residents	In impacted homes out of 6,700 residents

Data Source: *See Appendices A and B for Flood Model Information*

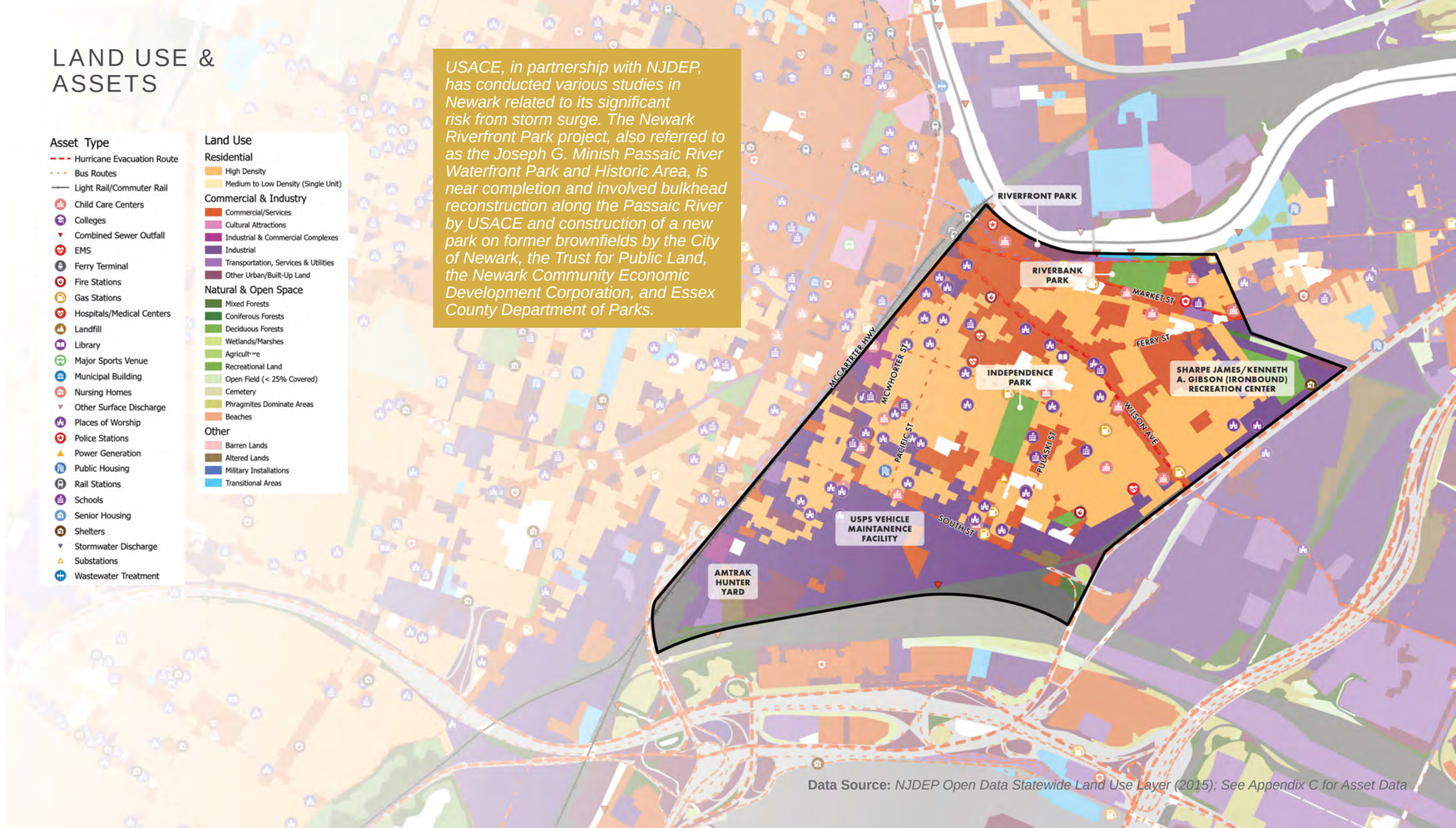
IRONBOUND

Ironbound is a multi-ethnic, lively area with many working-class, foreign-born or first generation, and non-English speaking families and residents. The residents treasure the diversity of this neighborhood, along with the many restaurants, bakeries, and shops in commercial corridors like Ferry Street, Wilson Avenue, and South Street. People in this neighborhood contribute significantly to the local and regional economy and tax base, but many people who live here are low income and in need of more resources and support. Parks like Independent Park and Newark Riverfront Park are greatly valued, but large portions of Ironbound are paved over, which can contribute to flooding as water cannot be absorbed into the ground.

The center of Ironbound is primarily commercial and residential, including some public housing properties. The edges of the neighborhood are largely industrial spaces with factories and warehouses, where trucks and freight trains pass by the area as they make their way inland from the port. This proximity to industry, and the presence of factories in the area, contribute to contamination and pollution that is already impacting people's health and wellbeing.

LAND USE & ASSETS

USACE, in partnership with NJDEP, has conducted various studies in Newark related to its significant risk from storm surge. The Newark Riverfront Park project, also referred to as the Joseph G. Minish Passaic River Waterfront Park and Historic Area, is near completion and involved bulkhead reconstruction along the Passaic River by USACE and construction of a new park on former brownfields by the City of Newark, the Trust for Public Land, the Newark Community Economic Development Corporation, and Essex County Department of Parks.



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

IRONBOUND

Many areas of Ironbound flood anytime it rains heavily, disrupting daily life by blocking travel, flooding homes and basements, and creating a financial burden to many residents. South Street reportedly had water on it for 2 days after Hurricane Ida. Some community members who flooded several times last year expressed that the flooding was so bad that it caused structural damage to homes. Much of this flooding is connected to the combined sewer systems, which collect both stormwater and sewage. Some people in the community also expressed concern about trash build-up in streets, clogs catch basins, contributes to flooding, and ends up scattered around places like Newark Riverfront Park.

While the areas with some of the worst flooding are more inland, Ironbound is also susceptible to coastal storm surge flooding, because the neighborhood's geography acts like a bowl and collects water from the surrounding areas. As mentioned previously, the Newark Flanking Plan (associated with USACE's Passaic River Tidal Area Study) is expected to avoid losses for nearly all of the Ironbound's modeled storm surge flooding but is not targeting rainfall flooding. The project is also expected to address some of the storm surge flooding in the Doremus, Downtown, and Upper Clinton Hill study areas.

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$570 - $650 Million	In expected losses
1,100* Buildings * Present and future	Impacted out of 2,200 total buildings
22,000 - 24,000 Residents	In impacted homes out of 46,000 residents

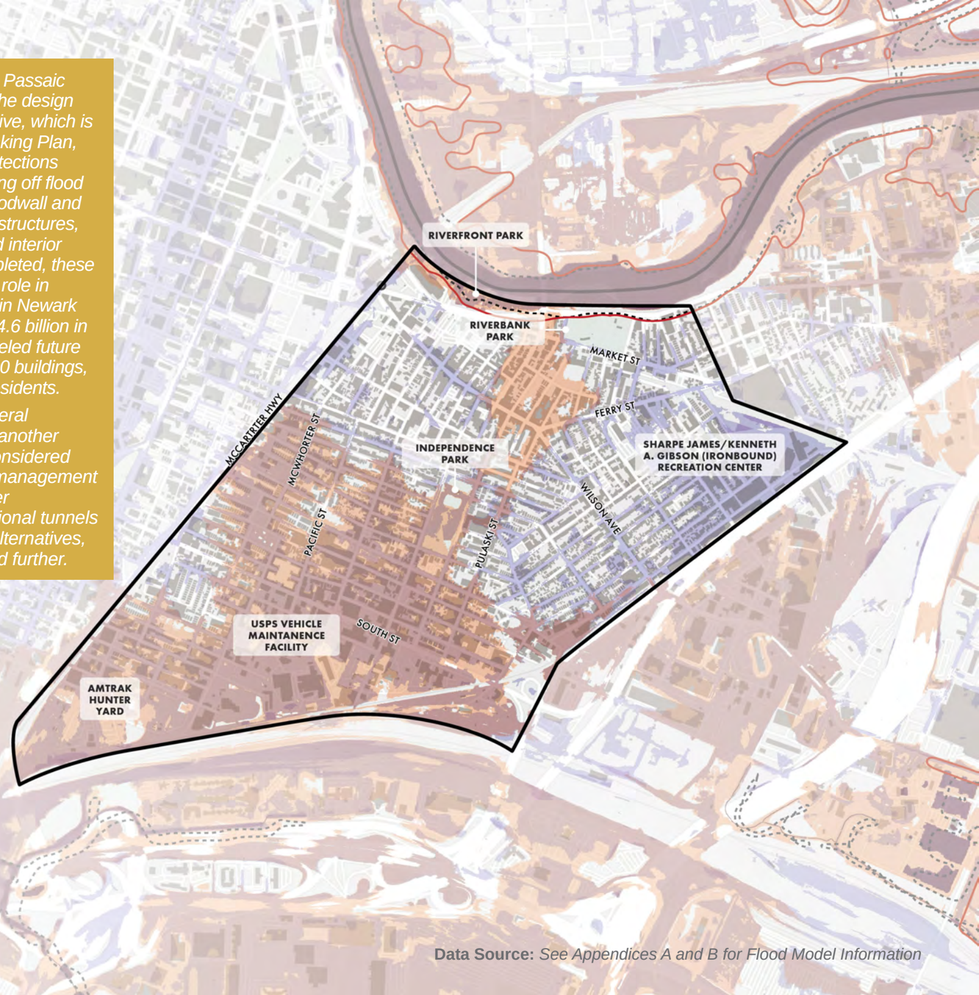
Coastal Storm Surge

Future modeled flood event

$3.9 Billion	In expected losses
1,500 Buildings	Impacted out of 2,200 total buildings
29,000 Residents	In impacted homes out of 46,000 residents

Another USACE initiative, The Passaic River Tidal Area Project, is in the design phase for the selected alternative, which is referred to as the Newark Flanking Plan, and proposes storm surge protections for the Ironbound area by cutting off flood pathways with a network of floodwall and levee segments, road closure structures, railroad closure structures, and interior drainage features. When completed, these projects may play a significant role in reducing storm surge impacts in Newark by potentially reducing up to $4.6 billion in expected losses from the modeled future storm surge event across 1,700 buildings, in an area impacting 32,000 residents.

The Passaic River Basin General Reevaluation Study is part of another study done by USACE that considered various alternatives for flood management across the wider Passaic River Watershed, such as large regional tunnels or floodwalls. None of these alternatives, however, have been advanced further.



LEGEND

- Modeled Future Areal Flooding (9.2 inches over 24 hours, 2.4 feet of sea level rise)
- 2070 Extent (Hurricane Sandy + Sea Level Rise)
- Areas of Overlap

Sea Level Rise

- 2070 MHHW + 2.4' SLR (expected)
- 2070 MHHW + 5.0' SLR (high)

Data Source: *See Appendices A and B for Flood Model Information*

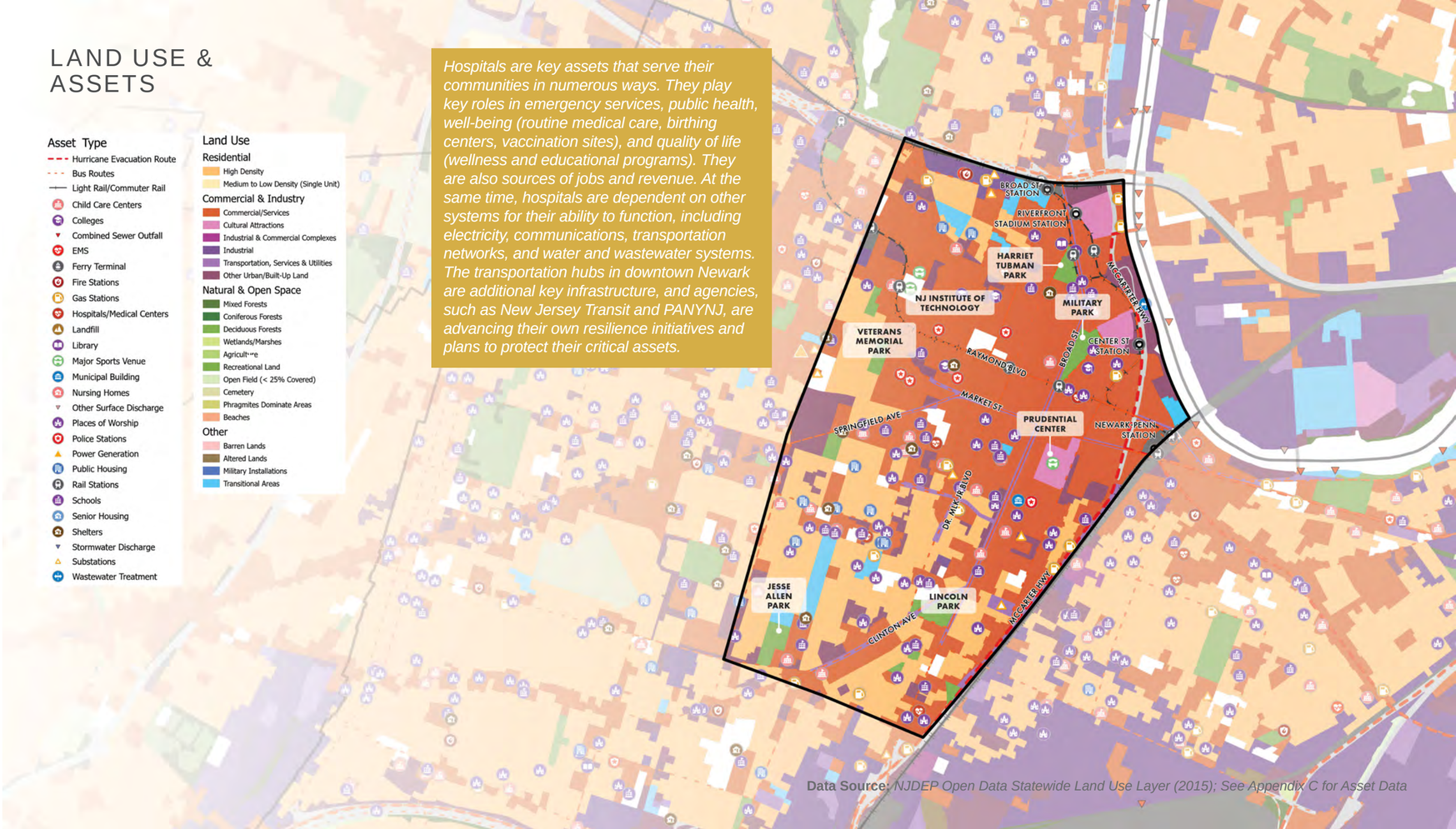
DOWNTOWN NEWARK

Downtown Newark is the commercial center of the city and the home of many city buildings; arts and cultural centers, such as the Prudential Center and New Jersey Performing Arts Center; several neighborhood parks; various academic institutions, such as New Jersey Institute of Technology (NJIT), Rutgers-Newark, and Essex County College. All of these stakeholders could be key players in the implementation of solutions for this area. The area is also a regional transportation center, with Newark Penn Station and Newark Broad Street Station bringing PATH trains, New Jersey Transit trains, and buses through. The state highway and interstate highway also run along the borders of the area. These places are important to the economy of Newark and the wider region, and the transportation infrastructure is crucial to mobility. The community also expressed appreciation for several beloved parks, including Lincoln Park, Jesse Allen Park, and Military Park.

In downtown Newark, the community reported that previous rainfall flooding has made it nearly impossible for cars to get through local roads and at points on Route 21 (McCarter Highway). This situation is reflected in the results of the flood models as well, which show large clusters of flooding between MLK Boulevard, University Avenue, and Washington Street and from Clinton Avenue to the area around NJIT. Rainfall flooding has impacted critical transportation infrastructure, including flooding rail tunnels across the Passaic as well as the areas north and south of Route 280.

LAND USE & ASSETS

Hospitals are key assets that serve their communities in numerous ways. They play key roles in emergency services, public health, well-being (routine medical care, birthing centers, vaccination sites), and quality of life (wellness and educational programs). They are also sources of jobs and revenue. At the same time, hospitals are dependent on other systems for their ability to function, including electricity, communications, transportation networks, and water and wastewater systems. The transportation hubs in downtown Newark are additional key infrastructure, and agencies, such as New Jersey Transit and PANYNJ, are advancing their own resilience initiatives and plans to protect their critical assets.



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

DOWNTOWN NEWARK

Rainfall flooding is expected to damage many of the buildings and cultural areas in downtown Newark. The Prudential Center and the commercial and retail areas along Washington Street and Clinton Avenue are expected to flood, damaging the buildings and goods. Two university campuses, Rutgers and NJIT, along with St. Michael's Medical Center are expected to flood during heavy rainfall events, disrupting a large student population and medical services. There is a large residential community and seven primary schools in this area that will be flooded. As in-person learning continues following the COVID-19 pandemic, flooding at these schools is likely to further disrupt the lives of the families in this community.

Coastal flooding is not expected to come far inland in this area, with coastal storms mostly impacting areas right along the Passaic River. Some areas closer to the Ironbound, however, are expected to be influenced by storm surge. Newark Penn Station may be exposed to future storm surge, which would have significant cascading impacts as it is connects Amtrak, the Light Rail, and Regional Rail. Implementation of the Passaic River Tidal Area Project's Newark Flanking Plan could reduce expected losses from the modeled future storm surge event by approximately 75 percent in this area by cutting off flood pathways impacting Ironbound and surrounding areas.

RISK CONTEXT

Rainfall Areal Flooding

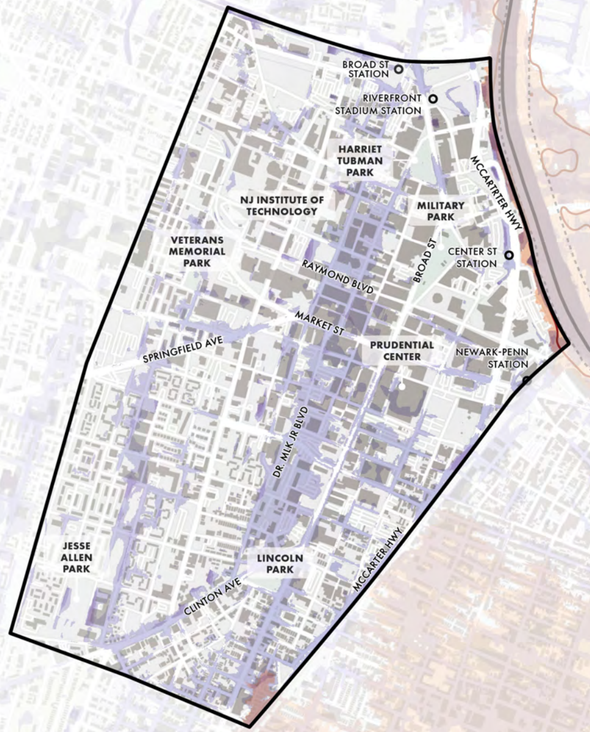
Range indicates change from present to future modeled flood events

$350 - $400 Million	In expected losses
300 - 330 Buildings	Impacted out of 1,100 total buildings
7,500 - 8,700 Residents	In impacted homes out of 25,000 residents

Coastal Storm Surge

Future modeled flood event

$49 Million	In expected losses
30 Buildings	Impacted out of 1,100 total buildings
170 Residents	In impacted homes out of 25,000 residents



LEGEND

- Modeled Future Areal Flooding (9.2 inches over 24 hours, 2.4 feet of sea level rise)
- 2070 Extent (Hurricane Sandy + Sea Level Rise)
- Areas of Overlap

Sea Level Rise

- 2070 MHHW + 2.4' SLR (expected)
- 2070 MHHW + 5.0' SLR (high)

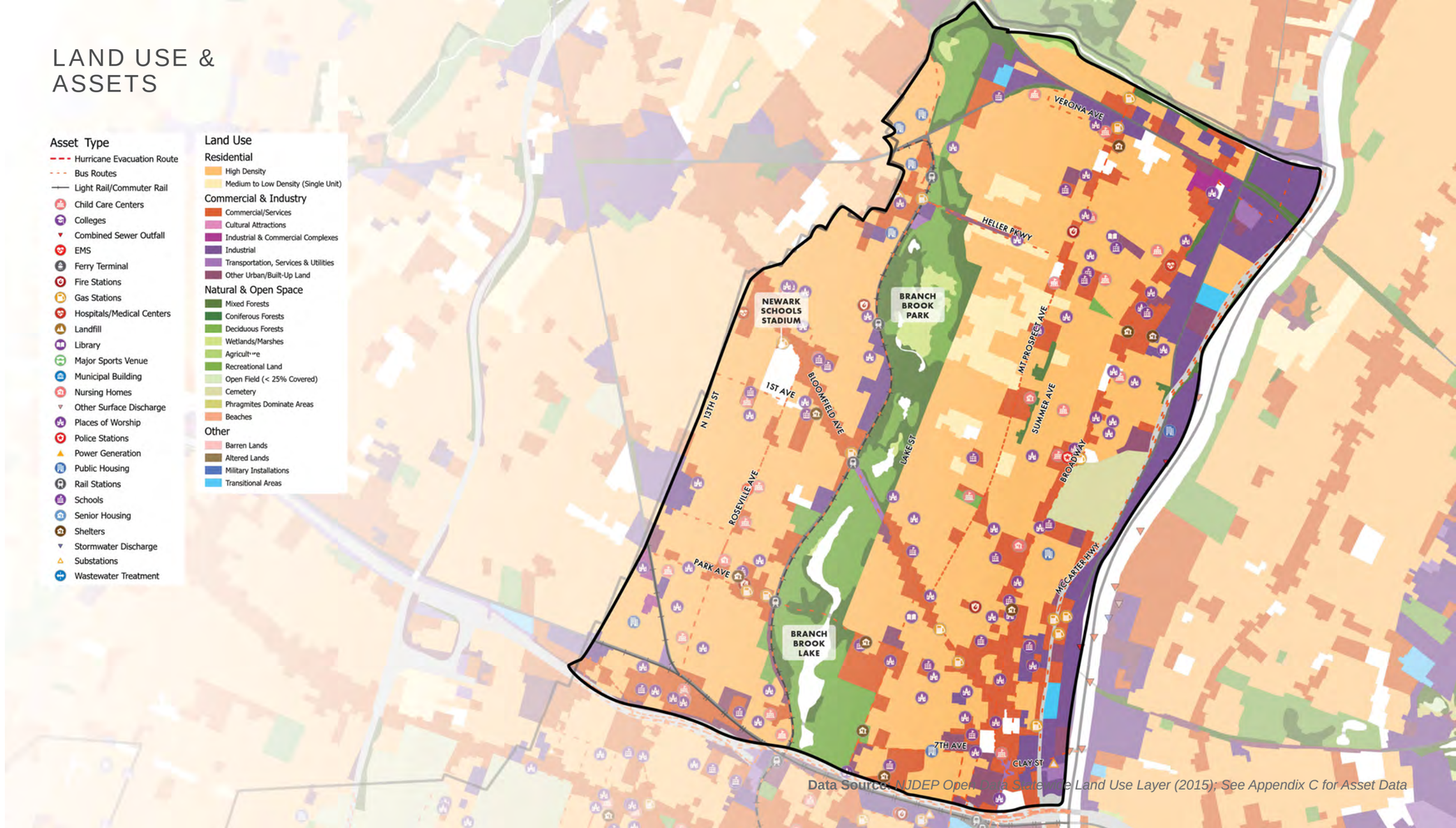
Data Source: *See Appendices A and B for Flood Model Information*

BRANCH BROOK PARK

The Branch Brook Park study area covers the areas north of Downtown that surround the Branch Brook Park, including Roseville, Upper Roseville, Forest Hill, and Woodside neighborhoods. This area is largely residential with industrial properties bordering the Passaic River, which limits public access to the waterfront. Residential areas are adjacent to Branch Brook Park – a county park that is an important place to many people in Newark. The Newark Light Rail also runs along the west side of the park. These neighborhoods have more trees than some other areas in Newark, and there are many historic properties in the Forest Hill Historic District that have been preserved.

Though the area's inland is at a higher elevation than the area along the Passaic River, rainfall flooding already impacts this area, especially along Broadway and within Branch Brook Park. Residents have reported serious basement flooding, with some areas having knee-deep flooding during the 2021 summer storms. Residents also reported that the area around Mt. Prospect Avenue was flooded during Hurricane Ida – a place that had not experienced much flooding previously.

LAND USE & ASSETS



Data Source: NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data

BRANCH BROOK PARK

The flood models show that during extreme rainfall events, flooding is widespread in Branch Brook Park study area, with flooding recorded in residences, commercial spots, and four schools. The models show flooding to the west of Branch Brook Park, with ponding on the interior of the Newark Light Rail line down North 13th street, and some of the most significant flooding in the most western streets along the border with Bloomfield. The models echo what residents reported after Hurricane Ida – significant flooding occurred around Davenport and 10th, 11th, and 12th streets. Some notable assets that are likely exposed to future rainfall flooding include the Columbus Hospital, the Baxter-Crane public housing units, and Police Precinct 7. Bloomfield Avenue crosses through this flooded area, and flooding of this road may cause disruptions to evacuations and emergency services reaching the residents.

Future coastal storm surge flooding is expected along the Passaic River in this study area, where it is likely to impact the industrial riverfront properties. There are also small areas adjacent to the river that could be regularly inundated during high tide with 2.4 feet of sea level rise.

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$510 - $580 Million	In expected losses
1,100 - 1,200 Buildings	Impacted out of 6,000 total buildings
17,000 - 19,000 Residents	In impacted homes out of 81,000 residents

Coastal Storm Surge

Future modeled flood event

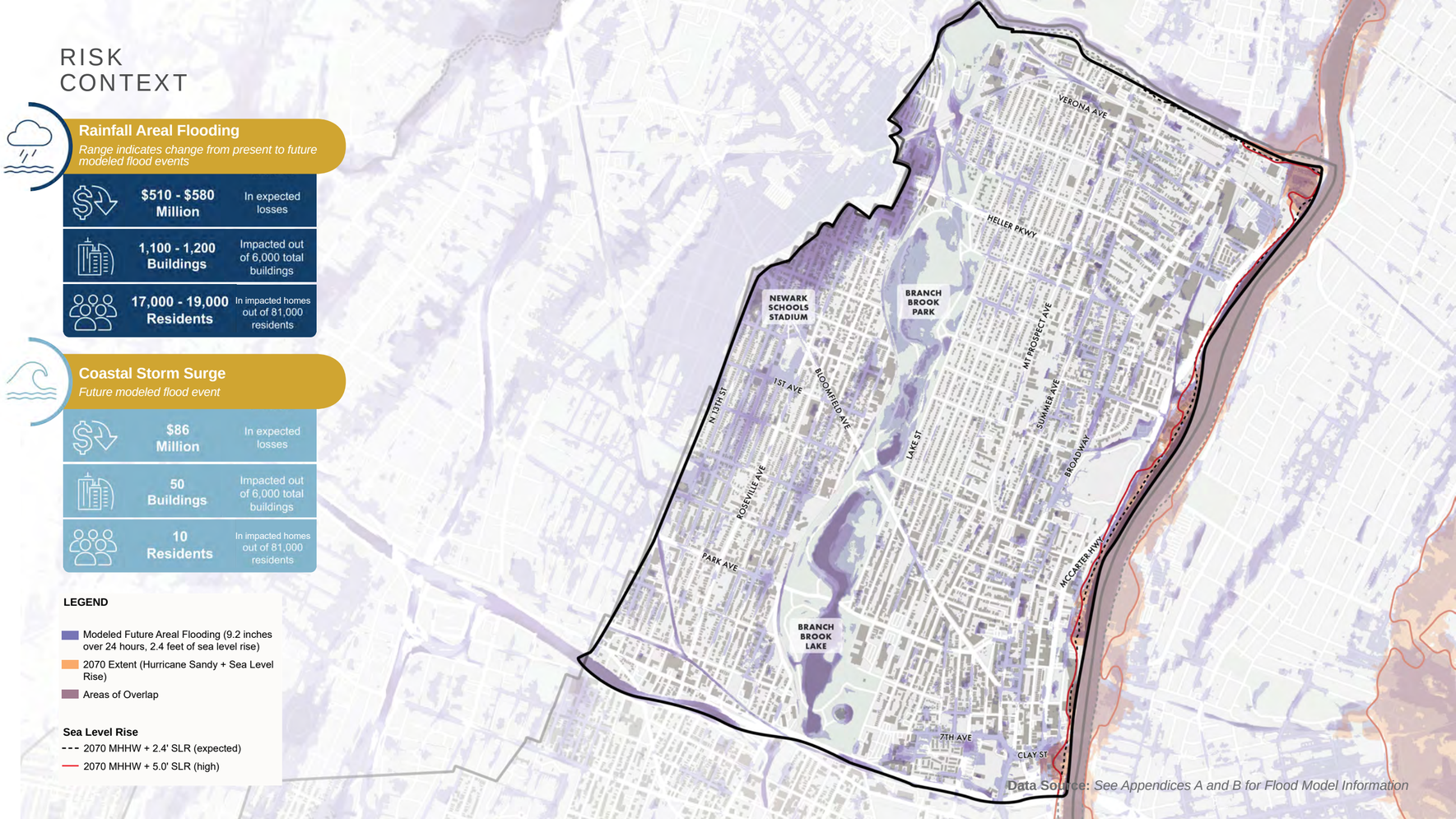
$86 Million	In expected losses
50 Buildings	Impacted out of 6,000 total buildings
10 Residents	In impacted homes out of 81,000 residents

LEGEND

- Modeled Future Areal Flooding (9.2 inches over 24 hours, 2.4 feet of sea level rise)
- 2070 Extent (Hurricane Sandy + Sea Level Rise)
- Areas of Overlap

Sea Level Rise

- 2070 MHHW + 2.4' SLR (expected)
- 2070 MHHW + 5.0' SLR (high)

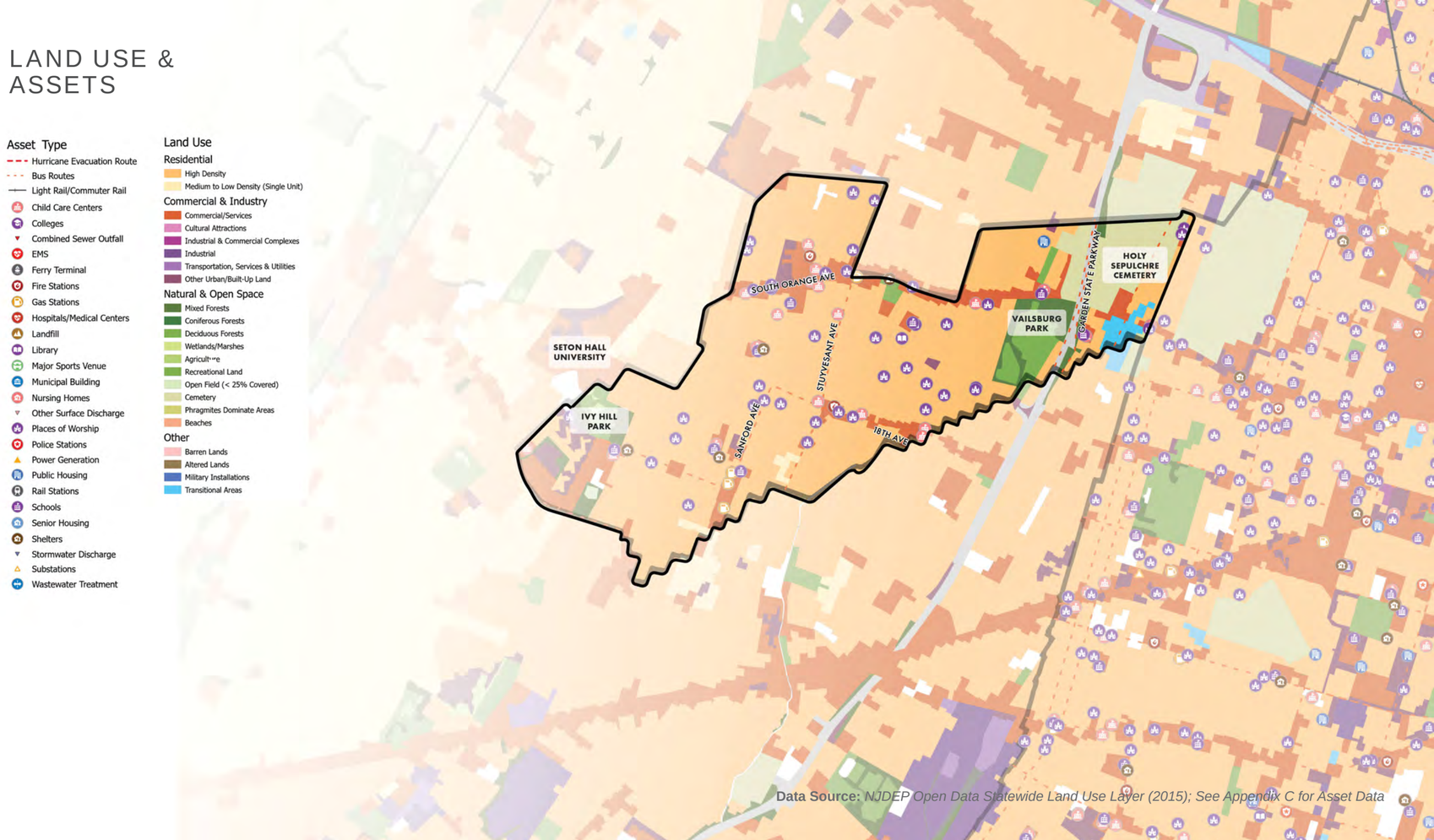


Data Source: *See Appendices A and B for Flood Model Information*

IVY HILL AND VAILSBURG

The Ivy Hill and Vailsburg study area represents the westmost part of Newark, west of the Garden State Parkway. This study area is largely residential and has a more suburban feel than other parts of Newark. Residential areas consist mostly of single family and two-family homes, mixed with some apartments. The area has a strong sense of community, with many local block associations. South Orange Avenue is the major commercial strip and hosts many small businesses. Ivy Hill Park and Vailsburg Park are two mid-sized parks in the area that are heavily used.

LAND USE & ASSETS



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

IVY HILL AND VAILSBURG

Because this area is inland, there is no expected coastal storm surge flooding, but rainfall flooding does impact the area. Specifically, the flood models show that water is expected to pool along Kerrigan Boulevard, where there are residential homes, as well as between Vailsburg Park to Norwood Street and south to Valley Street. Some residents reported significant flooding in their homes and streets during the remnants of Hurricane Ida in September 2021. Rainfall flooding is already severe and is expected to continue to impact in the area near Seton Hall University and in the Lower Vailsburg neighborhood around 18th Avenue. The flood models show significant flooding within Ivy Hill Park and Vailsburg Park. Residents in the area recorded video of flooding during Hurricane Ida that showed water halfway up cars in the areas around Ivy Hill Park. During the writing of this document in early April 2022, a rain event flooded homes again. The community has also reported about the role that trash plays in flooding, and how the trash clogs catch basins and prevents stormwater from entering the drainage system, leading it to back up into streets.

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$330 - $360 Million	In expected losses
1,500 - 1,600 Buildings	Impacted out of 8,800 total buildings
11,000 - 12,000 Residents	In impacted homes out of 34,000 residents

LEGEND

- Modeled Future Areal Flooding (9.2 inches over 24 hours, 2.4 feet of sea level rise)
- 2070 Extent (Hurricane Sandy + Sea Level Rise)
- Areas of Overlap

Sea Level Rise

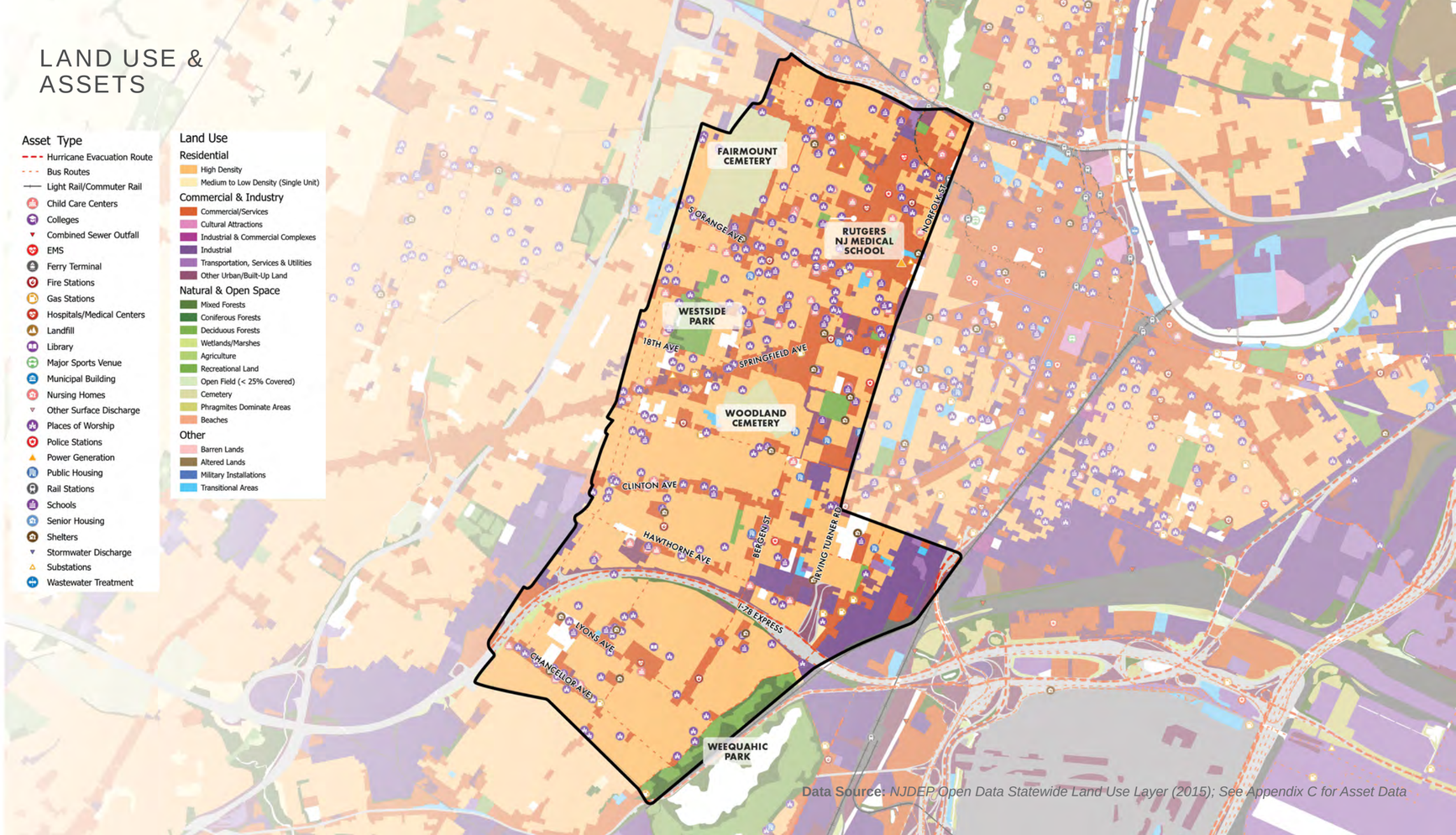
- 2070 MHHW + 2.4' SLR (expected)
- 2070 MHHW + 5.0' SLR (high)

Data Source: *See Appendices A and B for Flood Model Information*

CLINTON HILL, WEEQUAHIC & WEST SIDE

Like Ivy Hill and Vailsburg, the neighborhoods of Upper and Lower Clinton Hill, West Side, and Weequahic are inland, largely residential areas that could have significant impacts from rainfall flooding. This area includes large concentrations of vacant or abandoned lots. Portions of West Side were formerly marshes or a lake that were filled in to create the neighborhoods. I-78 divides Weequahic from Upper and Lower Clinton Hill. Important community assets in the area include Newark-Beth Israel Medical Center, West Side Park, various pocket parks, two libraries, and several historic properties.

LAND USE & ASSETS



Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

CLINTON HILL, WEEQUAHIC & WEST SIDE

Rainfall flooding is widespread in these residential areas, although lower in concentration than in other study areas. Some areas with the most concentrated flooding from the modeled future areal event are Boyd Street, Badger Avenue, Nat Turner Park, West Side Park, and S 17th and 18th Streets from Springfield Avenue to Clinton Avenue.

The flood models project that the future storm surge event could bring flood waters to the edges of this study area, near Route 21 (McCarter Highway). However, implementation of the USACE Newark Flanking Plan could eliminate nearly all of the expected losses from the modeled future storm surge event.

RISK CONTEXT

Rainfall Areal Flooding

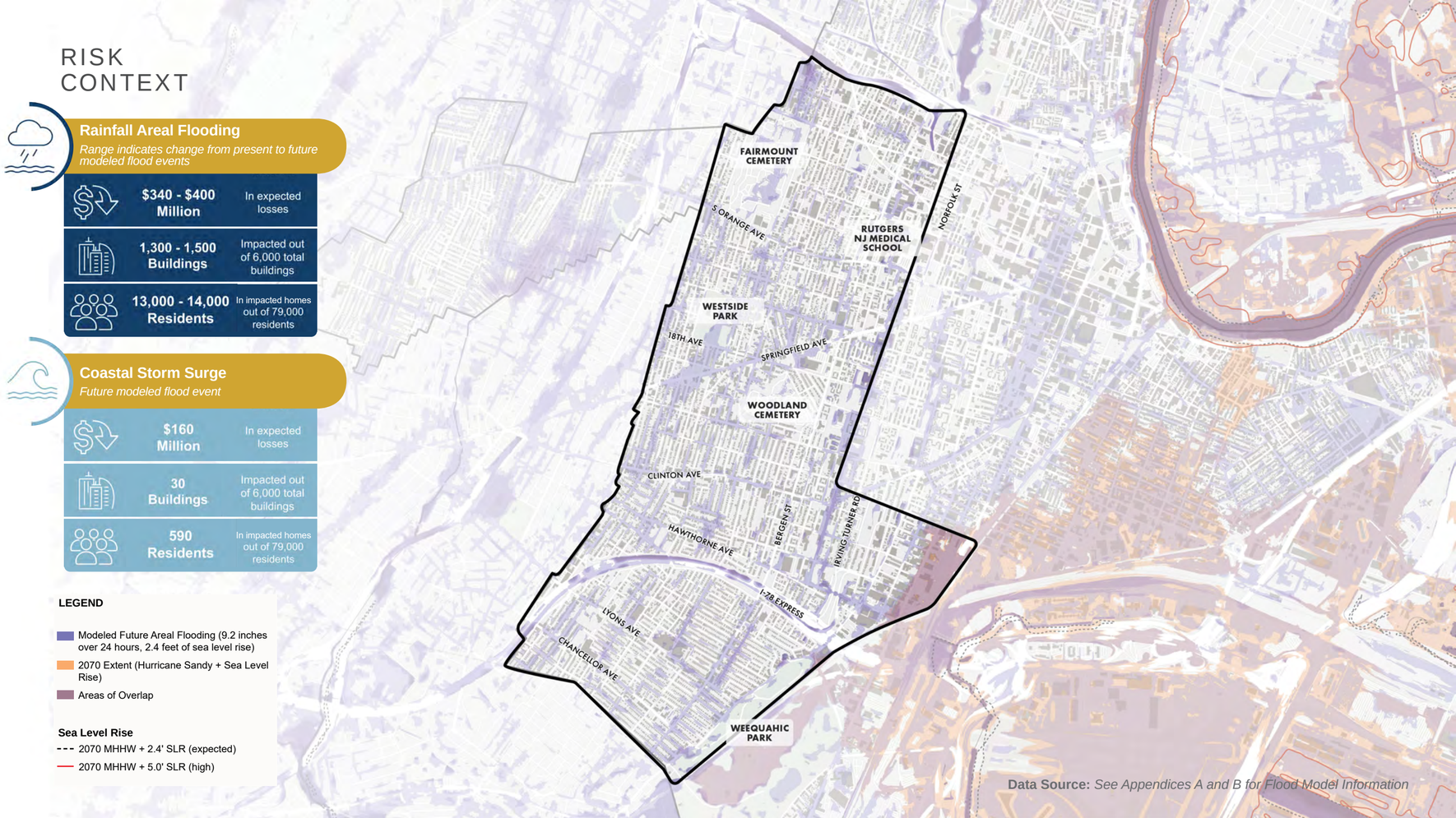
Range indicates change from present to future modeled flood events

$340 - $400 Million	In expected losses
1,300 - 1,500 Buildings	Impacted out of 6,000 total buildings
13,000 - 14,000 Residents	In impacted homes out of 79,000 residents

Coastal Storm Surge

Future modeled flood event

$160 Million	In expected losses
30 Buildings	Impacted out of 6,000 total buildings
590 Residents	In impacted homes out of 79,000 residents



Data Source: *See Appendices A and B for Flood Model Information*

HOBOKEN

Hoboken is a small but densely populated city of approximately 53,000[22] people with the highest median annual household income and average property values within NENJ. The city prides itself on being a walkable city with countless shops, parks, and waterfront piers. Its residents rely heavily on public transportation systems, including New Jersey Transit rail and buses, PATH, Hudson-Bergen Light Rail, New York Waterway Ferry, and the Hoboken Hop shuttle. Many of these transportation lines enter and exit New Jersey through the Hoboken Transit Terminal, which is the third largest transportation terminal in New Jersey and provides a range of transportation offerings, including ferry services, light rail, commuter rail, regional rail, and bus routes. Additionally, Stevens Institute of Technology is a large university in Hoboken. Since the city is smaller compared to the others in this region, all the critical services to the community are in one study area for this project.

Hoboken has been plagued with flooding issues for much of its history because the city was largely developed on fill. Some of the most significant flooding is in the low-lying western areas of the city that were formerly a tidal strait and is an area where many low-income and minority residents live. Hoboken was pummeled by Hurricane Sandy, leaving most residents without power and clean water. The city more recently experienced significant flooding during the remnants of Hurricane Ida.

Rainfall Flooding: Rainfall flooding impacts much of the city. Many intersections flood during heavy rainstorms, with less impacts along the Washington and Hudson Street corridors and in the elevated areas around Stevens Institute of Technology. Some of the most significant flooding during recent storms has been reported along Harrison, Paterson, and Jackson Streets in southwest Hoboken. Community members have also reported basement flooding throughout the city, including along Bloomfield and Garden Streets around 2nd and 3rd Streets. Without implementation of the various ongoing and planned projects, residents in Hoboken could be at risk of losing property and being temporarily displaced due to rainfall-based disruptions from the future modeled areal flood event. Additionally, the North Hudson water treatment and garbage collection facilities in the northwest part of the city are at risk of flooding, which could cause contamination of nearby waterways.

Coastal Storm Surge: While the flood extents are similar for both rainfall and coastal storm surge flooding, expected losses with no action are significantly higher for the coastal storm surge event. Coastal flooding can enter the city via low-lying pathways from the north and the south, leading to contiguous flooding between the Hudson-Bergen Line Light Rail along Congress Street until Park Avenue. The Stevens Institute of Technology campus and the two blocks behind it are the main areas of Hoboken not predicted to be flooded by a future extreme storm surge event.

Hoboken's Rebuild by Design – Hudson River project, currently underway, is being designed to manage coastal and rainfall flooding impacts in Hoboken. Based on the flood models for the future coastal storm surge event, the Resilient NENJ team estimated that the coastal mitigation portion of the Rebuild by Design project could potentially mitigate **$6.4 billion** of the estimated impacts to more than 640 impacted buildings that house nearly 37,000 residents from this event.

Rebuild by Design is expected to avoid nearly all of the estimated losses from the modeled future storm surge event, but the project does not include the Hoboken Transit Terminal, an important transportation node from New York City into New Jersey. The terminal serves more than 50,000 people daily and is one of the busiest transportation terminals in New Jersey. During a future extreme storm surge event, the terminal may experience flooding and could cause major disruptions and delays throughout the region. New Jersey Transit is conducting its own planning to protect its important infrastructure, including the Hoboken Transit Terminal, and has already completed some projects to improve resilience at the terminal and elevate key systems.

[22] *The most recent 2020 census estimates that the population is closer to 60,000, but this analysis is based on population data pulled from 2019 American Community Survey estimates, as the 2020 census data were not available at the time that data analyses were completed.. More information on the methodology can be found in Appendix C.*

Rainfall Areal Flood
Range indicates change from present to future modeled flood events

$660 - $810 Million	530 - 560 Buildings	36,000 - 37,000 Residents
In expected losses	Impacted out of 850 total buildings	In impacted homes out of 53,000 residents

Coastal Storm Surge
Future modeled flood event

$7.2 Billion	700 Buildings	43,000 Residents
In expected losses	Impacted out of 850 total buildings	In impacted homes out of 53,000 residents

DAMAGES FROM COASTAL STORM SURGE
(MODELED HURRICANE SANDY PLUS 2.4 FEET)

DAMAGES FROM AREAL FLOODING
(MODELED FUTURE AREAL FLOODING)

HOBOKEN

This list highlights a selection of prioritized critical assets within the city to demonstrate the variety of impacted asset types. The assets are examples that ranked high during the prioritization process but do not comprise the full list of critical assets in this city. The full asset list along with the prioritization methodology can be found in Appendix D. Note that most of these assets may be protected by the Rebuild by Design-Hudson River project and other projects that are being completed by the City of Hoboken and North Hudson Sewerage Authority.

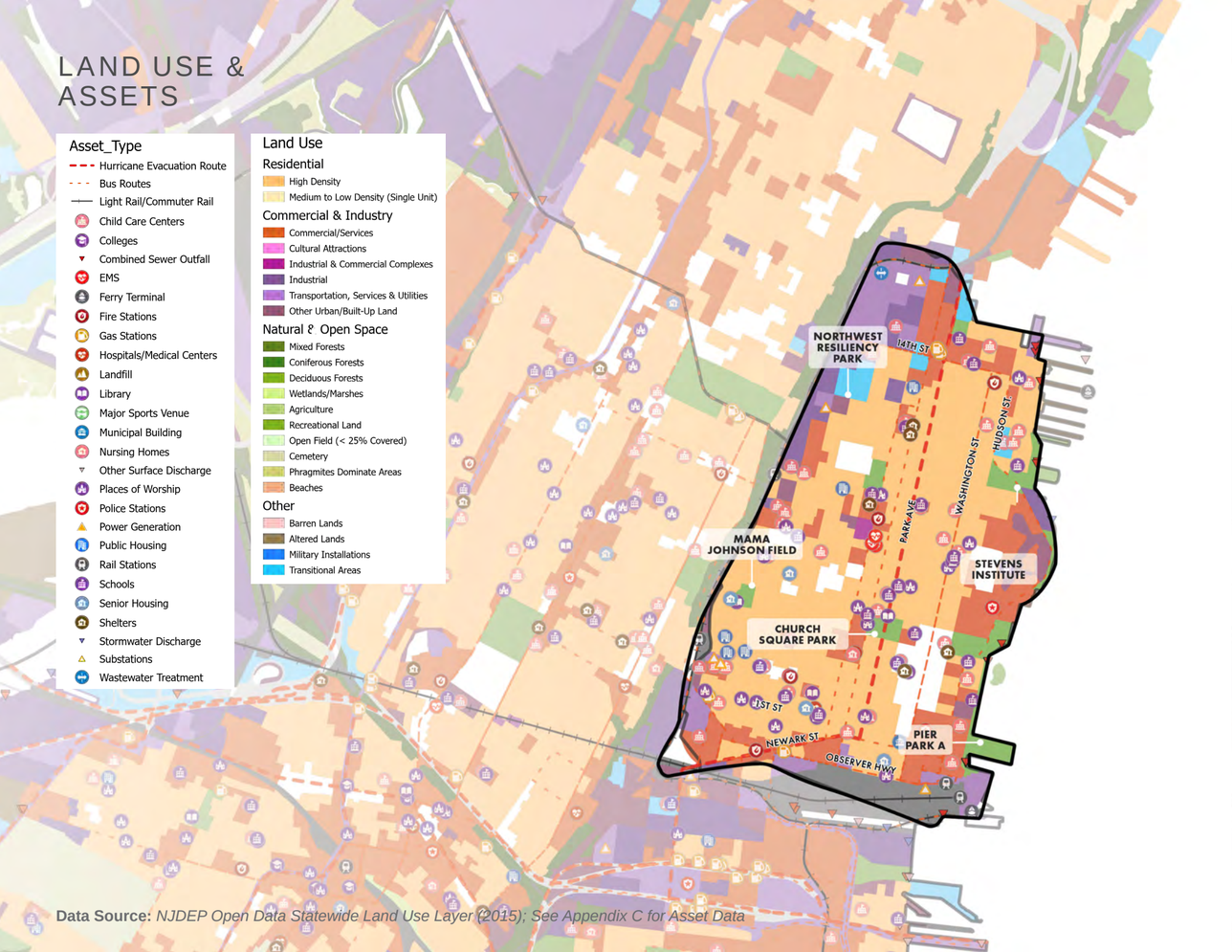
Hoboken has become a national leader in resilience and stormwater management as it endeavors to address its many challenges with flooding. The city, often in partnership with the North Hudson Sewerage Authority and NJDEP, has undertaken numerous projects to address flooding over the last decade. The Rebuild by Design-Hudson River project, which was awarded funding by HUD and is currently underway, includes both rainfall and coastal storm surge mitigation components, which are summarized as Resist, Delay, Store, and Discharge. The Resist, or coastal, portion involves construction of permanent and deployable flood barriers in the northern and southern portions of the city. This project is expected to reduce storm surge risk for 85 percent of Hoboken's population that resides within the 100-year FEMA-mapped flood hazard area. The Delay, Store, and Discharge portion is focused on rainfall stormwater management and green infrastructure components that complement Hoboken's long list of other ongoing and planned projects, such as resiliency parks like Northwest and Southwest Resiliency Park, sewer separation, and pump station improvements. More information on the Rebuild by Design-Hudson River project is available through the City of Hoboken's Coastal Flood Mitigation webpage, the City's Rainfal Flood Mitigation webpage, or NJDEP's Rebuild by Design-Hudson River webpage. The Resilient NJ team estimates that the Rebuild by Design project could reduce the modeled future storm surge impacts to 640 buildings in which 37,000 residents reside, for a total of $6.4 billion in avoided losses.

As previously stated, this report reflects the potential flood impacts with no action, meaning without completion of the already underway Rebuild by Design-Hudson River project and other ongoing stormwater management projects. The results of the impact assessment, therefore, act to provide a measure of the potential losses that will be avoided with the implementation of these projects, as well as to point to the areas of Hoboken with the most significant potential ongoing impacts.

EXAMPLE PRIORITIZED ASSETS

Category	Type	Name	Tidal Flood	Flash Flood	Areal Flood	Storm Surge
Emergency Response	Hurricane Evacuation Route	CR-677		●	●	●
	Hospitals and Medical Centers	Hoboken University Medical Center				●
	EMS	Hoboken EMS			●	●
Infrastructure	Heavy Rail*	Hoboken - World Trade Center	●	●	●	●
	Rail Stations	Hoboken				●
Public Heath	Parks	Pier A Park	●	●	●	●
	Schools	Hoboken Montessori School				●
Quality of Life	Library	Hoboken Public Library				●
	Community	Communities of Faith for Housing Inc (Shelter)				●
	Community	ShopRite of Hoboken		●	●	●
	Community	ACME Markets				●

LAND USE & ASSETS



Asset_Type

- Hurricane Evacuation Route
- Bus Routes
- Light Rail/Commuter Rail
- Child Care Centers
- Colleges
- Combined Sewer Outfall
- EMS
- Ferry Terminal
- Fire Stations
- Gas Stations
- Hospitals/Medical Centers
- Landfill
- Library
- Major Sports Venue
- Municipal Building
- Nursing Homes
- Other Surface Discharge
- Places of Worship
- Police Stations
- Power Generation
- Public Housing
- Rail Stations
- Schools
- Senior Housing
- Shelters
- Stormwater Discharge
- Substations
- Wastewater Treatment

Land Use

Residential
- High Density
- Medium to Low Density (Single Unit)

Commercial & Industry
- Commercial/Services
- Cultural Attractions
- Industrial & Commercial Complexes
- Industrial
- Transportation, Services & Utilities
- Other Urban/Built-Up Land

Natural & Open Space
- Mixed Forests
- Coniferous Forests
- Deciduous Forests
- Wetlands/Marshes
- Agriculture
- Recreational Land
- Open Field (< 25% Covered)
- Cemetery
- Phragmites Dominate Areas
- Beaches

Other
- Barren Lands
- Altered Lands
- Military Installations
- Transitional Areas

Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

RISK CONTEXT

Rainfall Areal Flooding

Range indicates change from present to future modeled flood events

$660 - $810 Million	In expected losses
530 - 560 Buildings	Impacted out of 850 total buildings
36,000 - 37,000 Residents	In impacted homes out of 53,000 residents

Coastal Storm Surge

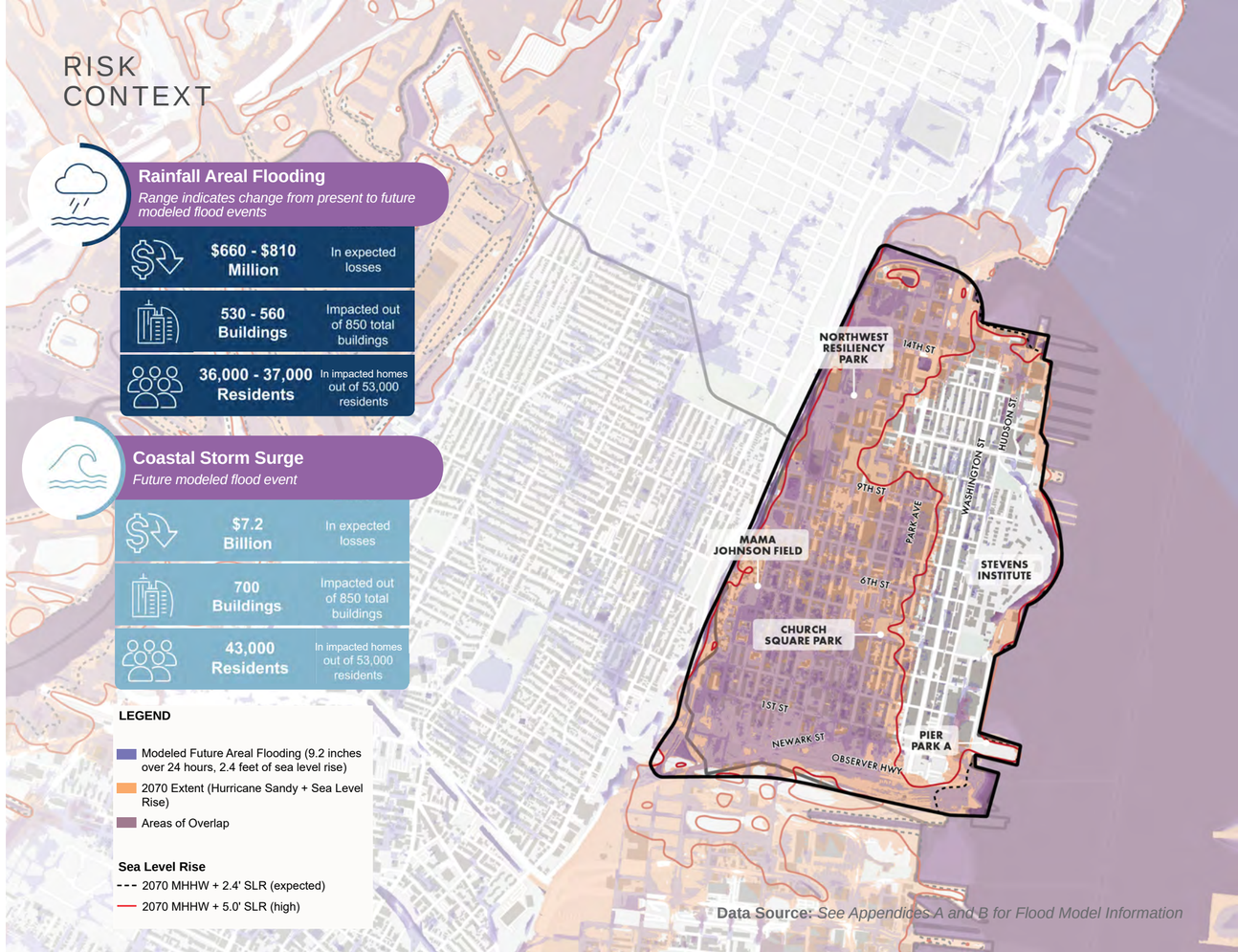
Future modeled flood event

$7.2 Billion	In expected losses
700 Buildings	Impacted out of 850 total buildings
43,000 Residents	In impacted homes out of 53,000 residents

LEGEND

- Modeled Future Areal Flooding (9.2 inches over 24 hours, 2.4 feet of sea level rise)
- 2070 Extent (Hurricane Sandy + Sea Level Rise)
- Areas of Overlap

Sea Level Rise
- 2070 MHHW + 2.4' SLR (expected)
- 2070 MHHW + 5.0' SLR (high)



Data Source: *See Appendices A and B for Flood Model Information*

BAYONNE

Bayonne has a unique identity within the Resilient NENJ region. It has more of a small town feel than the other cities of the region but also has a large presence of heavy industry along the Upper New York Bay and Kill Van Kull. Bayonne is split into two study areas for this project – East Bayonne (Bergen Point, Constable Hook, & MOTBY) and Central and West Bayonne.

Modeled flood impacts show both rainfall and storm surge flooding affecting the industrial areas of Constable Hook and waterfront parks along Newark Bay. Storm surge flooding is expected to impact Bergen Point, while rainfall flooding is spread across major corridors like Broadway and Route 440. As in Jersey City, the more elevated central spine of Bayonne is expected to be less vulnerable to future storm surge.

Rainfall Areal Flood
Range indicates change from present to future modeled flood events

$470 - $530 Million	1,400 - 1,500 Buildings	16,000 - 18,000 Residents
In expected losses	Impacted out of 6,000 total buildings	In impacted homes out of 65,000 residents

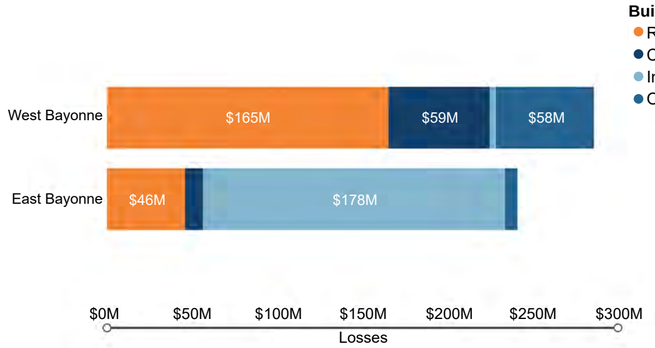
Rainfall Flooding: Rainfall flooding extends throughout the city. Broadway, the main commercial corridor, is expected to be particularly impacted, with flooding in storefronts from West 5th Street to West 56th Street. Residential areas along Avenue A are also at substantial risk of flooding. The roadways impacted by rainfall flooding also lead to access and egress issues along evacuation routes within the city. Additionally, the Hudson Bergen Light Rail is predicted to flood east of Broadway along Avenue E, incurring losses and service disruptions at the 8th Street, 34th Street, and 45th Street stations.

Coastal Storm Surge
Future modeled flood event

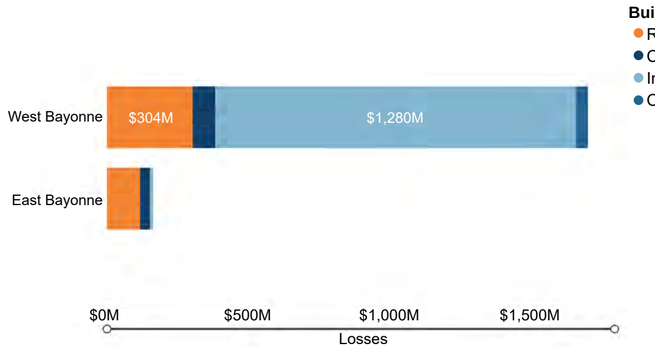
$1.9 Billion	1,000 Buildings	7,300 Residents
In expected losses	Impacted out of 6,000 total buildings	In impacted homes out of 65,000 residents

Coastal Storm Surge: Despite being protected from waves by Staten Island and Brooklyn, coastal storm surge increases water levels along the Upper New York Bay and Newark Bay and still results in losses in the city. Approximately 1,000 of the nearly 6,000 buildings in Bayonne are expected to be impacted by the modeled future storm surge event, with the overwhelming majority (70 percent) of losses coming from industrial buildings. These losses are largely concentrated in the Eastern Bayonne study area, where the shoreline was largely shaped by bringing in fill to create new land or raise low lying areas. Not only are these areas more exposed to storm surge but also contain large industrial terminals and warehouses. Global Marine Terminal (New York Harbor's closest deepwater port to the Atlantic Ocean) and IMTT (the East Coast's largest bulk liquid terminal) are both substantially vulnerable.

DAMAGES FROM AREAL FLOODING
(MODELED FUTURE AREAL FLOODING)



DAMAGES FROM COASTAL STORM SURGE
(MODELED HURRICANE SANDY PLUS 2.4 FEET)



EXAMPLE PRIORITIZED ASSETS

Category	Type	Name	Tidal Flood	Flash Flood	Areal Flood	Storm Surge
Emergency Response	Hurricane Evacuation Route	West 8th Street		●	●	
	Fire Stations	Bayonne Fire Department Station 7				●
Infrastructure	Transmission Lines*	Public Service Elec & Gas Co	●	●	●	●
	Rail Stations	8th St.		●	●	
	Rail Stations	E. 34th St.		●	●	●
Public Heath	Parks	James Donovan Park				●
	Child Care Centers	Smile of a Child			●	
	Schools	Beacon Christian Academy				●
Quality of Life	Places of Worship	First Assembly of God		●	●	●
	Places of Worship	Global Harvest Fellowship Inc		●	●	
	Community	Atlas Yacht Club of Bayonne				●

This list highlights a selection of critical assets within the city to demonstrate the variety of impacted asset types. The assets are examples that ranked high during the prioritization process but do not comprise the full list of critical assets in this city. The full asset list along with the prioritization methodology can be found in Appendix D .

EAST BAYONNE (BERGEN POINT, CONSTABLE HOOK, AND MOTBY)

This study area is a heavily industrial area, with the largest concentration of residents living in the southern portion of the study area near Bergen Point and south of Route 440. Community members have expressed that waterfront walkways like the Hudson River Waterfront Walkway at South Cove Commons and the restaurant and retail strips along Cottage Street and Broadway are particularly valuable to quality of life.

Bayonne is rapidly undergoing redevelopment, including in many waterfront areas that could be vulnerable to flooding. The City is requiring that all redevelopers consider flooding in their site design, including the following:

- Rigorous stormwater retention requirements
- Separation of stormwater from the CSO system, where possible (mostly for waterfront projects)
- Meet or exceed elevation requirements of buiilding code and NJDEP regulations designed to mitigate storm surge damage.

Community members remain concerned about redevelopment in flood areas, as well as its potential to worsen flooding in their communities.

LAND USE & ASSETS

The recent redevelopment at MOTBY is one of multiple projects in Bayonne reconnecting residents to the waterfront. The MOTBY redevelopment project included increasing the elevation and improving stormwater system capacities to significantly reduce future storm surge and rainfall flooding. Other large redevelopment projects include sites at the former Exxon, IMTT, Texaco, A&P, and South Cove properties, which each include provisions for on-site or off-site waterfront access improvements. Additional detail about these redevelopment projects is available in the About Our Region report.

Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

EAST BAYONNE (BERGEN POINT, CONSTABLE HOOK, AND MOTBY)

The coastal threats in Bayonne are primarily concentrated in this study area. As the maps show, flooding from rainwater flood events and future storm surge could be widespread in this area, impacting valuable waterfront parks, such as Dennis Collins Park, and the residential areas adjacent to it, including the Bayonne Housing Authority complex on 1st Street. Large swaths of industrial areas in Constable Hook, the Military Ocean Terminal at Bayonne (MOTBY) peninsula where a new ferry terminal is being planned, and the Global Marine Terminal may also be impacted from future storm surge and rainfall flood events. All redevelopment in these areas is required to elevate infrastructure above the 100-year floodplain elevation and to provide new stormwater infrastructure capable of accommodating substantial rainfall events. While many areas have already been elevated through redevelopment (such as the western portion of the MOTBY peninsula) based on the best data available at the time, some of this may need to be revisited over time due to sea level rise.

Flooding in industrial areas could have cascading impacts on the economy outside of Bayonne. Community members have raised concerns about health impacts associated with the flooding of these industrial areas due to the potential spread of contaminants. The results reflect community feedback about rainfall flooding being a particularly acute issue around Avenue E underpasses (like at 22nd Street, and in the areas around Cottage Street.[23] The Hudson Bergen Light Rail and its stations could also be flooded during heavy rains, impacting mobility for community members traveling within and through the area.

RISK CONTEXT

Rainfall Areal Flooding

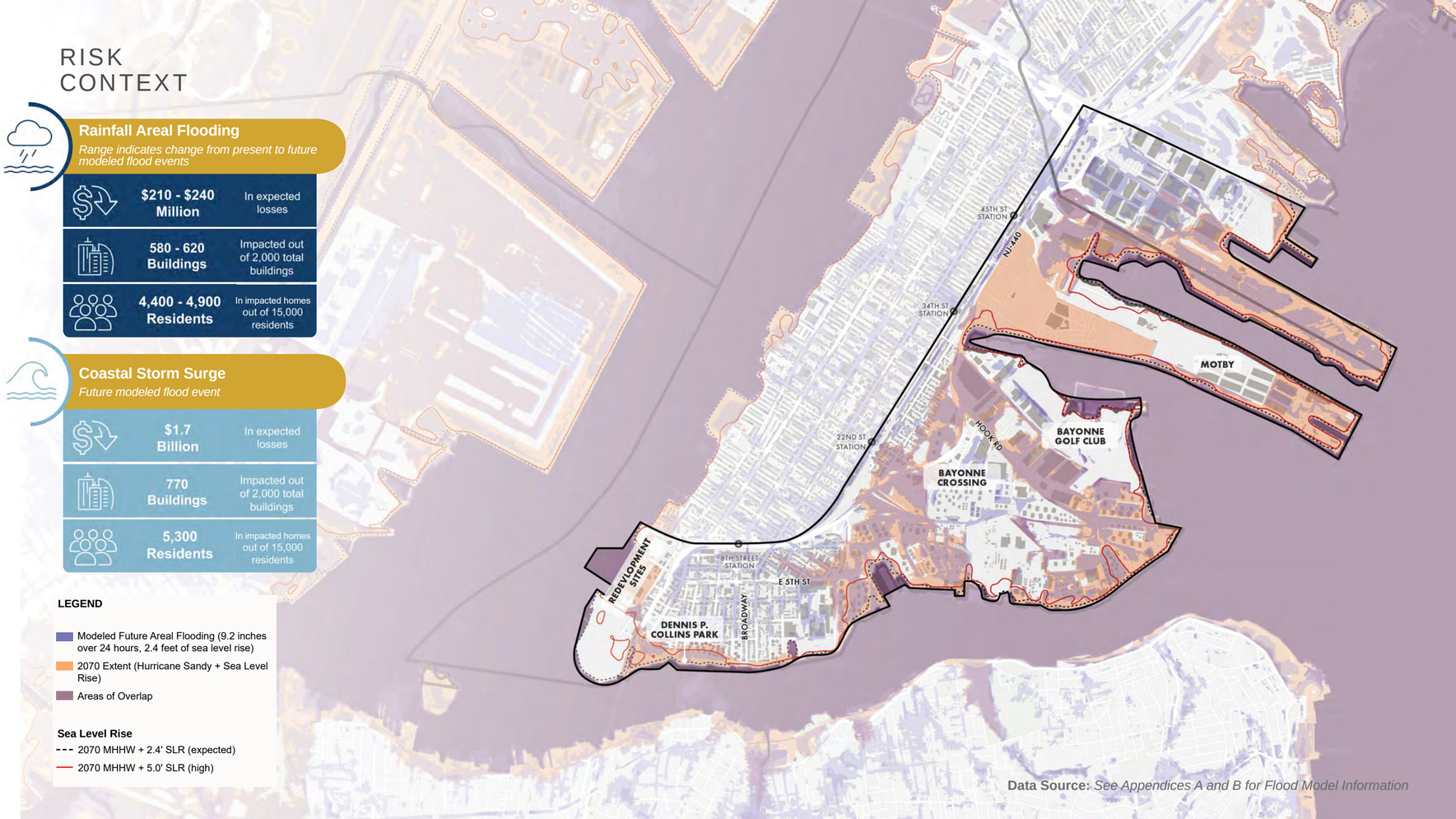
Range indicates change from present to future modeled flood events

$210 - $240 Million	In expected losses
580 - 620 Buildings	Impacted out of 2,000 total buildings
4,400 - 4,900 Residents	In impacted homes out of 15,000 residents

Coastal Storm Surge

Future modeled flood event

$1.7 Billion	In expected losses
770 Buildings	Impacted out of 2,000 total buildings
5,300 Residents	In impacted homes out of 15,000 residents



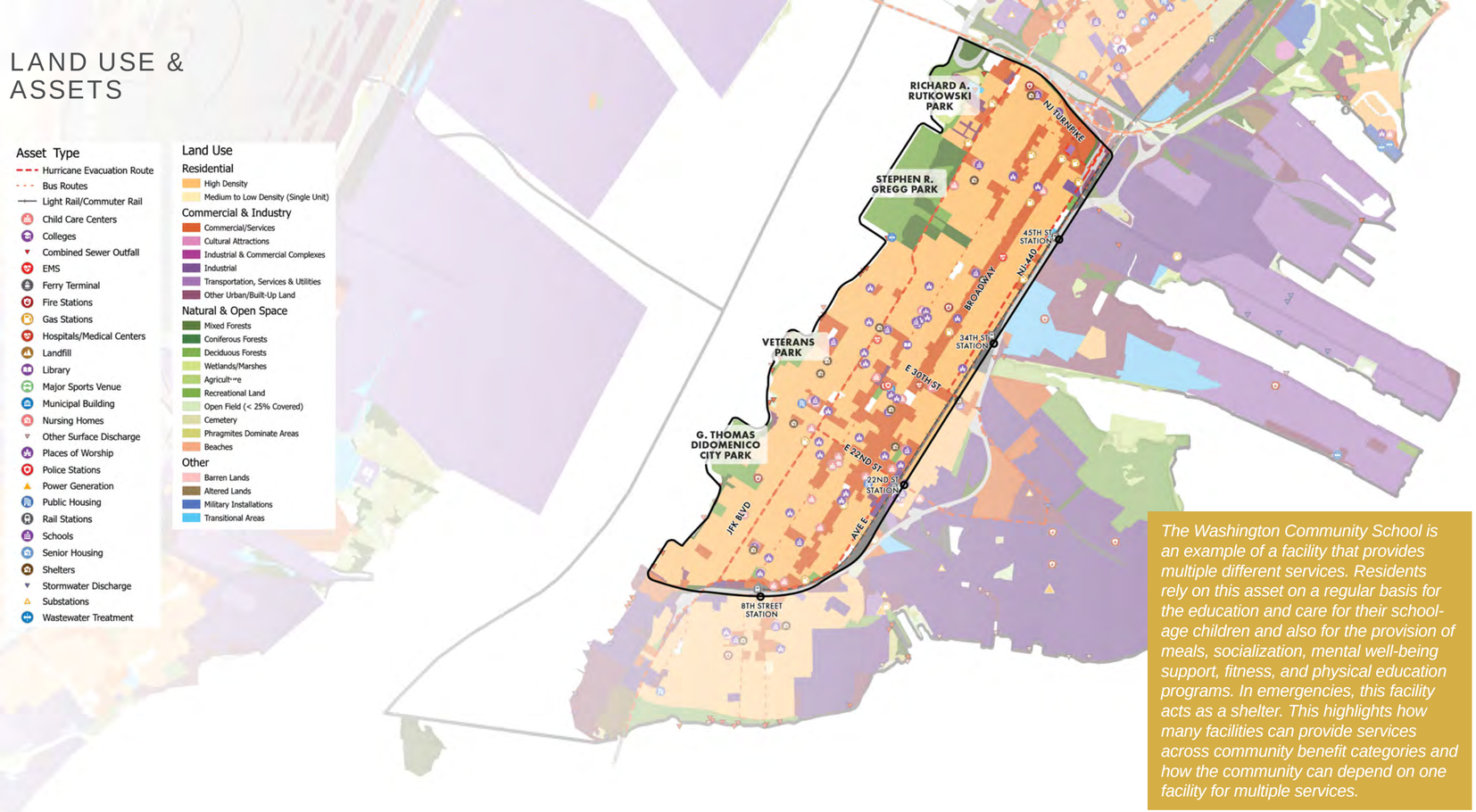
Data Source: *See Appendices A and B for Flood Model Information*

[23] *An application for federal funding has been proposed to develop stormwater storage at Cottage Street Park.*

CENTRAL AND WEST BAYONNE

Central and West Bayonne is home to most of Bayonne's residents, commercial areas, and open space. It is an area that is at risk for flooding during present and future rainfall events. As the maps show, flooding from coastal storms is expected to be concentrated in the waterfront parks, which would impact accessibility and use of these important spaces. The high frequency of tidal flooding could make portions of G. Thomas DiDomenico City Park, Veterans Park, Stephen R. Gregg Park, and Richard A. Rutkowski Park unusable in the future.

LAND USE & ASSETS



The Washington Community School is an example of a facility that provides multiple different services. Residents rely on this asset on a regular basis for the education and care for their school-age children and also for the provision of meals, socialization, mental well-being support, fitness, and physical education programs. In emergencies, this facility acts as a shelter. This highlights how many facilities can provide services across community benefit categories and how the community can depend on one facility for multiple services.

Data Source: *NJDEP Open Data Statewide Land Use Layer (2015); See Appendix C for Asset Data*

CENTRAL AND WEST BAYONNE

Located along Newark Bay, Bayonne High School, the city's main high school, is at risk of losses under rainfall and future storm surge flood events. Already, flooding at Bayonne High School has been reported to lead students to abandon their cars in the school parking lot during rainstorms. Additional important community assets, like the Washington Community School and Bayonne Medical Center, are also at risk of losses during a rainfall flood event.

RISK CONTEXT

Rainfall Areal Flooding

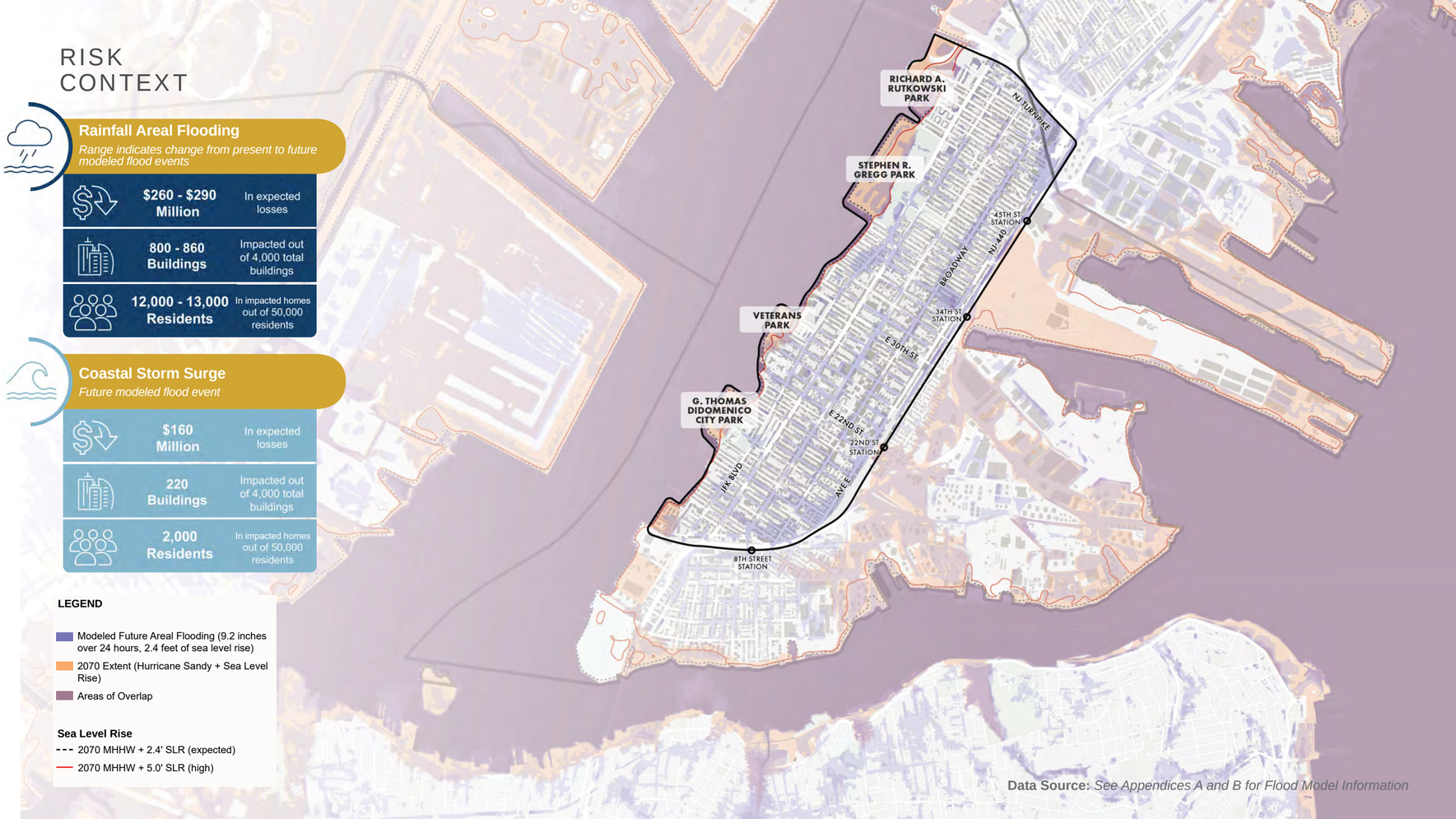
Range indicates change from present to future modeled flood events

$260 - $290 Million	In expected losses
800 - 860 Buildings	Impacted out of 4,000 total buildings
12,000 - 13,000 Residents	In impacted homes out of 50,000 residents

Coastal Storm Surge

Future modeled flood event

$160 Million	In expected losses
220 Buildings	Impacted out of 4,000 total buildings
2,000 Residents	In impacted homes out of 50,000 residents



Data Source: *See Appendices A and B for Flood Model Information*

STEAM URBAN EARTH WEEK EVENT

Residents gathered for the STEAM URBAN Earth Week Event at Kaboom Playground in Newark.

Image Source: *Resilient NENJ*

04 - NEXT STEPS

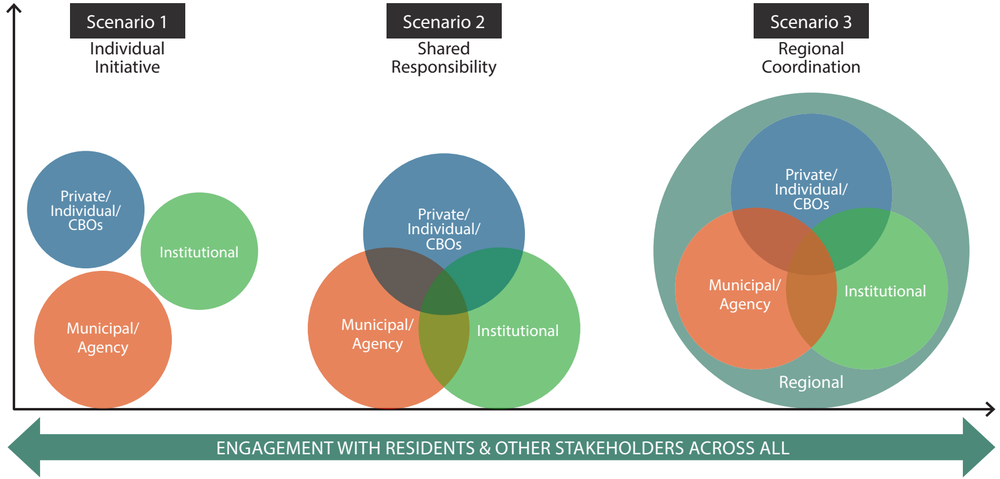
WHAT COMES NEXT

This flood impact assessment highlights what could happen to the community if nothing is done to reduce flood risk now and in the future. Using this information, the Resilient NENJ team can prioritize what can and should be done. Even knowing what is at risk, though, doesn't define a single path forward. Multiple actions and combinations of actions each result in different benefits and costs. To set the course of action going forward, Resilient NENJ developed three scenarios using different approaches to reducing the impact of flooding, as described in the Scenario Development report.

Scenarios allow stakeholders and decision-makers to understand the various pathways to enhancing resilience within the region over the next 50 years, given the challenges of climate change. These scenarios align with the region's vision, address the flood risks identified, and are a combination of a wide range of flood risk reduction tools. Moving forward, these three scenarios will be refined and consolidated into a preferred scenario, which will be the basis of the action plan.

The results of this flood impact assessment help define the preferred scenario. Information about losses will help prioritize solutions and establish timelines for implementation. By identifying what assets are protected under each scenario, the Resilient NENJ team can look at the costs associated with flooding that would be avoided and compare it to the cost of implementation. This analysis, along with community priorities and vision, will be weighed as part of developing the preferred scenario.

In parallel, the Resilient NENJ team is examining other ways that climate change could affect the region. These include extreme temperatures, impacts on water supply, and higher wildfire risk, as well as other potential hazards. More information on these can be found in the Climate Hazards Assessment. Like the flood impact assessment, the Climate Hazards Assessment highlights how climate change and flooding particularly affect socially vulnerable populations.



MORRIS CANAL BASIN

View of the Morris Canal Basin from Jersey Avenue in Jersey City.

Image Source: *Resilient NENJ*

APPENDICES

APPENDIX A: NJDEP Modeling Methodology

APPENDIX B: Resilient NENJ Model Updates

APPENDIX C: Methodology - Consequences & Asset Exposure

APPENDIX D: Critical Asset Inventory and Assessment

APPENDIX E: Loss Summary Tables for Each Study Area & Event

REFERENCES

REPORTS & PLANS

DOCUMENT TITLE	YEAR	AUTHOR
2019 New Jersey State Hazard Mitigation Plan	2019	NJ OEM (Office of Emergency Management)
Amended and Restated Bayonne Bay East Redevelopment Plan	2018	City of Bayonne
Amended Redevelopment Plan: Texaco Redevelopment Area	2020	CME Associates
Amendment to the Peninsula at Bayonne Harbor Redevelopment Plan	2018	City of Bayonne
Amendment to the Peninsula at Bayonne Harbor Redevelopment Plan – Maritime, the Landing and Loft Districts	2020	City of Bayonne
Assessing New Jersey's Exposure to Sea-level Rise and Coastal Storms: A Companion Report	2016	Rutgers
Bayonne Bay East Redevelopment Plan	2017	City of Bayonne
Bayonne Bay West Redevelopment Plan	2015	City of Bayonne
Bayonne Coastal Vulnerability Index Map	2014	NJDEP, NJCMP
Bayonne Green Infrastructure Feasibility Study	--	Rutgers, PVSC
Bayonne Master Plan Re-examination Report	2017	DMR Architects
Bayonne Selection and Implementation of Alternatives Report CSO LTCP	2020	Bayonne
Bayonne Urban Coastal Design Project Report	2019	Rutgers, Stevens
Bayview Redevelopment Plan	2020	City of Bayonne, CME Associates
Building Ecological Solutions to Coastal Community Hazards Guide	2017	NWF, NJDEP
CDBG-DR Action Plan	2013	NJDCA
CDBG-DR Citizen Participation Plan	2013	NJDCA
Changes to Municipal Land Use Law	2020	NJ Future
Climate Change Adaptation in the Water Supply Sector	2016	Rutgers
East Ironbound Neighborhood Plan	2018	ICC
Essex County Comprehensive Transportation Plan	2013	Dewberry, NJTPA
Essex County Hazard Mitigation Plan	2020	Essex County (Sheriff's Office)
Final Integrated Hurricane Sandy General Reevaluation Report (GRR) & Environmental Assessment (EA)	2019	NJDEP, USACE
Flood Hazard Area Control Act Technical Manual	2018	NJDEP
Floodplain Management in NJ Quick Guide	2015	NJAFM
Former Best Foods Site Redevelopment Plan	2017	City of Bayonne
Harbor Station South Redevelopment Plan	2015	City of Bayonne
Hoboken CCNY Capstone Resilience Indicator Plan (3 PDFs)	2020	CCNY
Hoboken Coastal Vulnerability Index Map	2014	NJDEP, NJCMP
Hoboken Green Infrastructure Strategic Plan	2013	Together North Jersey
Hoboken Master Plan Land Use Element	2018	City of Hoboken
Hoboken Master Plan Re-examination Report	2018	City of Hoboken
Hoboken Master Plan: Green Building and Environmental Sustainability Element	2017	City of Hoboken

DOCUMENT TITLE	YEAR	AUTHOR
Hoboken Microgric Feasibility Study	2019	Concord Engineering
Hoboken Re.invest Feasibility Study	2015	Hoboken
Hoboken Resiliency and Readiness Plan	2013	City of Hoboken
Hoboken Resilient Buildings Design Guidelines	2015	City of Hoboken
Hudson County Ferry Service Expansion Study	2020	NJTPA, Hudson County
Hudson County Land Development Regulations (not yet adopted)	2016	NJTPA, Hudson County
Hudson County Master Plan Re-examination Report	2017	Hudson County Division of Planning
Hudson County Strategic Recovery Report	2014	Hudson County Division of Planning
JC Coastal Vulnerability Index Map	2014	NJDEP, NJCMP
JC Plan to Reduce Localized Flooding and CSOs	2019	JC Start
JC Resilient Design Handbook	2018	Jersey City
JCMUA Selection and Implementation of Alternatives Report CSO LTCP	2020	JCMUA/Arcadis
JCMUA Stormwater Management Plan	2008	
Jersey City Adaptation Master Plan	2017	
Jersey City Alternate Transportation Modes Assessment	2020	NJTPA
Jersey City Baker Report (Visualization of Adaptation Scenarios and Next Steps White Paper)	2015	Michael Baker International
Jersey City Circulation Plan Element	2011	Jersey City
Jersey City Environmental Resource Inventory	2017	
Jersey City Master Plan + Reexamination Reports		Jersey City
Jersey City Parking Plan	2020	NJTPA, Jersey City
Jersey City Pededstrian Enhancement Plan	2018	Jersey City, NJTPA, Fitzgerald & Halliday
Jersey City Pedestrian Enhancement Plan Final Report	2018	NJTPA
Jersey City Urban Environmental Green Infrastructure Design Plan	2017	Maser, ORG, MATRIXNEWORLD, City of Jersey City
Jersey City/Hoboken Connectivity Study	2011	Eng-Wong, Taub & Associates, NJTPA
Liberty State Park Circulator Cost Benefit Analysis	2013	NJTPA
Morris Canal Greenway Plan	2013	NJTPA, RBA
New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Pane	2019	Rutgers
Newark Coastal Vulnerability Assessment 2017	2017	Rutgers
Newark Coastal Vulnerability Index Map	2014	NJDEP, NJCMP
Newark Downtown Circulation Improvement Study	2019	Newark, NJTPA, SSE
Newark Green Infrastructure Feasibility Study	--	Rutgers, PVSC
Newark Master Plan	2012	Newark

DOCUMENT TITLE	YEAR	AUTHOR
Newark Master Plan Mobility Element	2012	SSE, NJTPA
Newark Sea Level Rise Maps	--	CRSSA
Newark Sustainability Action Plan	2013	City of Newark
Newark Sustainability Action Plan Process	2020	City of Newark
NHSA Selection and Implementation of Alternatives LTCP - Adams Street	2020	NHSA
NHSA Selection and Implementation of Alternatives LTCP - River Road	2020	NHSA
NJ Coastal Management Program Section 309 Assessment & Strategy	2015	NJDEP, NJCMP
NJ Scientific Report on Climate Change	2020	NJDEP
NY/NJ Harbor and Tributaries Coastal Storm Risk Management Interim Report	2019	USACE, NJDEP
Overview of State Coastal Management Policies Designed to Promote Coastal Resilience	2019	Rutgers
PANYNJ Climate Resilience Design Guidelines	2018	PANYNJ
Plan 2040	2013	NJTPA
Plan 2045 Connecting North Jersey	2017	NJTPA
Populations Vulnerable to Climate Change in New Jersey: Update of a Statistical Analysis	2015	Rutgers
Port of NY and NJ Post Sandy Approach to Resiliency	2018	PANYNJ
Post-Sandy Design Guidelines and Practice at PANYNJ	2017	PANYNJ
PVSC Selection and Implementation of Alternatives LTCP	2020	PVSC, Bayonne, JCMUA
Rebuild by Design Hudson River FEIS Executive Summary	2017	Dewberry, NJDEP
Redevelopment Plan: Block 301.01, Lots 1 & 6 – 219 West 5th Street	2020	City of Bayonne, CME Associates
Resilience Strategies Case Studies Local Options/Local Actions	2019	NJ Future
Resilient Jersey City Summary Doc	2019	Jersey City - City Planning Division
Riverwalk at South Cove Redevelopment Plan	2018	City of Bayonne
Sandy Recovery Strategic Planning Report	2014	City of Jersey City
South Ironbound Resiliency Action Plan	2015	ICC and APA-NJ
Strategies for Flood Risk Reduction for Vulnerable Coastal Populations along Hudson River at Hoboken and Jersey City	2014	Rutgers
The Peninsula at Bayonne Harbor: BLRA Redevelopment Plan	2008	City of Bayonne
Sustainable & Resilient Coastal Communities: A Comprehensive Coastal Hazard Mitigation Strategy	2017	NJ Future
Urban Coastal Flood Mitigation Strategies for Hoboken and JC	2017	Rutgers (Eleni Athanasopoulou)

ADDITIONAL SOURCES

Resilient Northeastern NJ, New Jersey. 2021. Resilient NJ: Northeastern New Jersey – About Our Region Report. Available online at https://www.resilient-nj.com/wp-content/uploads/2021/04/RNJ_NENJ_About-Our-Region-Report_210426.pdf. April.

Resilient Northeastern NJ, New Jersey. 2021. Resilient NJ: Northeastern New Jersey – Vision and Priorities. Available online at https://www.resilient-nj.com/wp-content/uploads/2021/11/211029_NENJ_VisionDoc_FinalDraft.pdf. October.

New Jersey Transit. 2022. NJ Transit – The Way to Go Rail Map. Available online at https://d2g63oyneaimm8.cloudfront.net/sites/default/files/pdfs/rail/Rail_System_Map.pdf. Retrieved on April 19, 2022.

NOAA. 2022. Tides and Currents – Tidal Datums. Available online at Available online at https://tidesandcurrents.noaa.gov/datum_options.html. Retrieved on April 19, 2022.

Port Authority of New York and New Jersey. 2017. Port Master Plan 2050. Available online at https://www.panynj.gov/port/en/our-port/port-development/port-master-plan.html.

Port Authority of New York and New Jersey. 2022. Data and Statistics - Airport Traffic Statistics. Available online at https://www.panynj.gov/airports/en/statistics-general-info.html. Retrieved on April 19, 2022.

Port Authority of New York and New Jersey. 2022. Traffic & Volume Information: Monthly and Percent of EZ Pass Usage. Available online at https://www.panynj.gov/bridges-tunnels/en/traffic---volume-information---b-t.html. Retrieved on April 19, 2022.

Rutgers University. 2019. New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel. Available online at https://climatechange.rutgers.edu/images/STAP_FINAL_FINAL_12-4-19.pdf. November.

U.S. Census Bureau. 2022. Income and Poverty in the United States: 2020. Available online at Income and Poverty in the United States: 2020 (census.gov). Retrieved on April 19, 2022.

USGS. 2022. Flood Event Viewer – Hurricane Sandy. Available online at https://stn.wim.usgs.gov/FEV/#Sandy. Retrieved on April 19, 2022.