

Evacuation

Mapping Disparities in Hurricane Evacuation Ability in NYC



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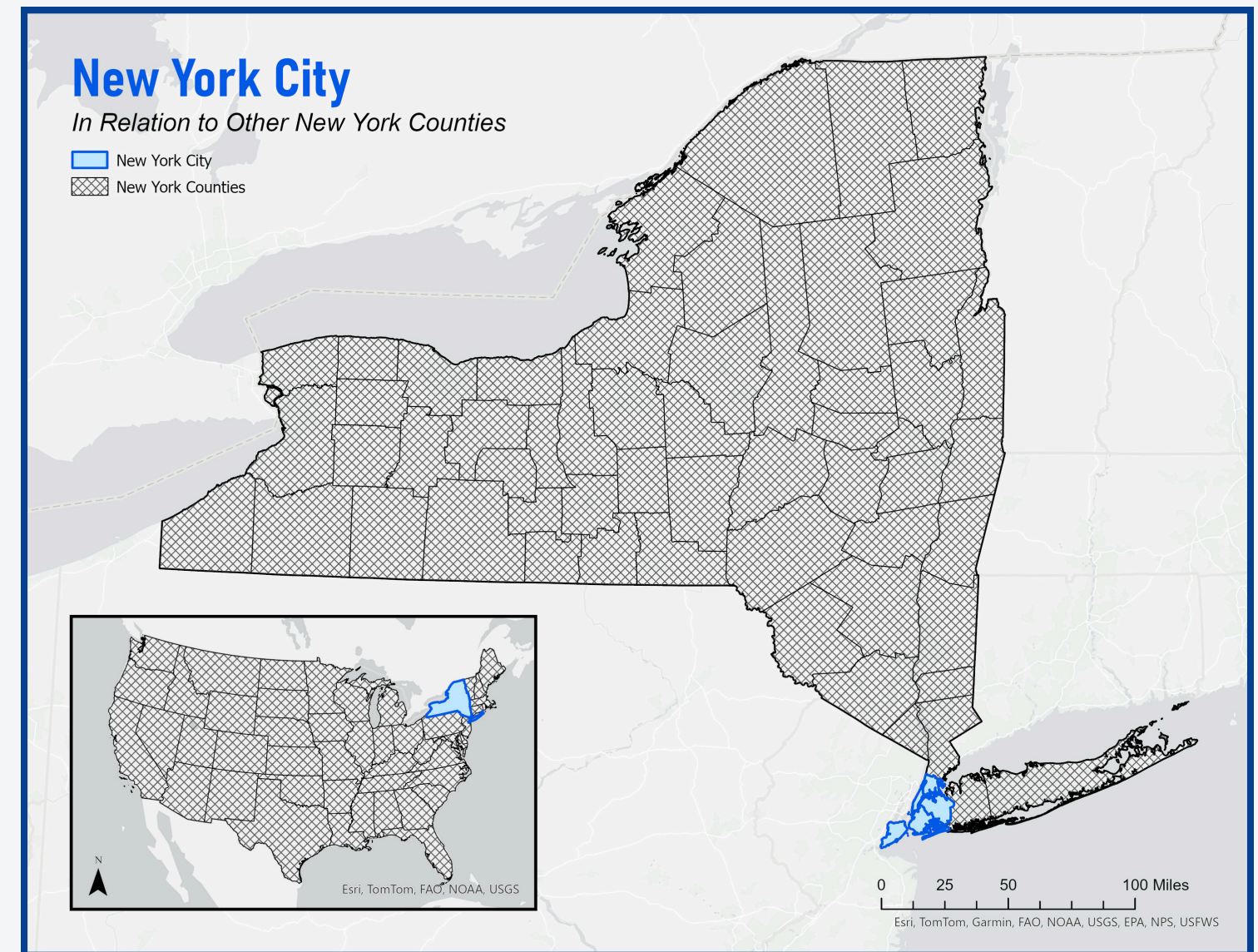
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Defining the Problem

Since the early 1980's the Atlantic has seen a substantial **increase in the intensity, frequency, and duration of hurricanes.**¹ As climate change continues on its path and natural disasters become more frequent and severe, disaster preparedness and adaptation are more critical than ever.

Disaster response and evacuation strategies vary greatly from city to city, shaped by factors such as **geography, the built environment, and the demographics of the city's residents.** All across the United States, disaster-struck communities face such problems as gridlock on their roads when thousands of people flood the highways in a panic. This is the norm for the **sprawling car-dependent majority that dominates the country.**

New York City is different. **The city is characterized by dense development, narrow streets, and a high transit-dependent population,** presenting unique evacuation challenges and opportunities.

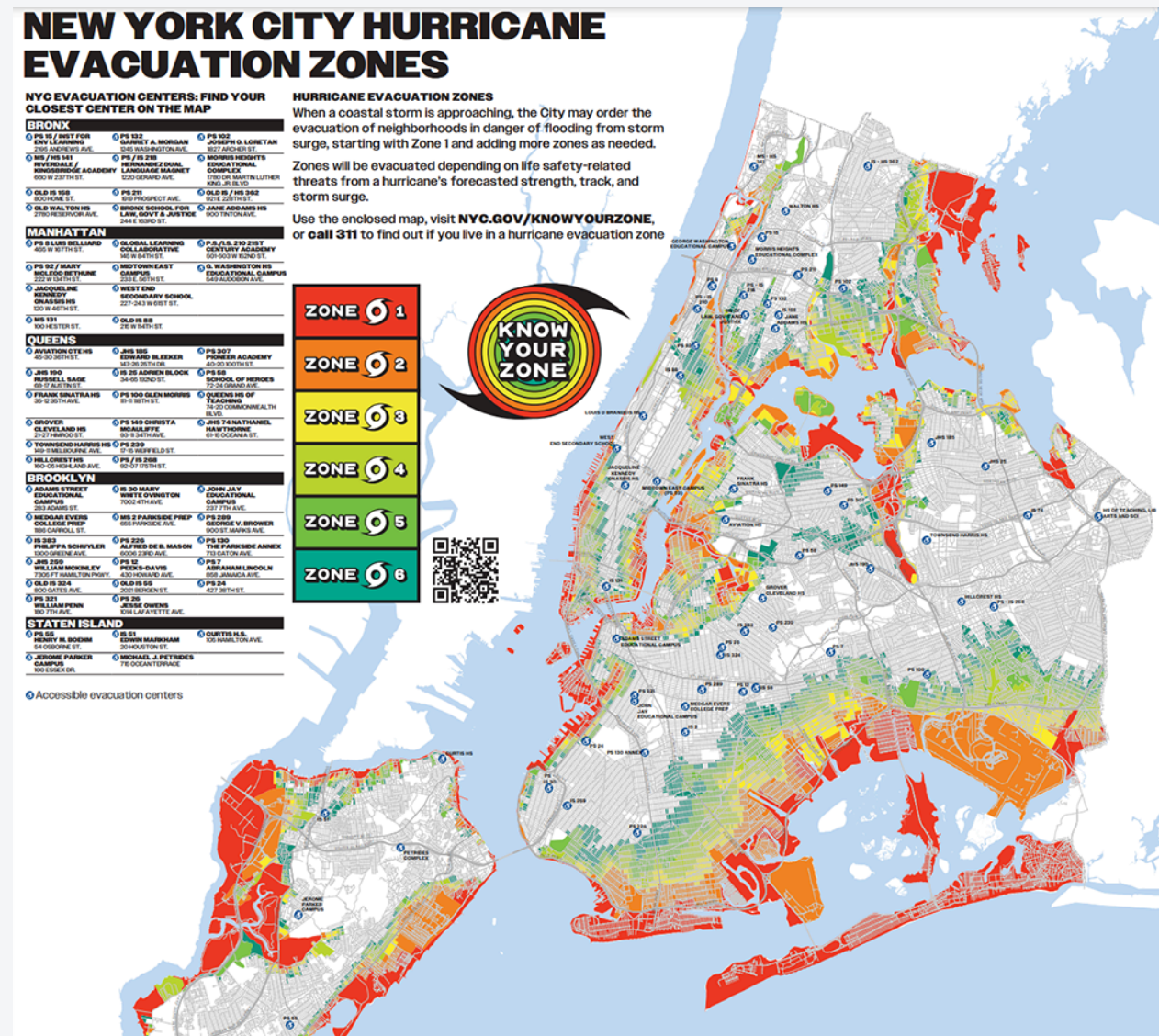


Houston Highways During Evacuation in Preparation for Hurricane Rita in 2005



New York City

Current Protocols



(Source: New York City Emergency Management)

Evacuation in New York City mostly falls under the responsibility of the citywide agency, New York City Emergency Management (NYCEM).

In the case of hurricanes, emphasis is placed on education and personal responsibility. Residents are encouraged to **“know your zone!”**, and have pre-planned destination and travel routes.²

During a hurricane, NYCEM alerts residents to **shelter in place** or **evacuate**, with the latter option saved for communities facing possible storm surge threats. When prompted to evacuate, residents are expected to know their zone and respond to evacuation orders accordingly.

There are three main modes of evacuation – mass transit, car, and foot – but the **city urges residents to utilize mass transit if possible** as it “reduces the volume of evacuees on the roadways, lowering the risk of dangerous and time-consuming traffic”.

NYCEM emphasizes the importance of **leaving early** as hazards such as strong winds, heavy rain, and flooding may force the early closure of vital transportation infrastructure.

What Factors Influence Evacuation Effectiveness in NYC?



Research Questions

Q1

How does existing geography affect evacuation ability?

Q2

How does the built environment affect evacuation ability?

Q3

How do people and behavior affect evacuation ability?

Q4

How does the digital divide affect evacuation ability?

Q5

Where do disparities in evacuation ability lie in NYC?

Q6

What are the demographics of the communities that are disproportionately affected?

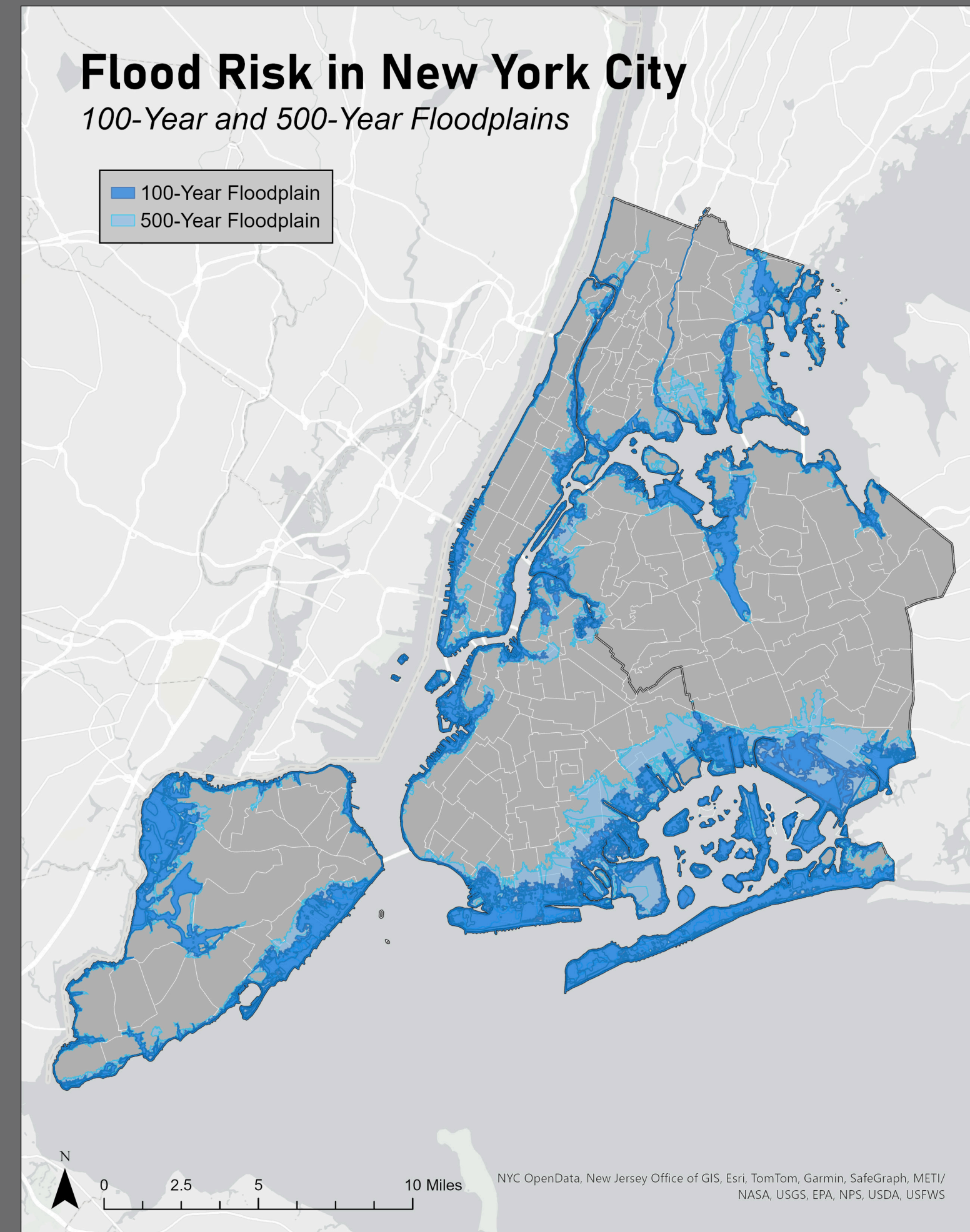
Q1: How Does Geography Affect Evacuation Ability?

The geography of NYC sets the foundation for how the city inherently experiences hurricanes. As a city comprised **primarily of islands**, NYC is surrounded by water, leaving all five boroughs susceptible to flooding from multiple directions. With an average citywide elevation of **33 feet**, many coastal neighborhoods are at risk of inundation during hurricanes.

This map depicts flood risk in New York City by layering the 100 and 500-year floodplain, as provided by the Federal Emergency Management Agency (FEMA).

100-year flood plain - a flood that statistically has a 1% chance of occurring in any given year.

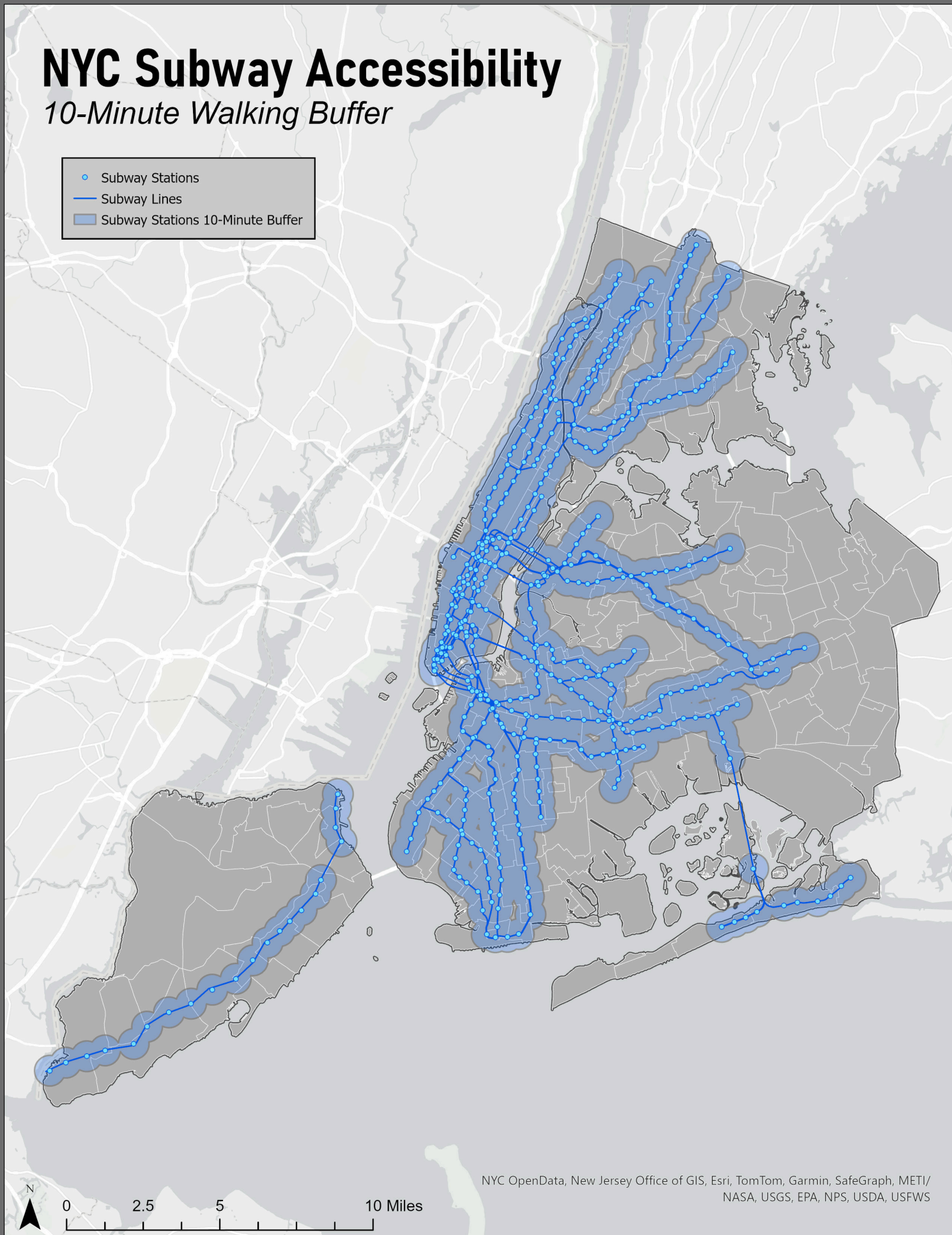
500-year flood plain - a flood that statistically has a 0.2% chance of occurring in any given year.



NYC Subway Accessibility

10-Minute Walking Buffer

- Subway Stations
- Subway Lines
- Subway Stations 10-Minute Buffer



Q2: How Does the Built Environment Affect Evacuation Ability?

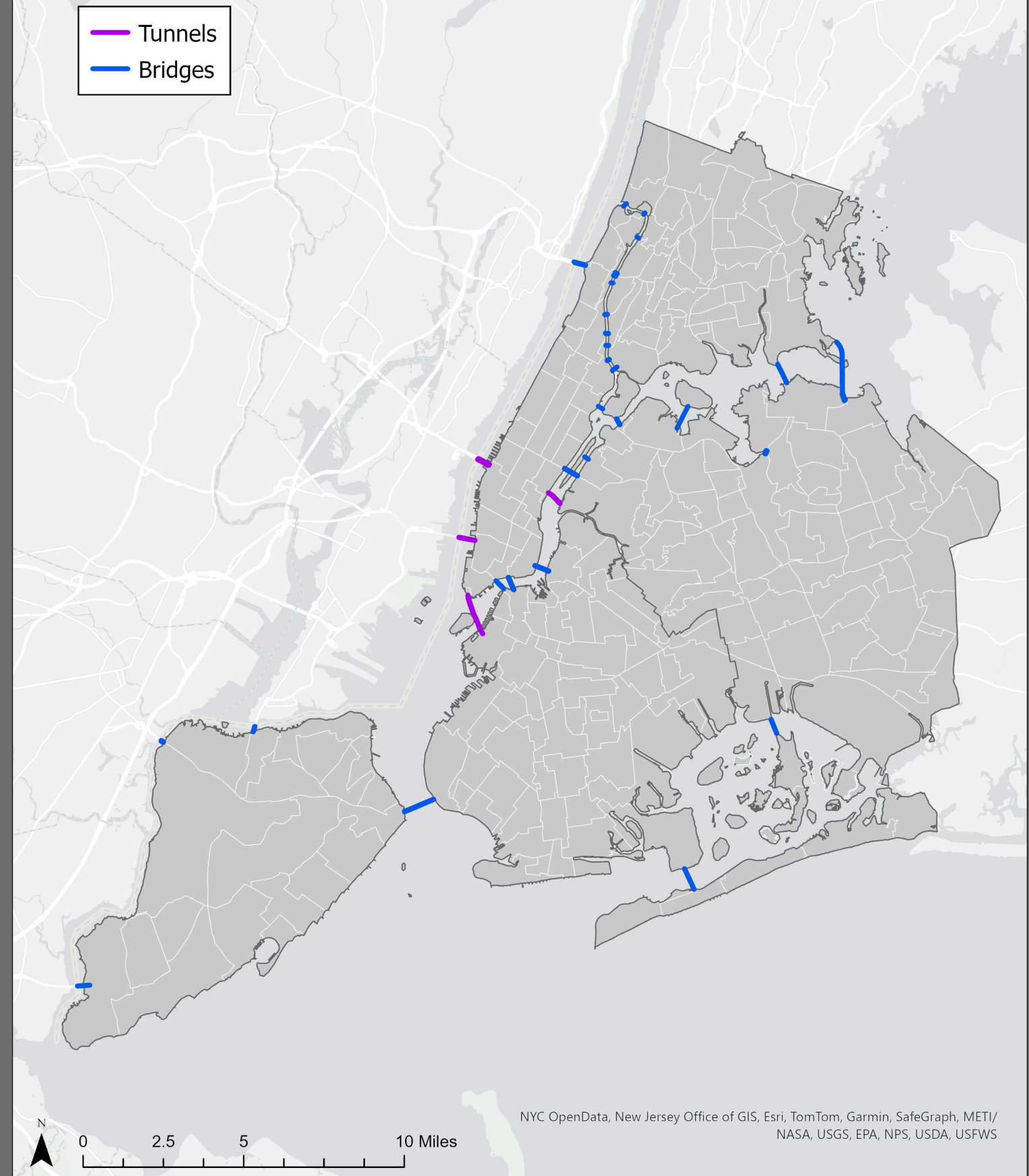
Equally as impactful as topography are **connectivity and accessibility** - facets of the built environment. Due to the city's unique weaving of urban and aquatic, transportation infrastructure consists of **bridges and tunnels**. These vital pieces of infrastructure connect the boroughs within the city and the city to the rest of the state and country, serving as the arteries that allow for the successful transportation of goods and people in and out of the city.

The transit map depicts NYC's subway network and is outlined by a 10-minute (0.5 mile) buffer zone to visualize pedestrian accessibility. Manhattan emerges as the borough with the most extensive transit infrastructure, followed by Brooklyn and the Bronx. **Significant transit gaps are evident in Queens and Staten Island.** Staten Island faces unique challenges; its only public transit link to the rest of the city is through the Staten Island Ferry, which connects the island to Manhattan.

In terms of vehicular accessibility, Manhattan benefits from unparalleled connectivity with **21 bridges and 5 tunnels** linking it to the surrounding land. The Bronx and Queens also enjoy direct access to surrounding land without reliance on bridges or tunnels. Brooklyn is well-connected via bridges, but **lacks direct access to mainland areas outside of NYC**, requiring residents to travel through other boroughs to exit the city entirely.

Staten Island fares better when analyzing vehicular accessibility versus transit accessibility. The borough has **4 drivable bridges** connecting it to surrounding areas - three to New Jersey and one to Brooklyn.

Vehicular Accessibility in NYC



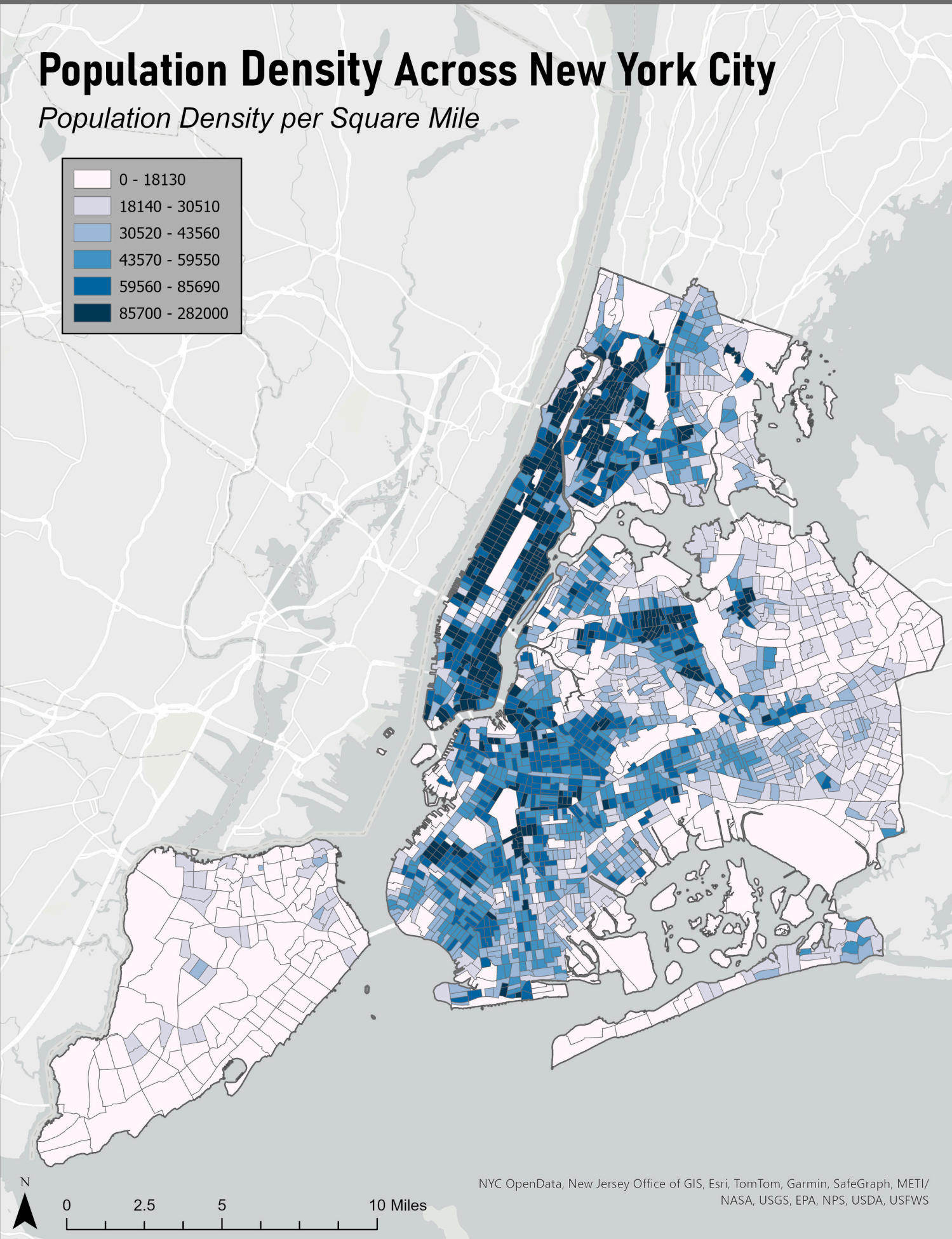
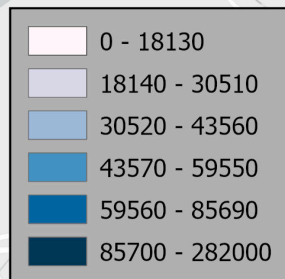
Q3: How Do People and Behavior Affect Evacuation Ability?

A city's geography and its built environment form the foundation of evacuation strategies. Geography presents inherent challenges, like susceptibility to flooding, that are exacerbated during crises like hurricanes. While the built environment can mitigate some of these challenges through mindful planning, the human factor plays a pivotal role in shaping evacuation outcomes. **People are the dynamic force within the stationary city.**



Population Density Across New York City

Population Density per Square Mile



NYC OpenData, New Jersey Office of GIS, Esri, TomTom, Garmin, SafeGraph, METI/
NASA, USGS, EPA, NPS, USDA, USFWS

In New York City, the abundance of high-density residential and mixed-use zoning results in dense development patterns, narrow pedestrian-focused streets, and a high population density. High population density and urbanization **increase a population's vulnerability to disasters** through effects such as congestion, limited escape routes, and dense infrastructure.³

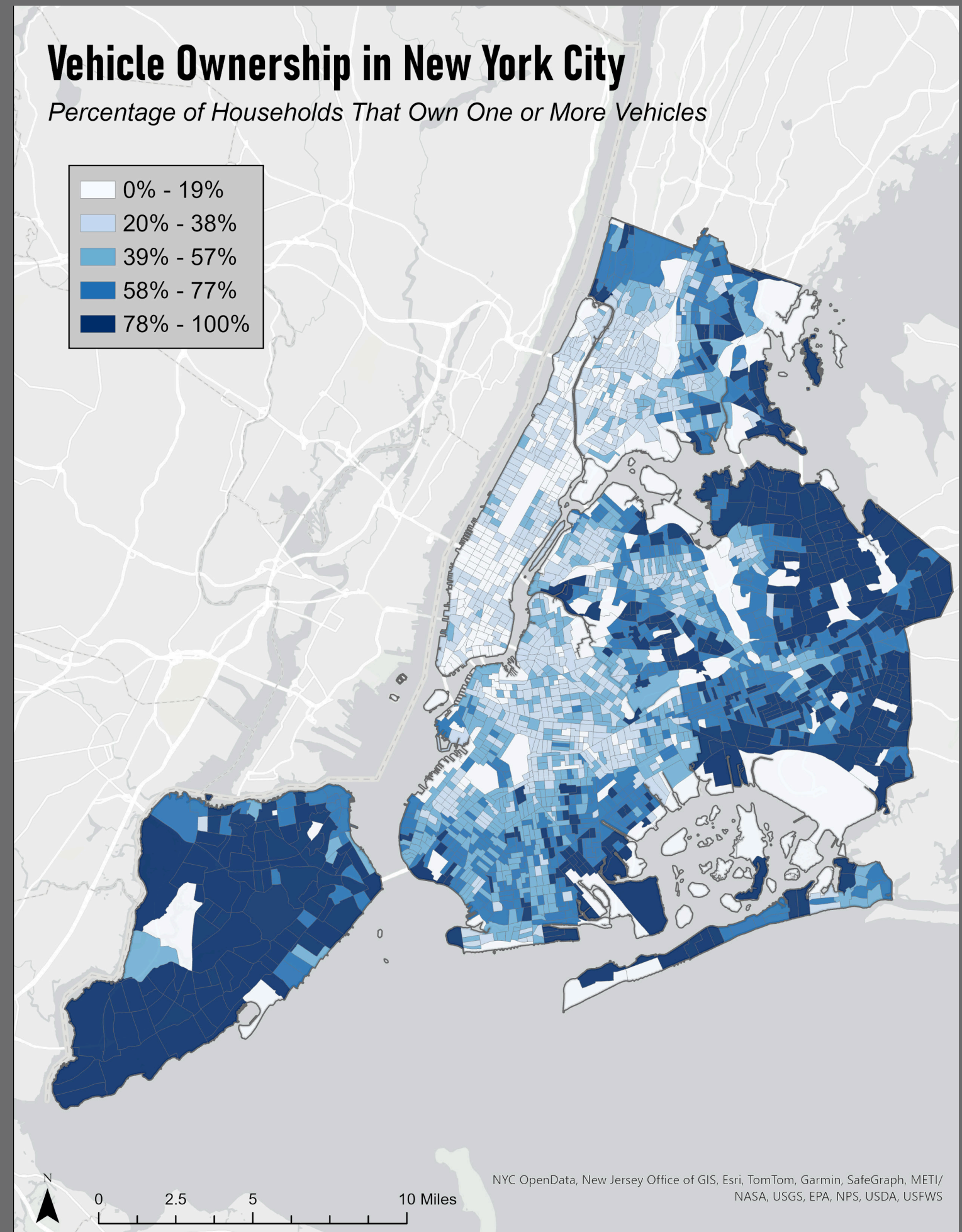
While Manhattan benefits from extensive connectivity through transit and vehicle networks, high population density can strain these systems. On any given day, nearly **700,000 vehicles** enter Manhattan's Central Business District.⁴ Similarly, **450,560 commuters** travel into the borough through public transit each day.⁵

Though the Bronx shares similar density levels as Manhattan, its direct mainland access offers smoother traffic flow, mitigating some impacts. Brooklyn also experiences pockets of high density. Queens and Staten Island have the **lowest population densities**, providing a possible degree of reprieve during evacuation.

Just as zoning shapes settlement patterns and population density, New York City's highly developed, interconnected transit system greatly influences vehicle ownership patterns. Between 2018 and 2022, **only 45% of NYC households owned a car**. The map shown depicts vehicle ownership patterns across NYC during this period.

Staten Island is the outlier, with approximately **84% of households owning vehicles**, reflecting the borough's dependence on vehicles due to limited public transit options. In contrast, Manhattan exhibits **lower car ownership rates at just 22%**, aligning with its extensive transit system and dense urban form.⁶

Queens and the Bronx present a middle ground, with car-owning residents benefiting from direct access to surrounding areas outside of the borough boundaries. For these residents, early evacuation by car provides an advantage, allowing them to leave disaster zones entirely.



Q4: How Does the Digital Divide Affect Evacuation Ability?

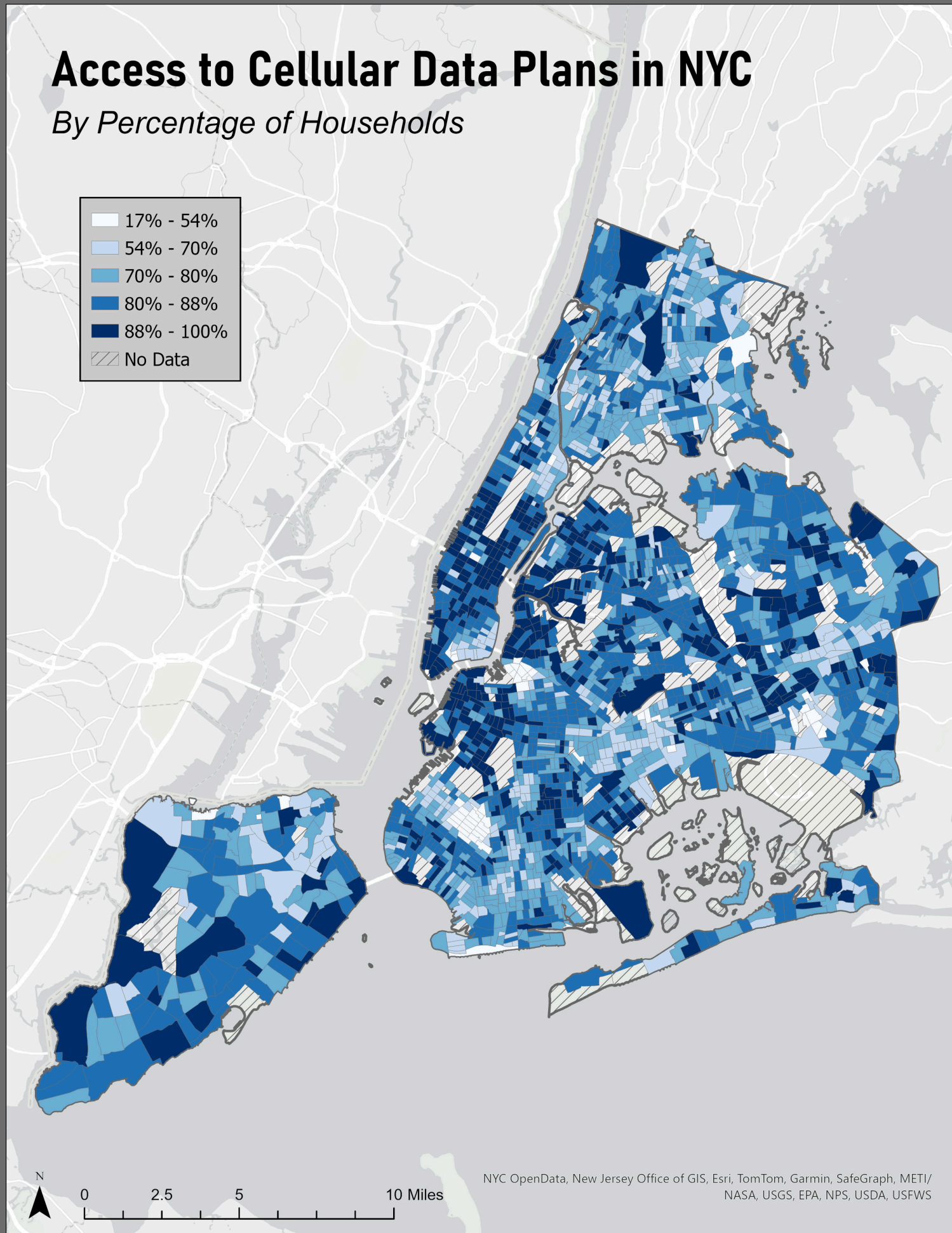
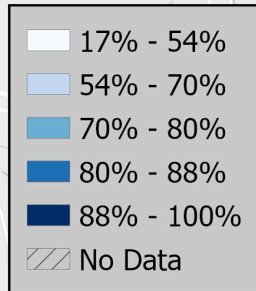
The digital divide refers to the **widening gap** created by society's **increasing reliance on technology**. This divide highlights how certain populations' access to information is limited, despite said information being readily available to the majority of the population. This disparity **disproportionally affects marginalized groups** and has a significant impact on evacuation response and information distribution.

In New York City, evacuation success is heavily dependent upon residents' readiness and prompt response to instruction. **Effective evacuation coordination relies on accurate and up-to-date information**. As technology is the tool for its dissemination, digital access becomes a critical component to mapping vulnerable communities.



Access to Cellular Data Plans in NYC

By Percentage of Households



The map depicted illustrates cellular data access in NYC, serving as a proxy for residents' ability to receive critical evacuation information.

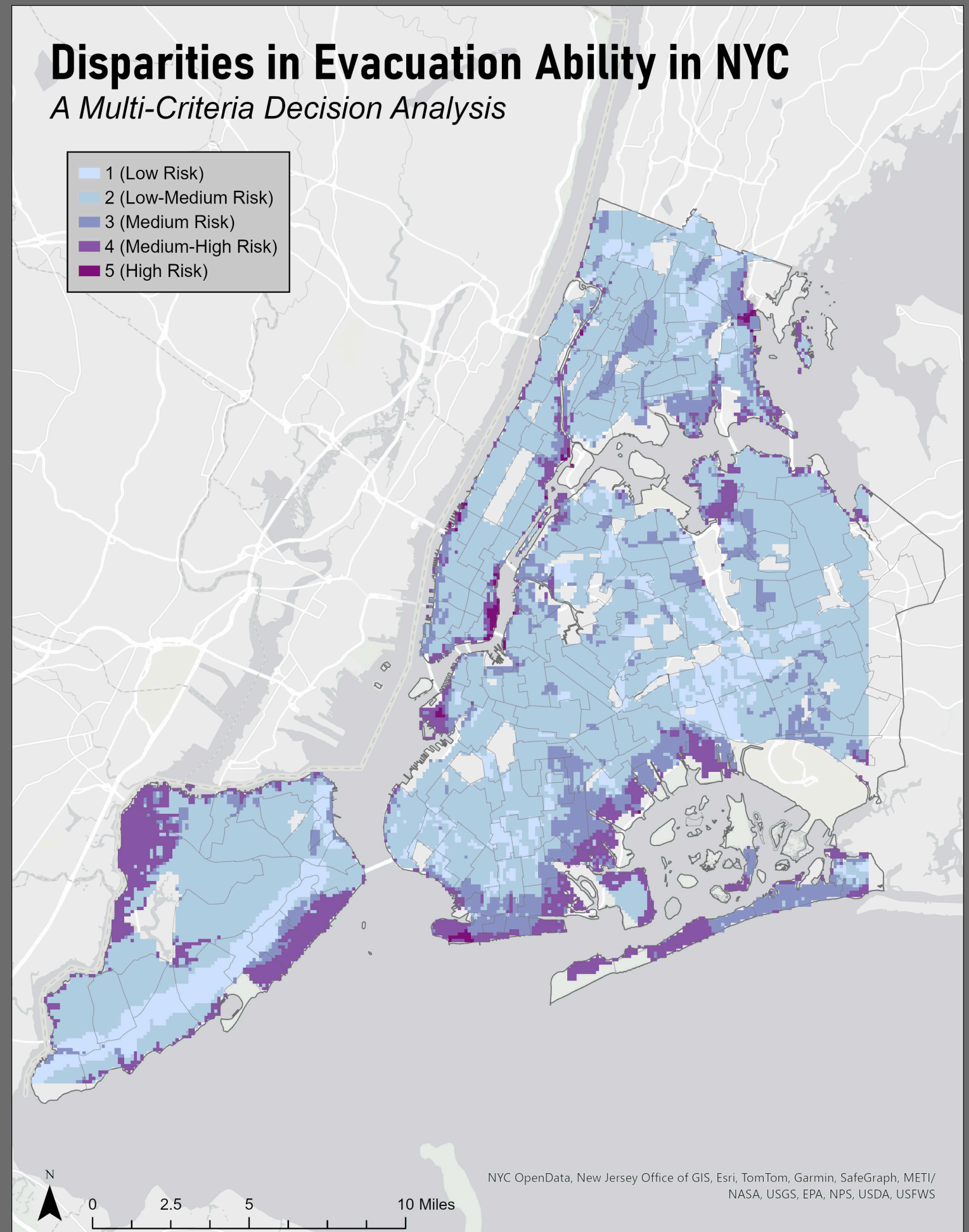
Despite widespread cellular data coverage, significant barriers may prevent some residents from accessing or acting on evacuation information. Technological barriers, for example, may still exist even for those who own phones. **Navigating the city's emergency website or understanding digital alerts may not be intuitive for certain populations**, including elderly individuals, non-English speakers, and those generally unfamiliar with digital platforms.

Other barriers include language accessibility and systemic mistrust of government. The latter is crucial to address, as many already at-risk communities during hurricanes are also ones that have been historically underserved and neglected. For these communities, a lack of trust in government may lead to skepticism about evacuation orders, further compounding their vulnerability during disasters.

Q5: Where do Disparities in Evacuation Ability Lie in NYC?

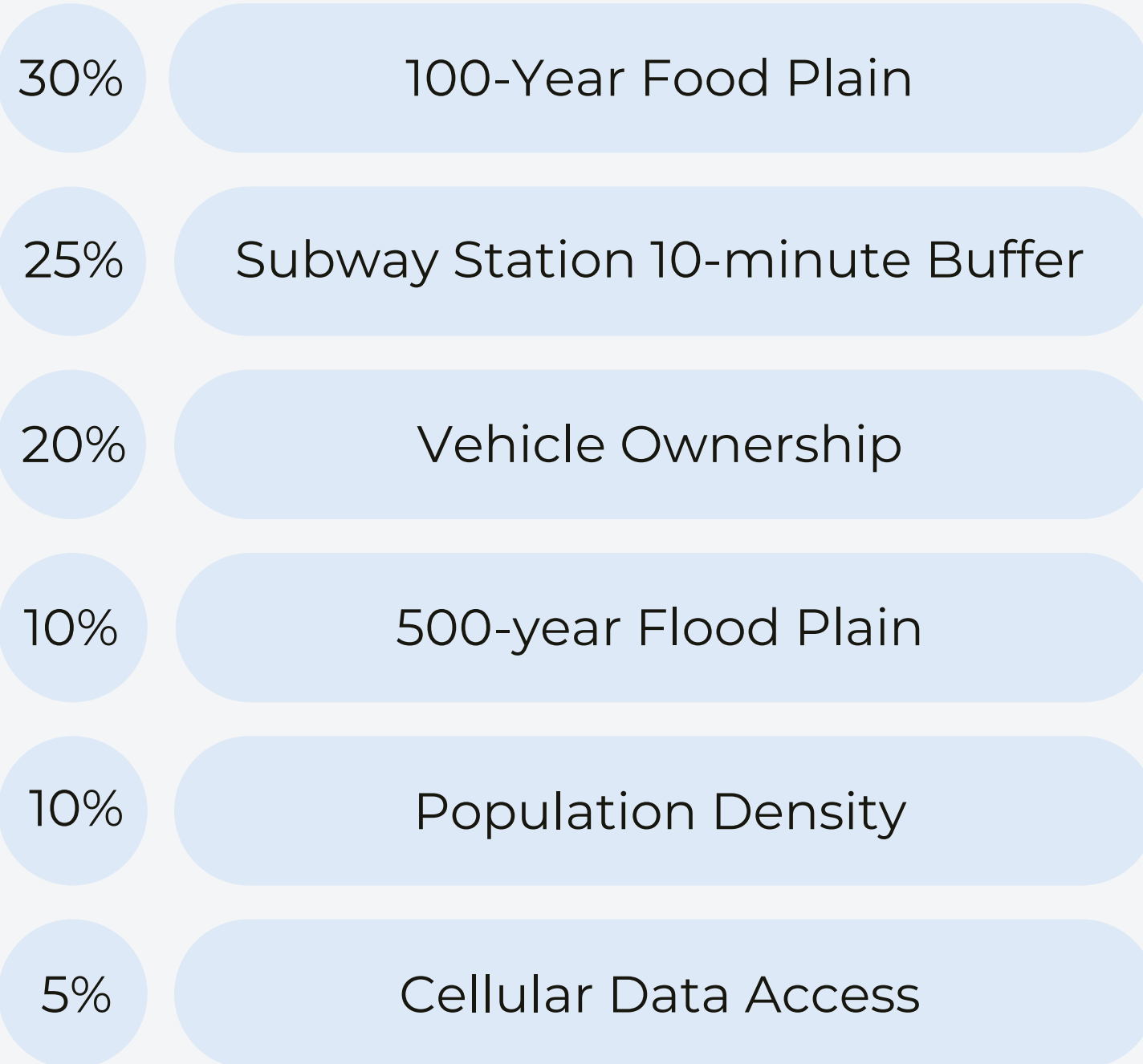
Utilizing a Multi-Criteria Decision Analysis helps to identify communities in NYC that experience disparities in evacuation ability during hurricanes.

Analysis shows parts of Staten Island along with south Brooklyn and south Queens to be the most vulnerable during hurricane evacuation in NYC based on factors such as geography, the built environment, people, behaviors and access to information.



Weighting Variables

All previous maps were included as layers and weighted as follows:



Weights were determined through analysis of existing literature on NYCEM evacuation strategies.

Justification for weights are as follows:

100-Year Flood Plain - Residents within the 100-year floodplain are inherently impacted by geography and will require evacuation in the case of a flood or resulting storm surge.

Subway Station 10-minute Buffer - NYCEM recommends use of mass transit during evacuations

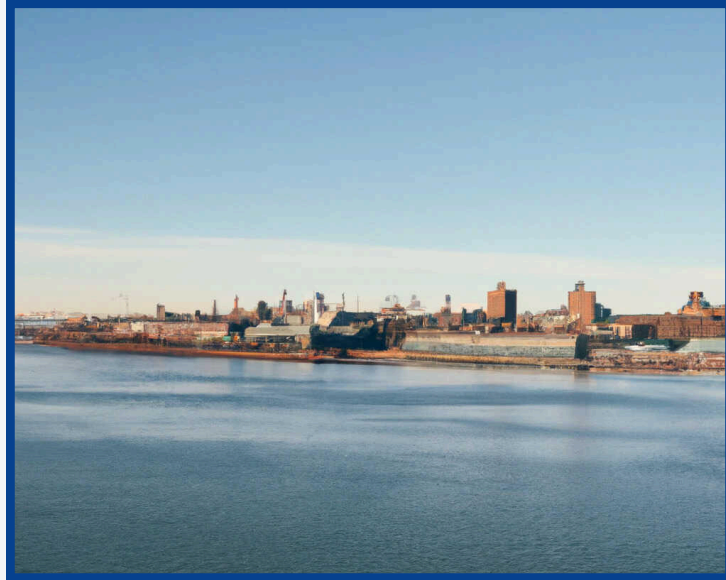
Vehicle Ownership - Though NYCEM advises against vehicular evacuation, vehicle owners are advantaged if the response to evacuation orders is prompt.

500-year Flood Plain - Residents within the 500-year flood plain still inherently face danger, with a 0.2% chance of a flood occurring in any given year.

Population Density - Though population density has an effect on evacuation, its effects are not as measurable as other factors.

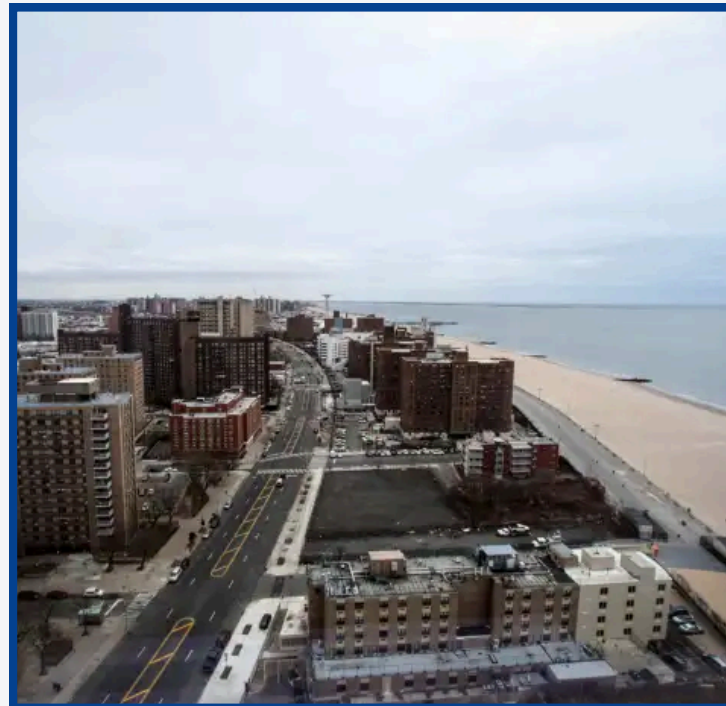
Cellular Data Access - Arguably the most important factor, but due to a limitation of data, excess weight cannot be assigned.

Taking a Closer Look at New York City's Most Vulnerable Communities



New Springville - Bloomfield - Travis: Neighborhood Tabulation Area (NTA) SI05 is comprised of the three abutting neighborhoods along the western coast of Staten Island. The three communities are a mix of residential and industrial. West Staten Island is served by two Bus Rapid Transit (BRT) lines, but there is no accessible subway line.

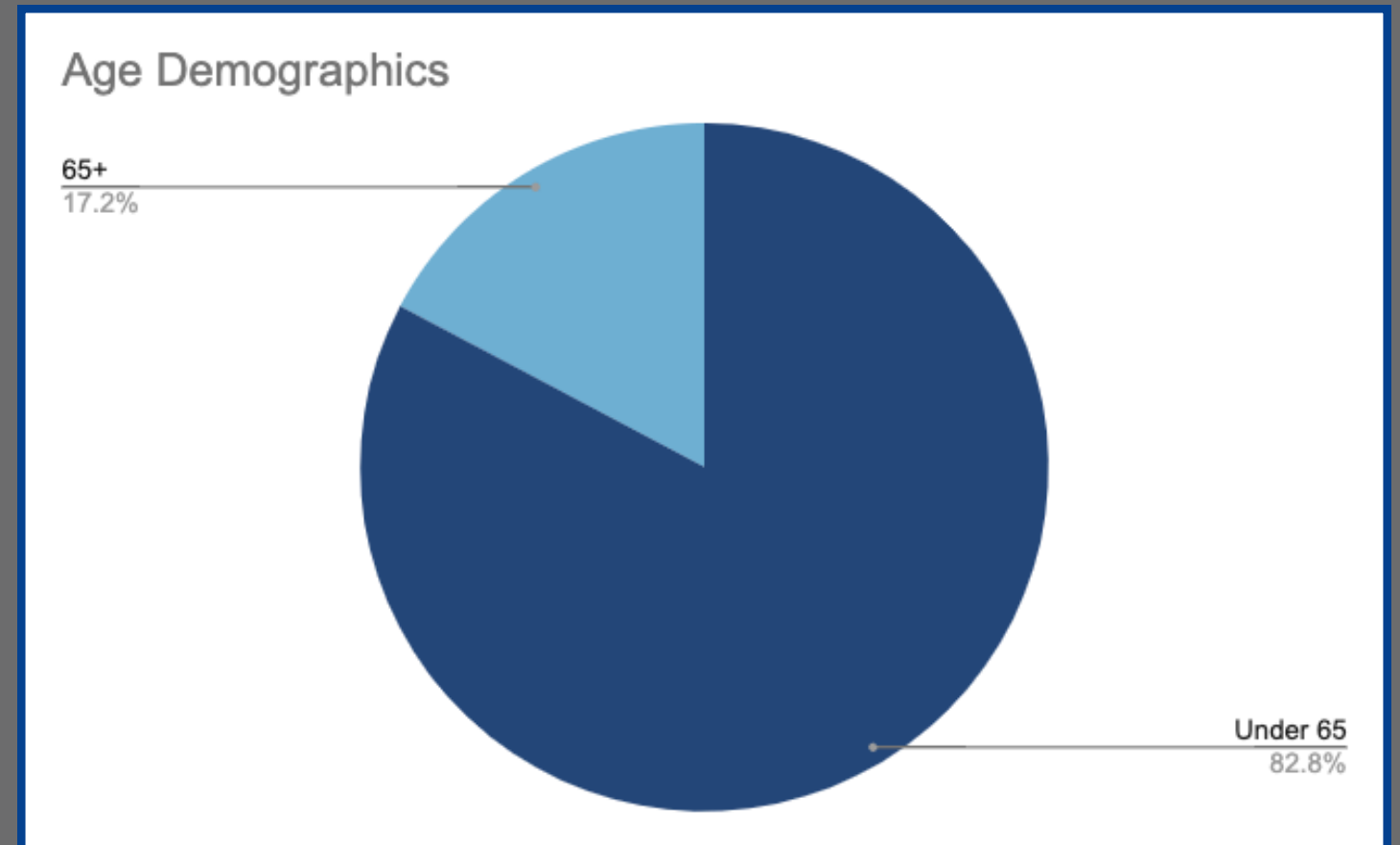
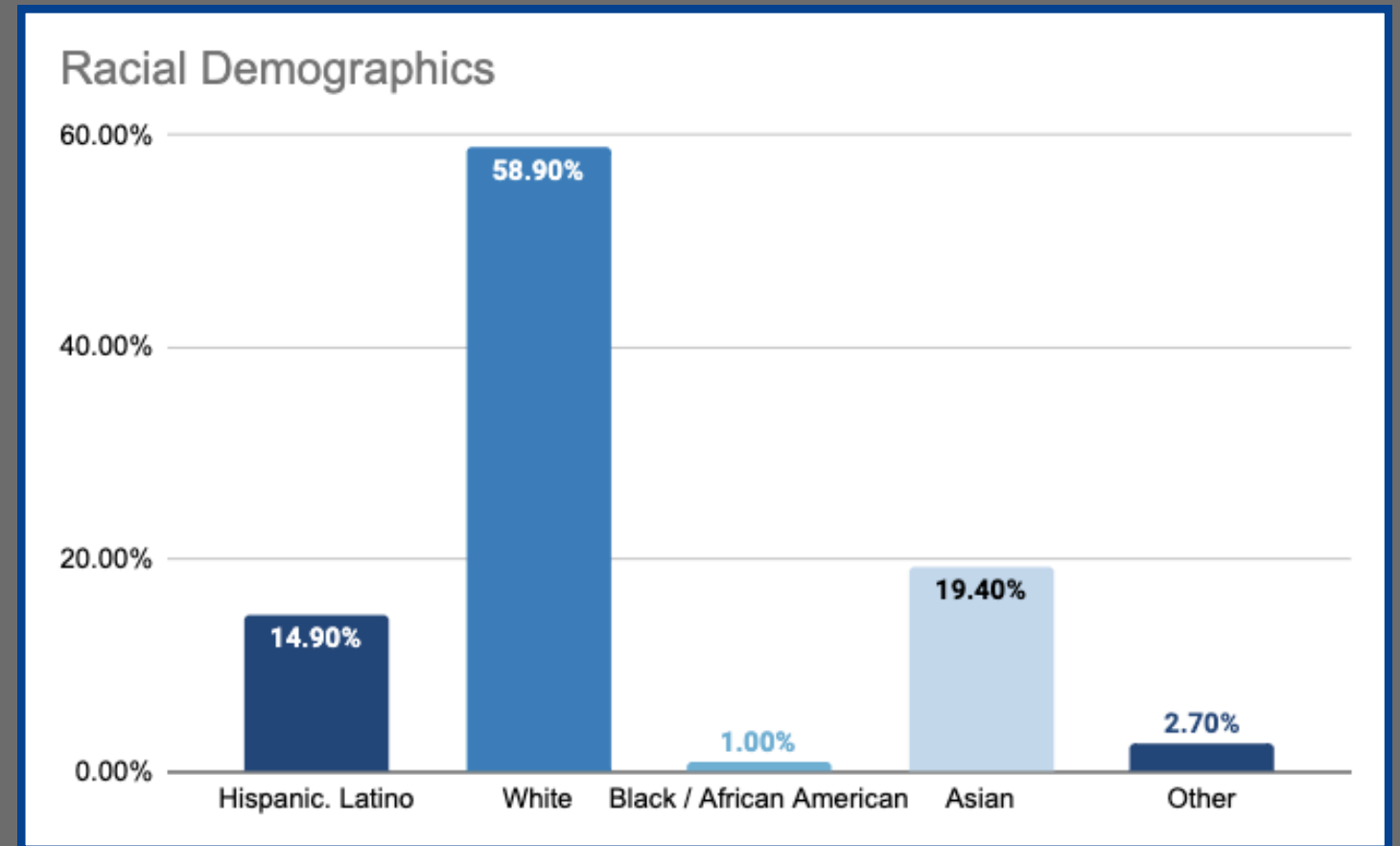
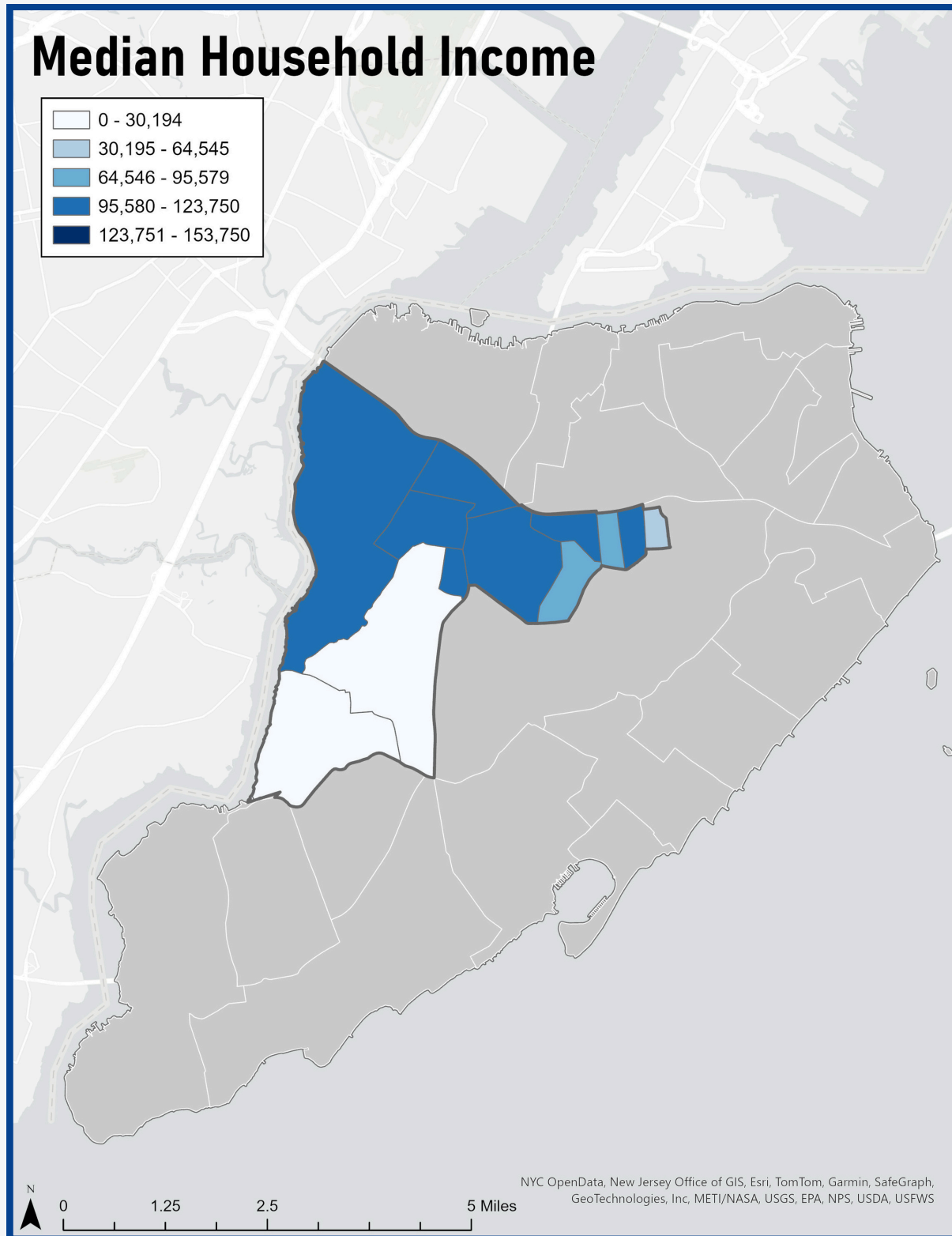
Seagate-Coney Island: NTA BK21 is comprised of two abutting neighborhoods along the southern coast of Brooklyn. Seagate, located to the west, is a private gated community consisting of single-family homes. Conversely, Coney Island consists mainly of multi-family residences. Nearly 20% of the population is 65 and older and approximately 43% of that population is below the poverty line.⁷



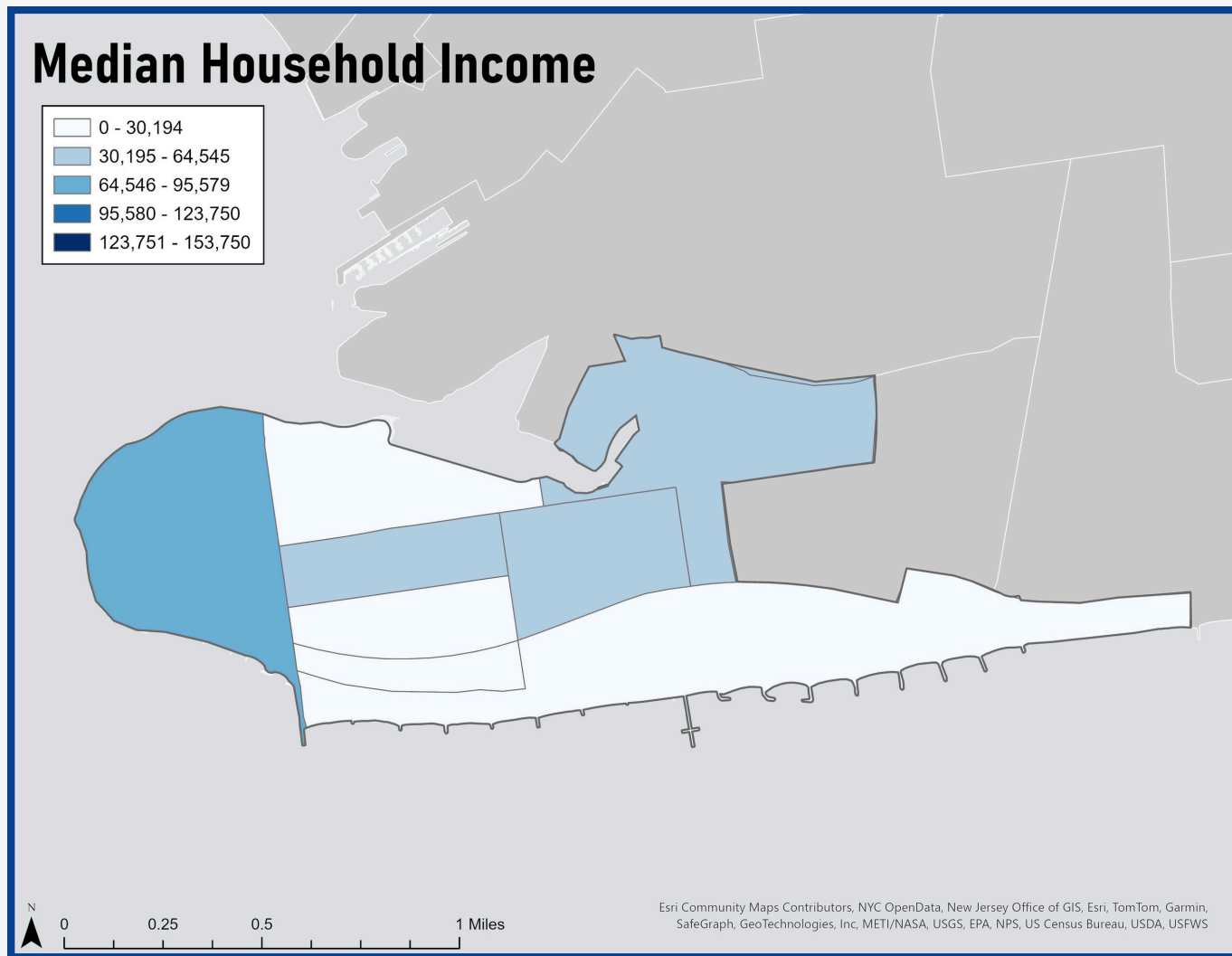
Zooming In: South Brooklyn & East Staten Island



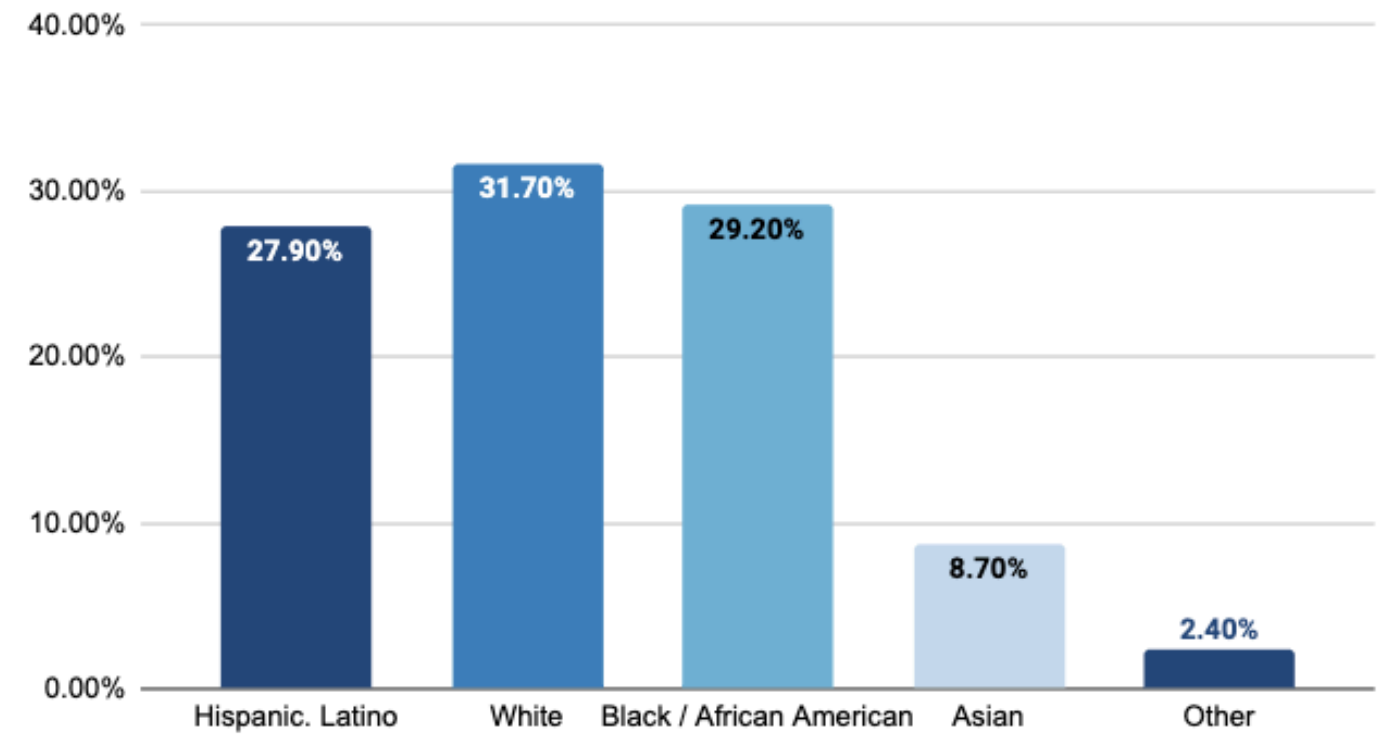
New Springville- Bloomfield-Travis



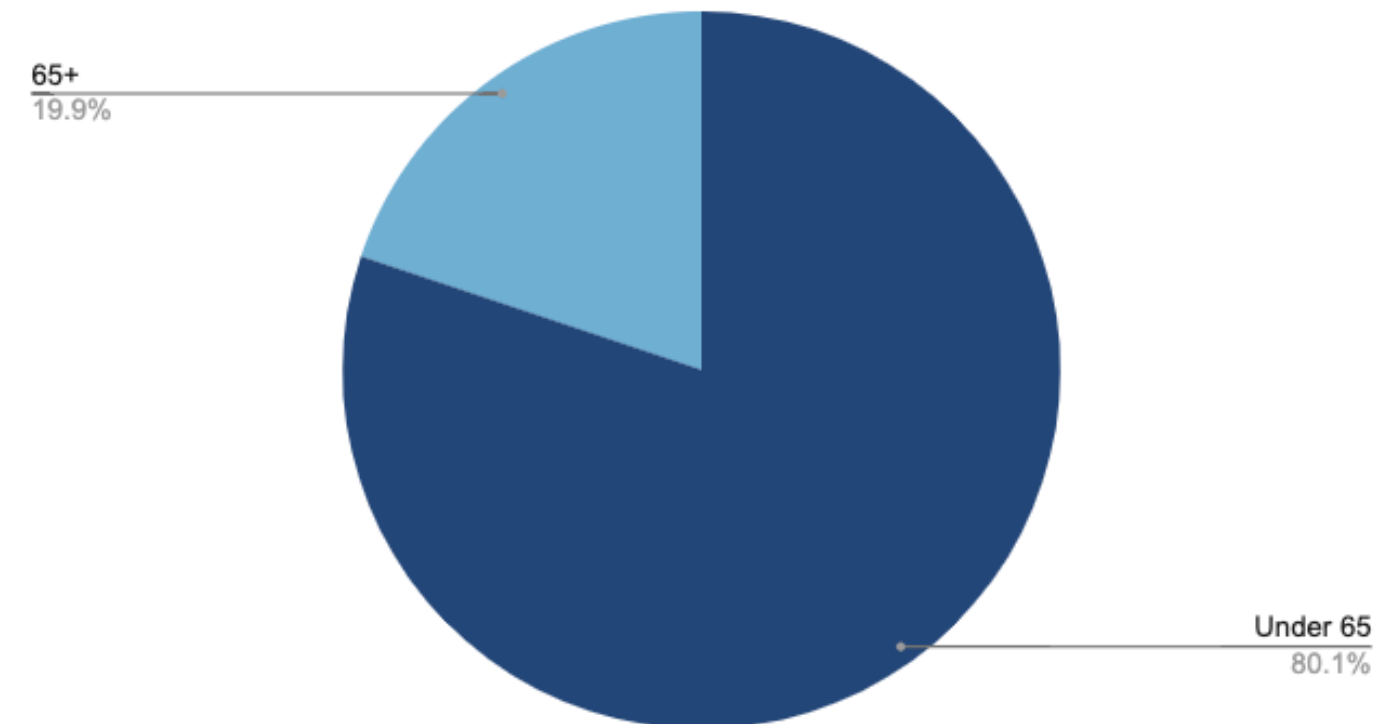
Seagate-Coney Island Demographics



Racial Demographics



Age Demographics



Infrastructure Closure & Failure

While the city promotes mass transit as the ideal transportation mode of choice during evacuation, effectiveness depends on its functionality. On a typical day, 700 pumps throughout the subway system drain 13 million gallons of water. That same system can pump up to 1.5 inches of rainwater per hour during a storm. However, if rates exceed these numbers, and excessive water enters the subway, the system must be shut down to avoid safety hazards and excessive damage.

During Hurricane Sandy in 2012, Mayor Bloomberg announced mandatory evacuations for Zone A on Sunday, October 28th in New York City. The subway was shut down hours later, **17 hours before landfall**. This left residents with minimal time to make alternative evacuation plans.⁸

Additionally, tunnels and bridges closed down during Hurricane Sandy, limiting vehicular evacuation routes, and stranding vehicle dependent residents.



Conclusion

From the analysis, several key conclusions emerge. First, the **communities identified as most at risk** (under the best circumstances) **experience a compounding negative effect on evacuation ability** when systems begin to shut down

Second, the **success of hurricane evacuation hinges on time, mobility, and access to information**. According to the city, mass transit is the most effective mode of transportation during evacuation. However, for transit to be effective, residents must utilize transit before it is shut down. This tight timeframe highlights the importance of the **timely dispersion of reliable information**.

Important to note is that **some populations may be inaccessible** due to certain barriers (technological, language, cultural), or may have a lack of trust in government due to previous experiences.

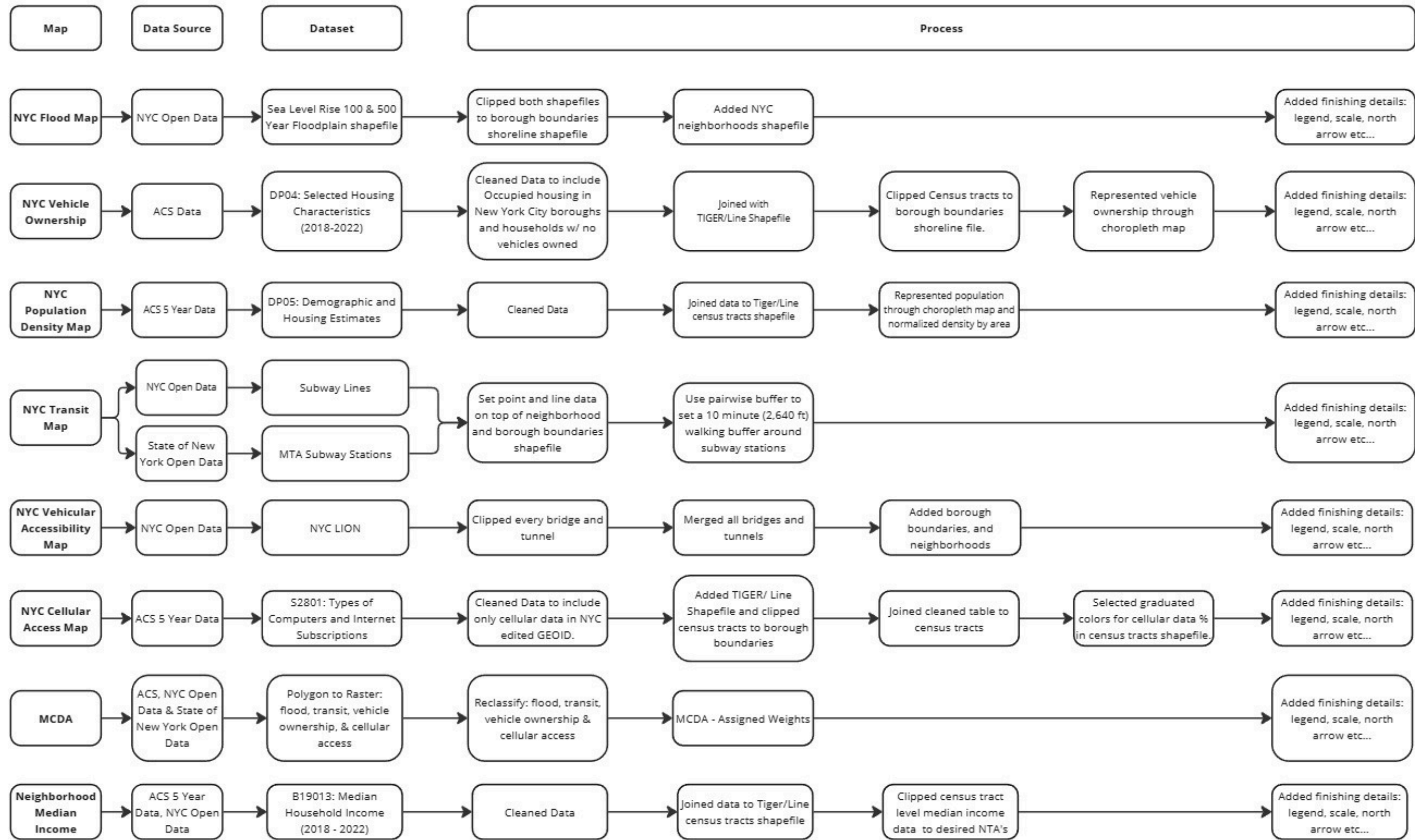
Recommendations

Improve Emergency
Communication Strategies

Expand Multimodal Transportation
Options for Vulnerable Communities

Improve and Invest in Flood Resilience
Infrastructure in At-Risk Coastal
Communities.

Methodology



Sources

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