

# Exposure, Socio-Economic Vulnerability, and Infrastructure at Risk to Current and Projected Coastal Flooding in New York City

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**City College of New York**

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# Introduction

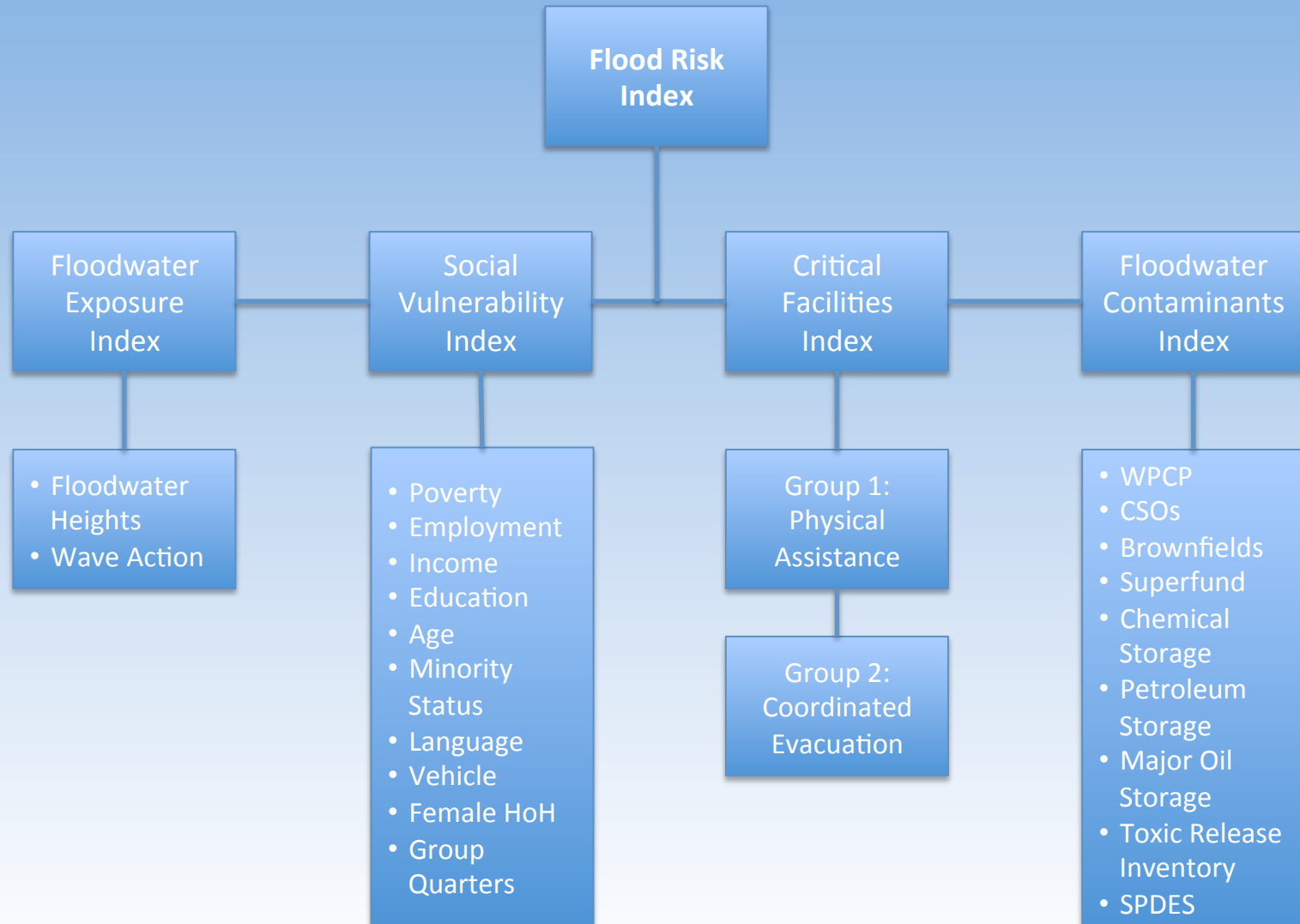
This work uses a GIS-based methodology to develop and map a composite biophysical exposure, social vulnerability, and critical facilities index for New York City populations exposed to the current and predicted 100- and 500-year flood. The **objective** is to assess overall flood risk at the intersection of exposure and vulnerability.

- Storms are not equal impact events. Social and physical geography interact to expose vulnerable populations to elevated risk.
- Due to sea-level rise, more communities are becoming vulnerable, existing communities are becoming more vulnerable and both are becoming less disaster resilient.
- The combination of floodwater exposure, social vulnerability, critical facilities, and floodwater contaminants provides a metric to rank neighborhood risk to flood hazards through an overall risk index that characterizes site-specific levels of risk to flood hazard.
- Using recent publically available data at block group level resolution will allow planners and emergency managers to identify pockets of socially and physically vulnerable populations.
- Overlapping socially vulnerable populations with physical hazard will identify communities that may require special attention, planning efforts and mobilization to respond to and recover from disasters and hazards.

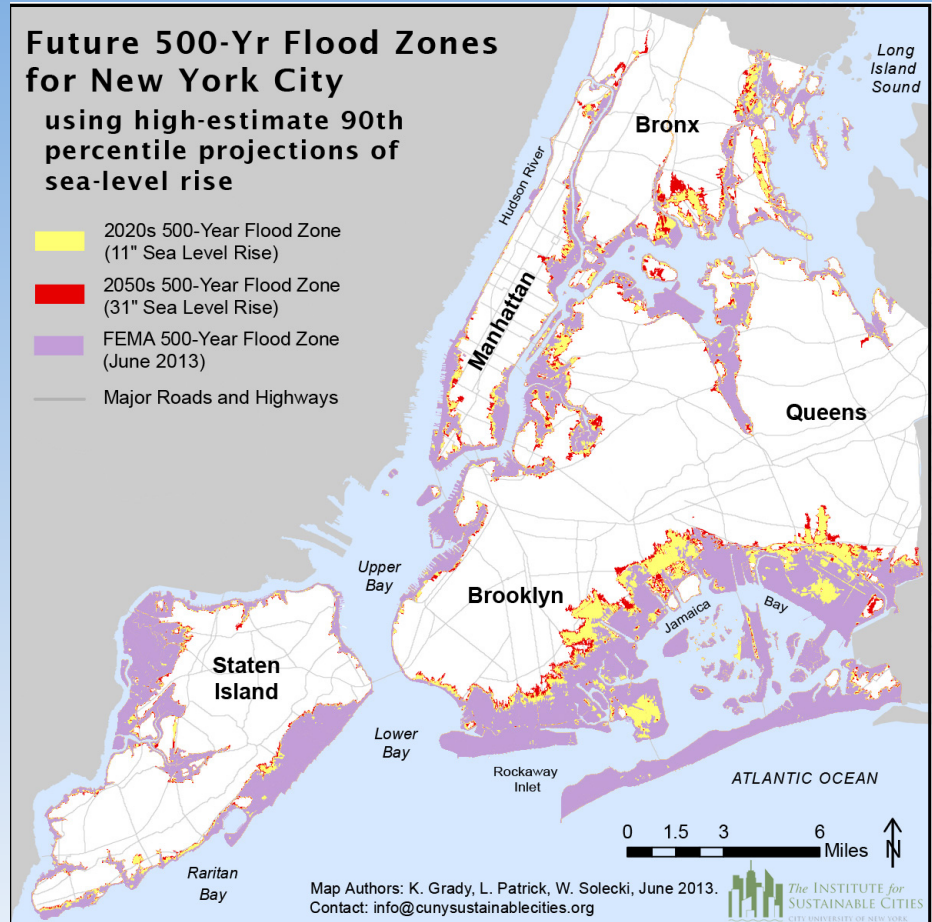
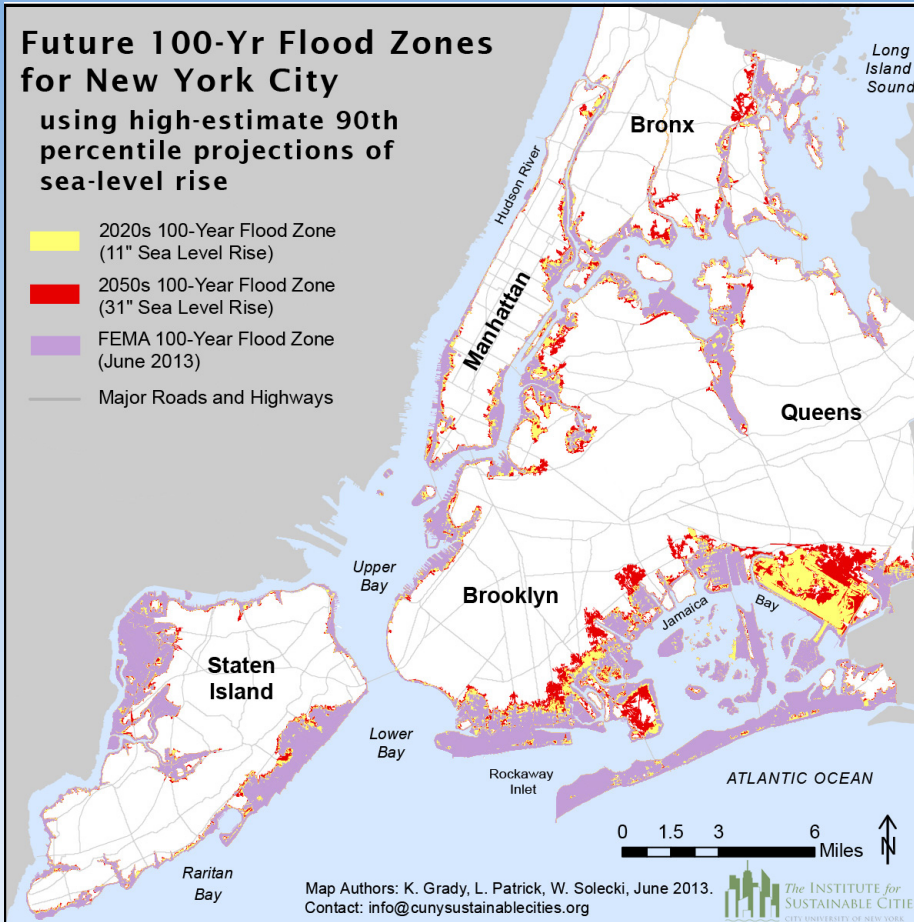
# Flood Risk Index

$$\text{Risk}_{(i)} = \text{Hazard}_{(i)} \times \text{Elements at Risk}_{(i)} \times \text{Vulnerability}_{(i)}$$

Granger, 2003

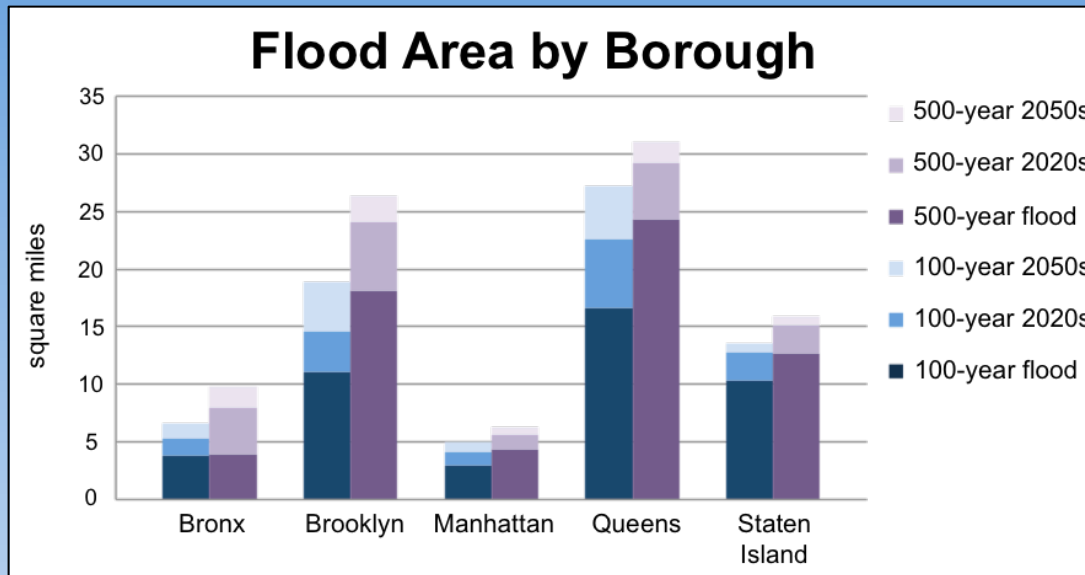


# Areas potentially at-risk to the 100-year and 500-year floods in New York City based on 90<sup>th</sup> percentile sea-level rise projections



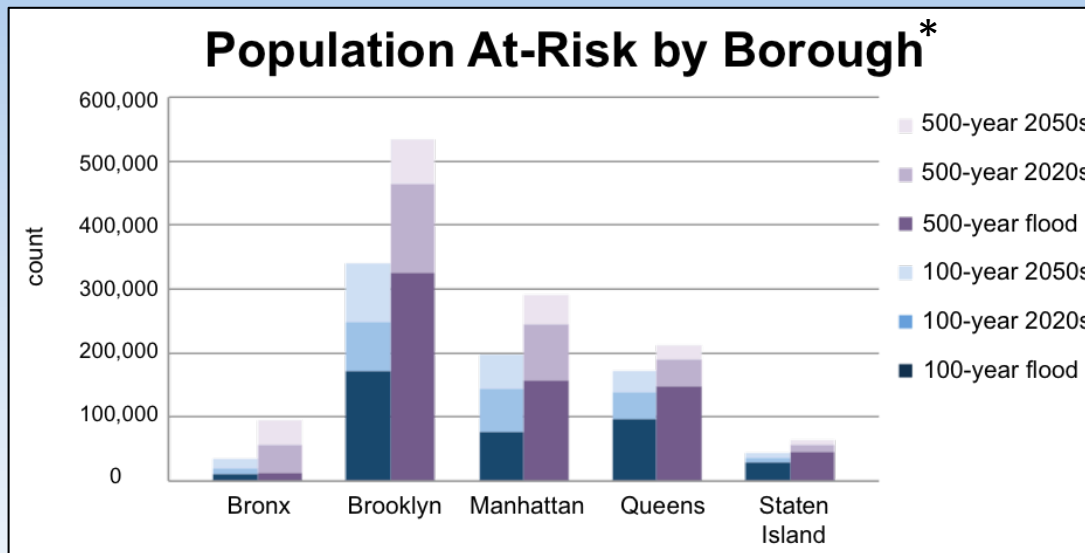
Source: New York City Panel on Climate Change, 2013: Climate Risk Information 2013: Observations, Climate Change Projections, and Maps. C. Rosenzweig and W. Solecki (Editors), NPCC2. Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency, New York, New York.

# New York City land area and population at risk to the current and future 100- and 500-year floods



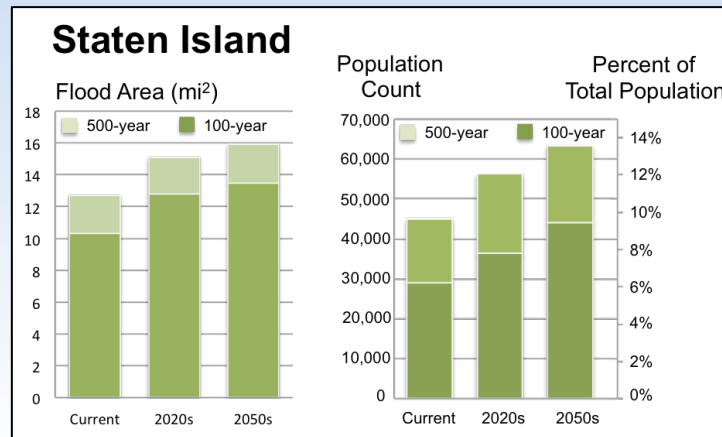
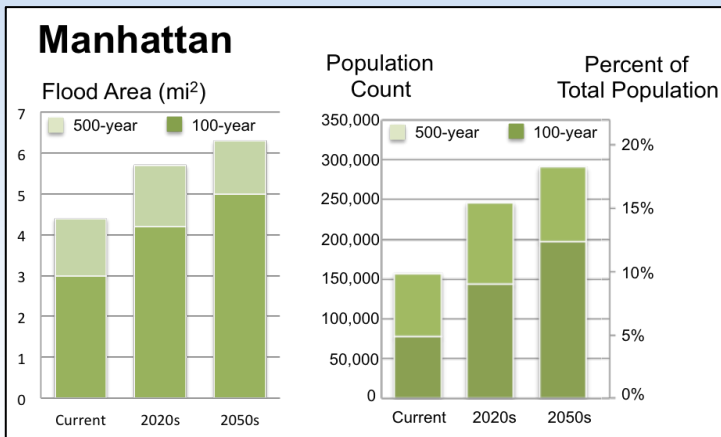
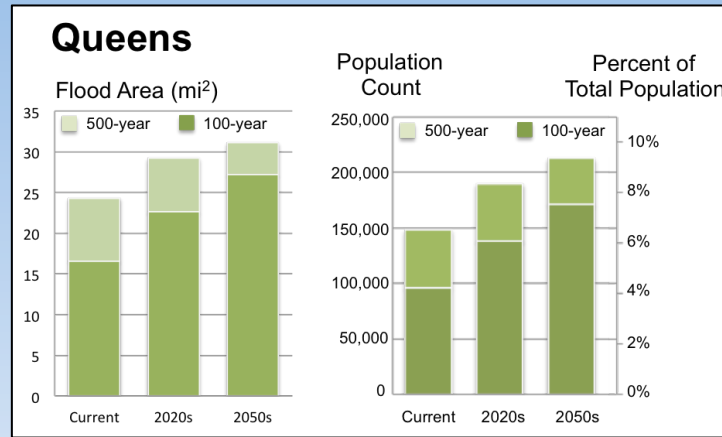
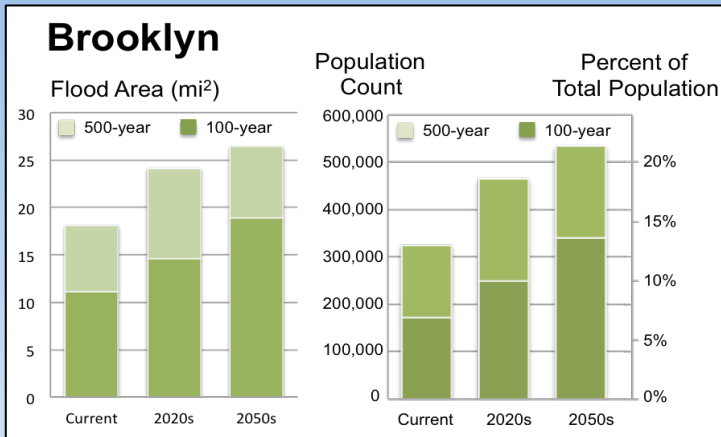
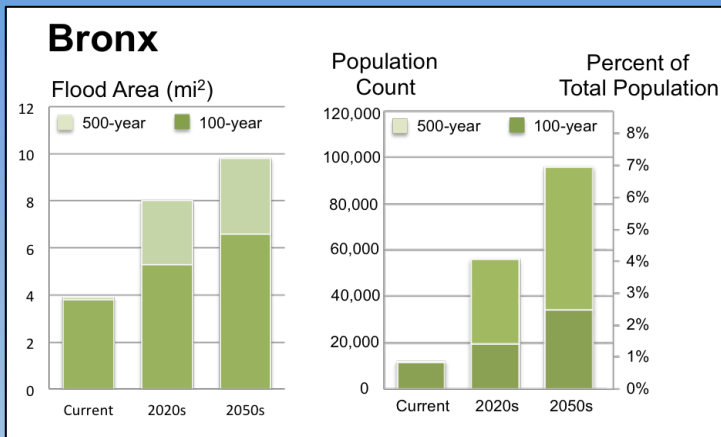
## Citywide Calculations

Flood Scenario	Area (mi <sup>2</sup> )	Population
100 Year Flood, 2013	44.9	385,254
100-Year Flood 2020s	58.8	587,265
100-Year Flood 2050s	71.2	787,596
500-Year Flood, 2013	63.4	687,733
500-Year Flood 2020s	82.1	1,012,045
500-Year Flood 2050s	89.5	1,196,422



\* The U.S. Census Bureau forecasted that the population of New York State will increase by 2.6% by the 2030s. New York City's population is expected to grow to 9.1 million persons by 2030.

# Land area and population at risk to the current and future 100- and 500-year floods by Borough



# Floodwater Exposure Index: Ranking

Lower Vulnerability	<b>Rank 1</b> - Projected 500-Year Flood, 2050s
↑	<b>Rank 2</b> - Projected 500-Year Flood, 2020s
↑	<b>Rank 3</b> - Projected 100-Year Flood, 2050s
↑	<b>Rank 4</b> - Projected 100-Year Flood, 2020s
↑	<b>Rank 5</b> - FEMA Shaded X Zones FEMA Shaded X areas are located between the limits of the current 100-Year and 500-Year floods. High velocity wave action is not a factor.
↑	<b>Rank 6</b> - FEMA AE and AO Zones, BFE < 10 ft FEMA AE Zones are subject to shallow flooding (average depths between 1 and 3 feet) in the current 100-Year flood. High velocity wave action is not a factor. The base flood elevations in these tax lots are less than 10 feet.
↑	<b>Rank 7</b> - FEMA AE Zones, BFE 10 ft FEMA AE Zones are subject to the current 100-Year flood. High velocity wave action is not a factor. The base flood elevations in these tax lots are equal to 10 feet.
↑	<b>Rank 8</b> - FEMA AE Zones, BFE > 10ft FEMA AE Zones are subject to the current 100-Year flood. High velocity wave action is not a factor. The base flood elevations in these tax lots are greater than 10 feet.
↓	<b>Rank 9</b> - FEMA VE Zones FEMA VE Zones are subject to the current 100-Year flood and also exposed to storm-induced breaking waves greater than 3 feet in height (high velocity wave action).
Higher Vulnerability	

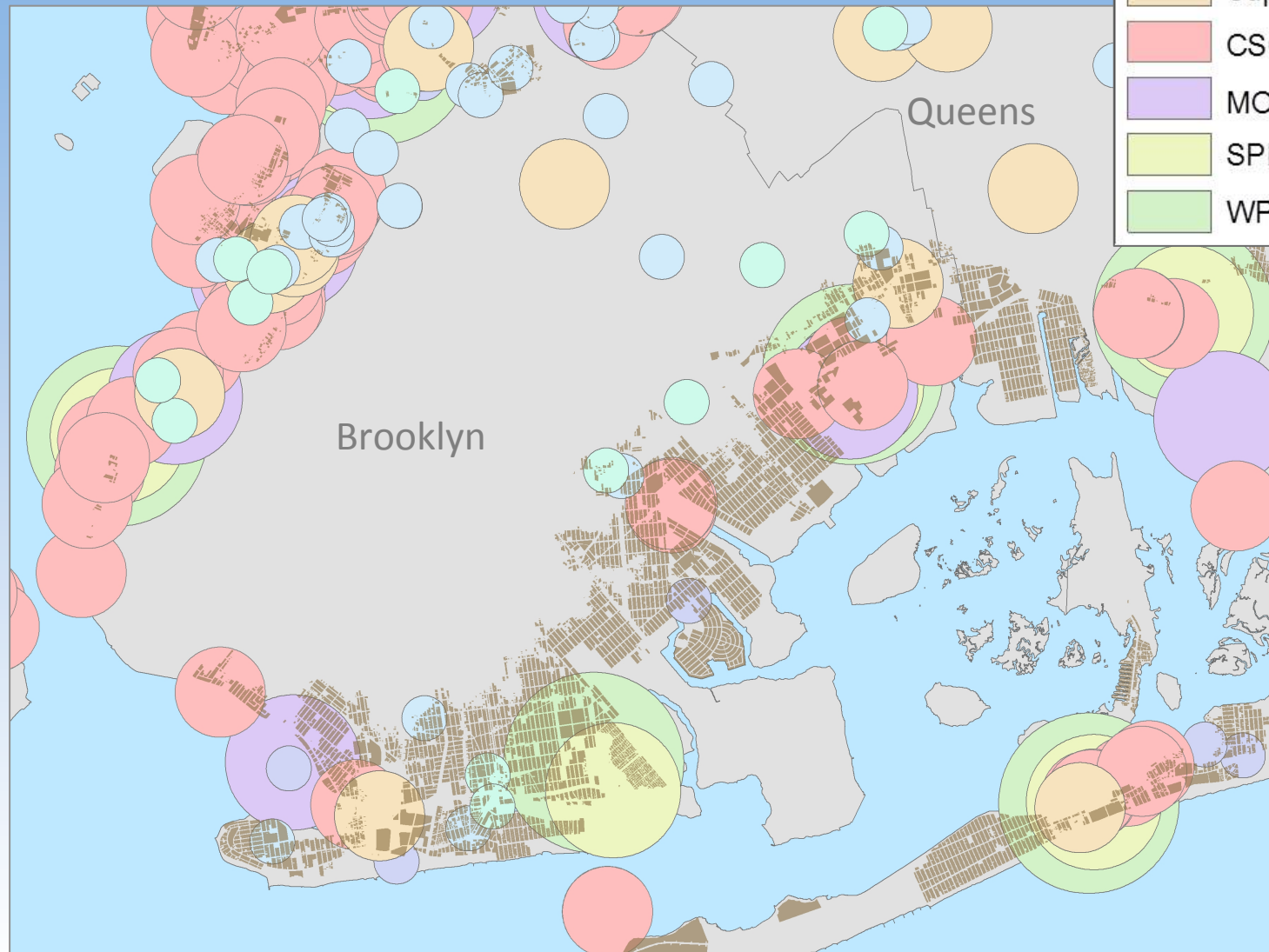
NYC tax lots were ranked based on their potential to experience high storm surge elevations and high velocity wave action. The higher the rank the greater the exposure to floodwaters and the greater the physical vulnerability of the residential population.

# Social Vulnerability Index: Indicators

Social Vulnerability Variables	Source	Unit	Description
<b>Domain A: Socioeconomic Status</b>			
1. Percent persons below <b>poverty</b>	ACS 5-Yr: 2006-2010	Block Group	Difficulty absorbing and recovering; lack of insurance, social safety nets, and entitlements programs.
2. Percent civilian <b>unemployed</b>	ACS 5-Yr: 2006-2010	Census Tract	Less financial resources, slower recovery.
3. Per Capita <b>Income</b> in the past 12 months	ACS 5-Yr: 2006-2010	Census Tract	Less financial resources, slower recovery.
4. Percent adults with <b>no high school diploma</b>	ACS 5-Yr: 2006-2010	Block Group	Lower education affects the ability to access and understand warning and recovery information.
<b>Domain B: Household structure and disability</b>			
5. Percent persons <b>65 years</b> of age or older	2010 Census SF1	Block Group	Mobility constraints/concerns; lack of resilience.
6. Percent persons <b>10 years</b> of age or younger	2010 Census SF1	Block Group	Movement out of harm's way. Time and money lost when daycare facilities are affected.
7. Percent male or female <b>single householder</b> with children under 18 years	ACS 5-Yr: 2006-2010	Census Tract	Limited finances to outsource child care. Affects resilience to and recovery from hazards.
<b>Domain C: Minority Status and Language</b>			
8. Percent <b>Minority</b>	2010 Census SF1	Block Group	Language and cultural barriers; Residences in high hazard areas; Access to post disaster funding.
9. Percent persons 5 years of age or older who <b>speak English</b> less than well	ACS 5-Yr: 2006-2010	Block Group	Language and cultural barriers; Residences in high hazard areas; Access to post disaster funding.
<b>Domain D: Group Housing and Transportation</b>			
10. Percent <b>multi-unit structure</b>	ACS 5-Yr: 2006-2010	Block Group	High density structures can complicate evacuation.
11. Percent <b>Crowded</b> Households	ACS 5-Yr: 2006-2010	Block Group	May lack shelter options when lodging becomes uninhabitable or too costly to afford.
12. Percent households without a <b>vehicle</b>	ACS 5-Yr: 2006-2010	Block Group	Ability to move out of harms way.
13. Percent persons in <b>group quarters</b>	2010 Census SF1	Block Group	Can be difficult to identify and measure; due to community invisibility can be ignored during recovery.



# Floodwater Contaminants Index: Potential Point Sources of Hazardous Materials



# Critical Facilities Index

## GROUP 1 - PHYSICAL ASSISTANCE

### \* Hospitals and Residential Health Centers

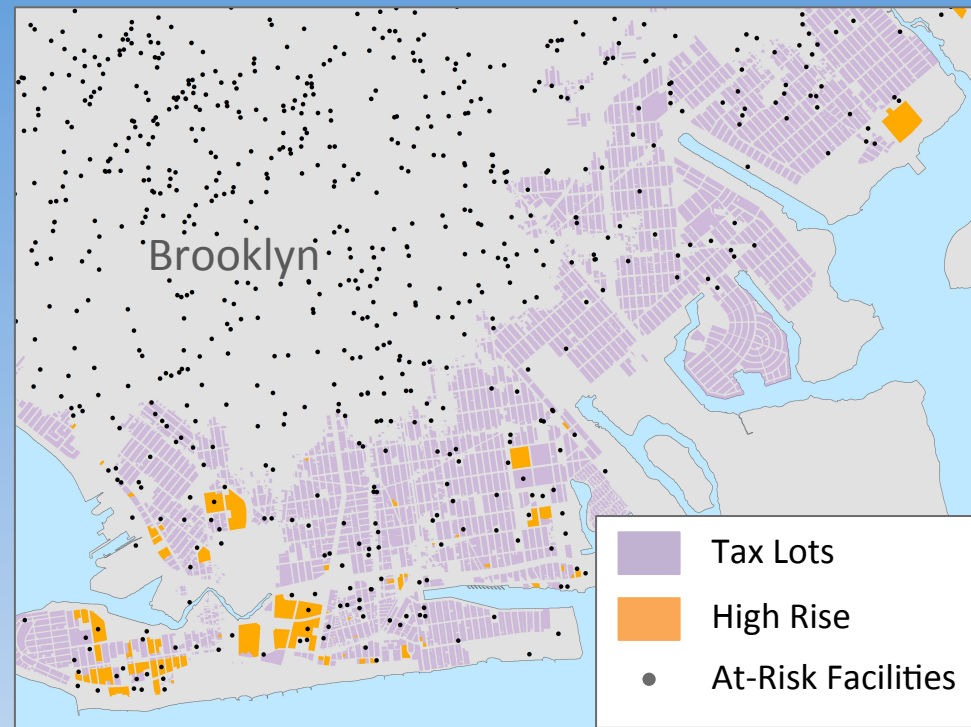
Nursing Home, Hospital, Hospice

### \* Residential Disability Centers

Community and Supervised Individual Residence

### \* High Rise Buildings

Multi-family elevator buildings > 7 stories high.



## GROUP 2 – COORDINATED EVACUATION

### \* Correctional Facilities

Federal, State, and City Correctional Facilities

### \* Residential Mental Health Facilities

Hospital and Psychiatric Center Care

### \* Residential Chemical Dependency Centers

Detoxification and Withdrawal Centers

### \* Group Homes

Residential Group Homes for Children and Adults

### \* Day Care Centers and Schools

Head Start, Public, Private, Charter, Pre-K, K-12

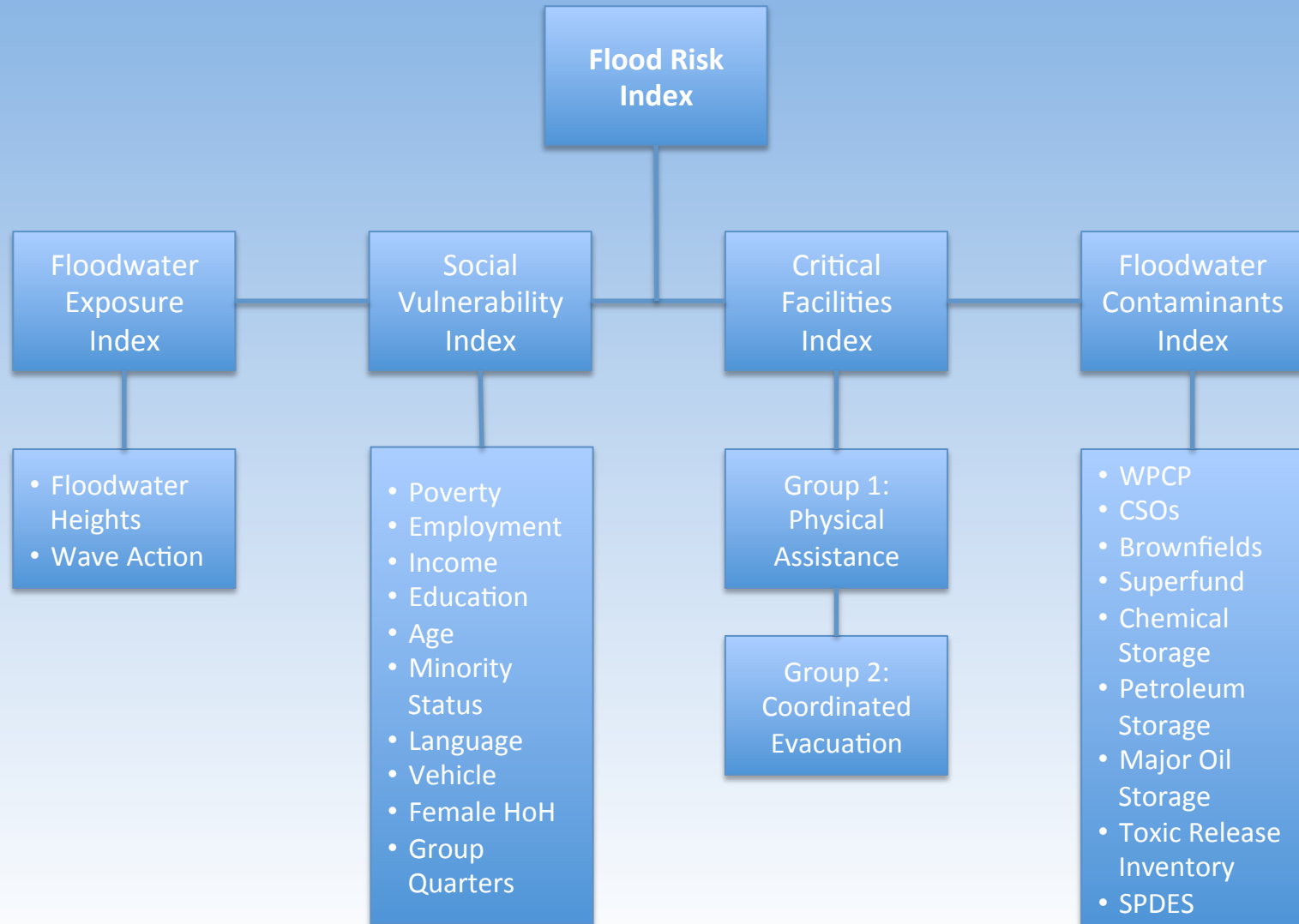
### \* Temporary/Transitional Housing Residents

Shelter for Singles and Family Homeless Facilities

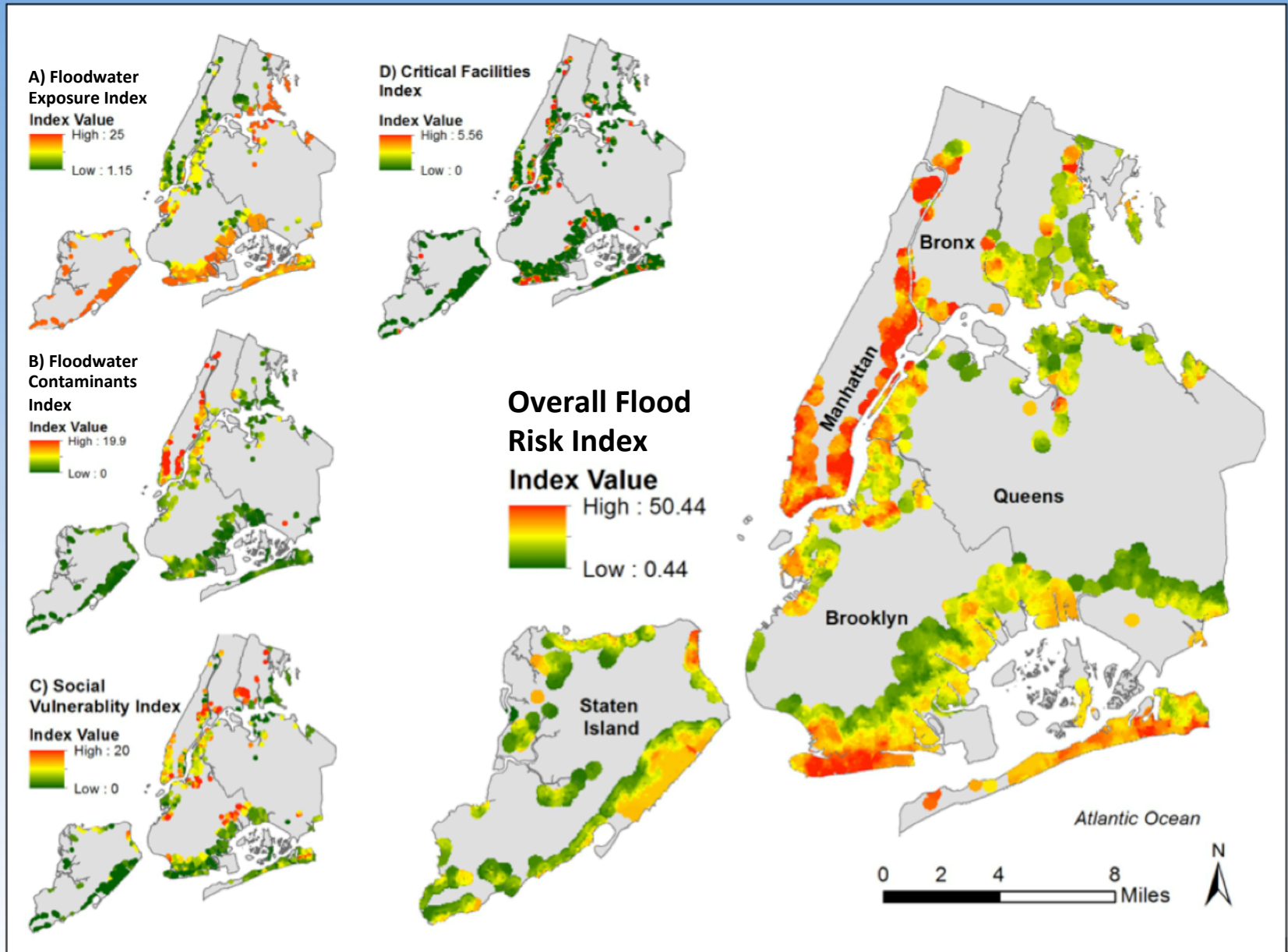
# Flood Risk Index

$$\text{Risk} = \text{Hazard} \times \text{Elements at Risk} \times \text{Vulnerability}$$

Granger, 2003



# Four component indices and the Overall Flood Risk Index for New York City for the 500-year flood in the 2050s



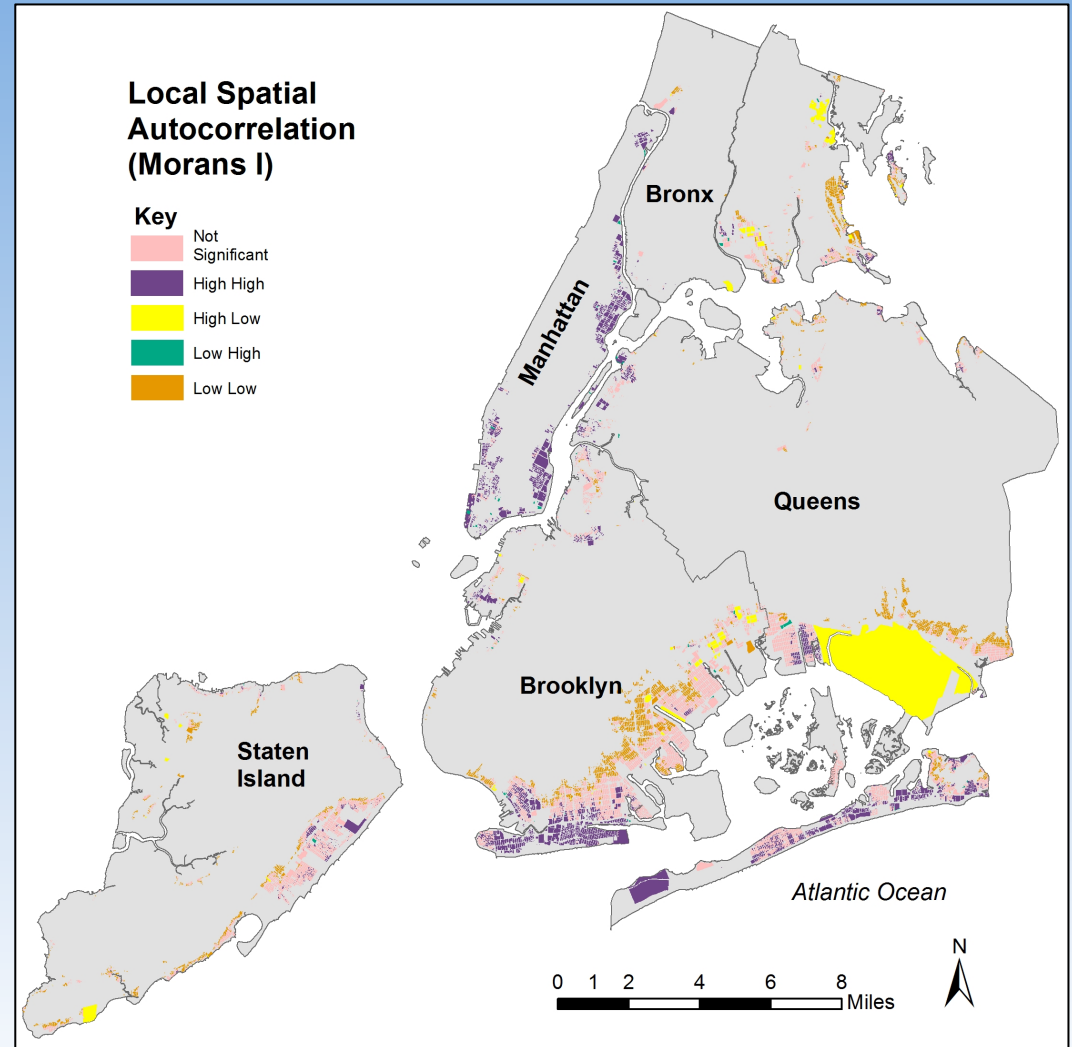
# Local Spatial Autocorrelation – Moran's I

## Concentrated Clusters

- High values surrounded by high values
- Low values surrounded by low values

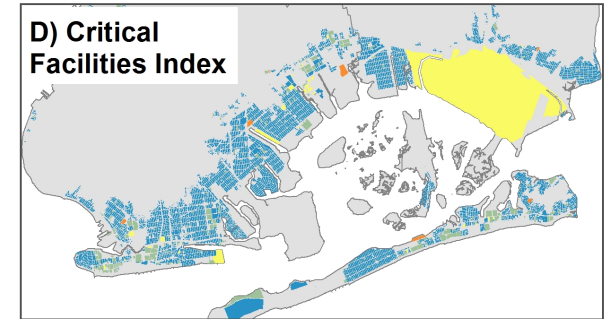
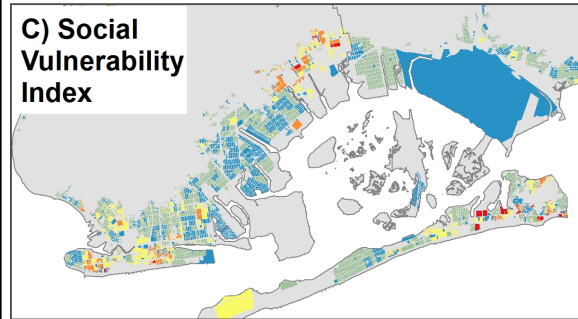
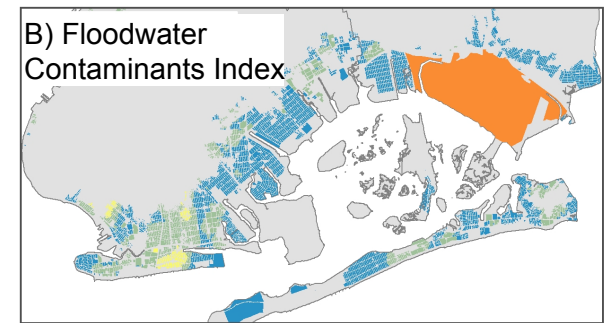
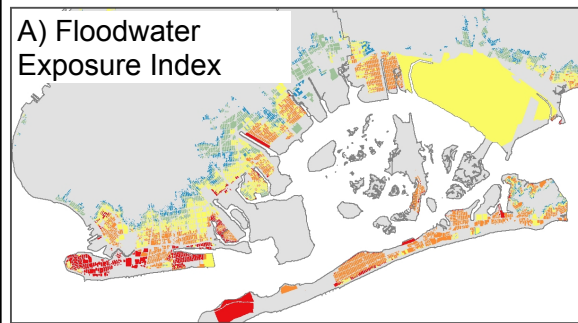
## Anomalous Areas

- High values surrounded by low values
- Low values surrounded by high values

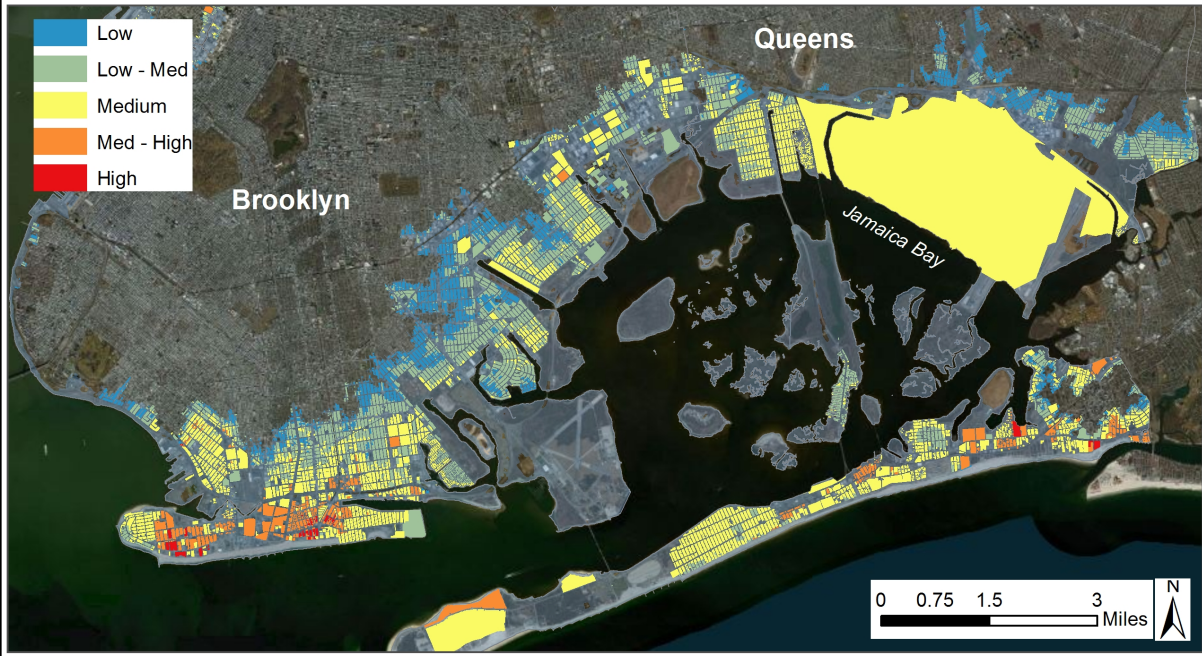


# South Brooklyn and Jamaica Bay, Queens

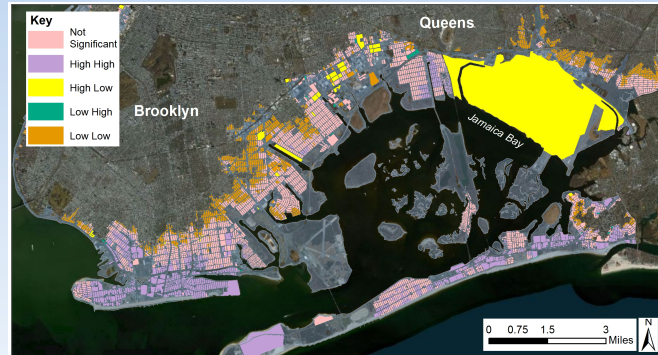
Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s



## Overall Flood Risk Index



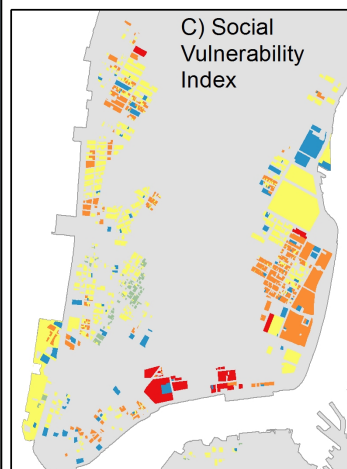
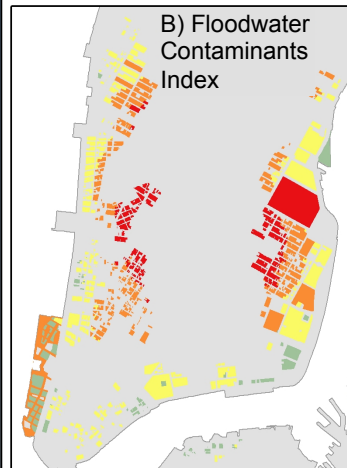
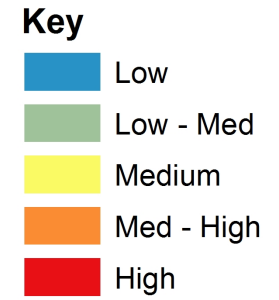
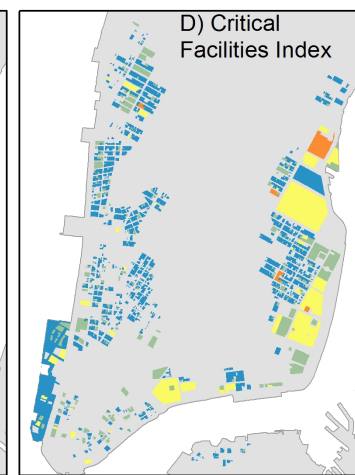
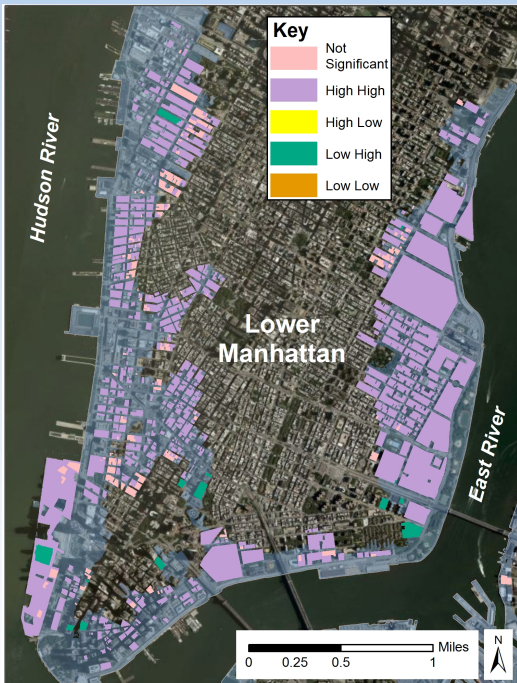
## Local Spatial Autocorrelation



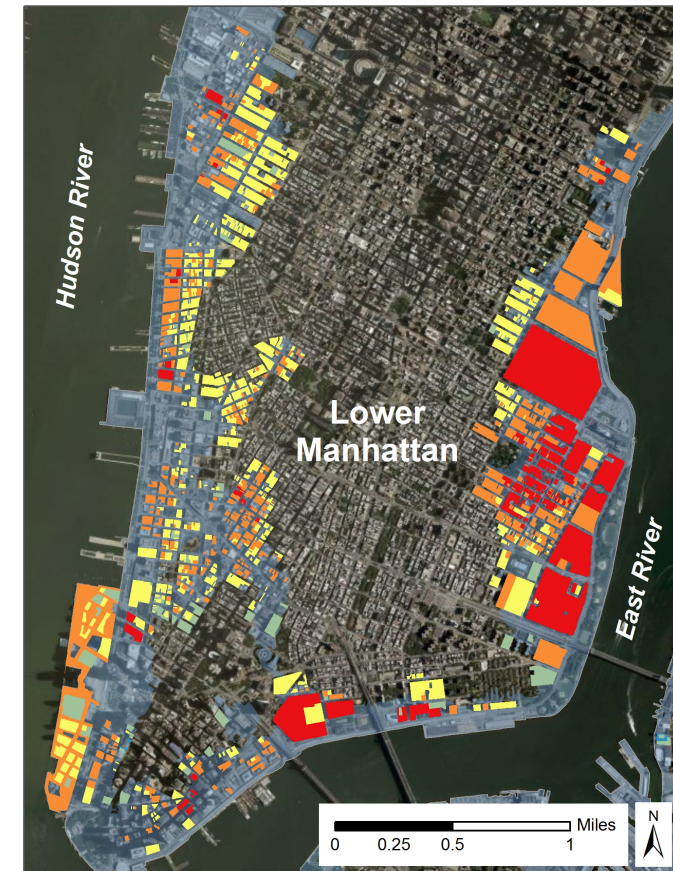
# Lower Manhattan

Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s

## Local Spatial Autocorrelation



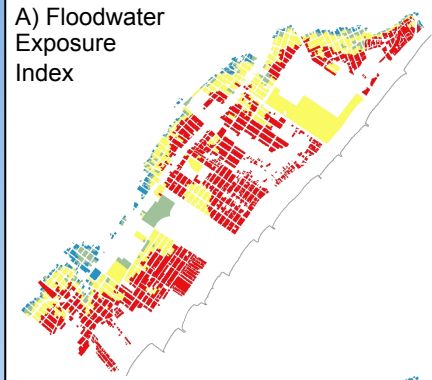
## Overall Flood Risk Index



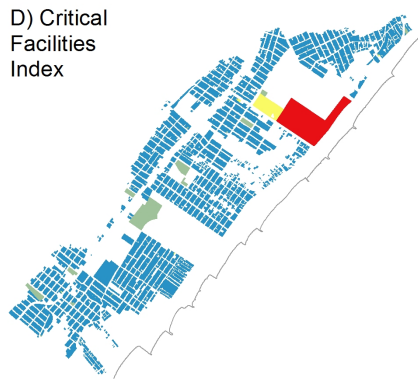
# Eastern Staten Island

Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s

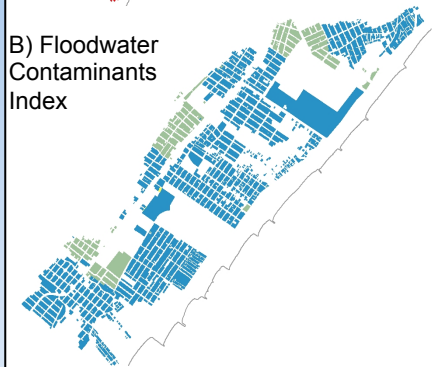
A) Floodwater Exposure Index



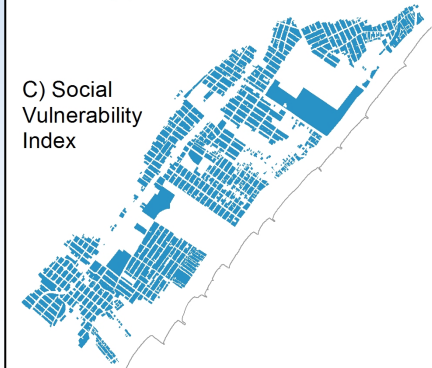
D) Critical Facilities Index



B) Floodwater Contaminants Index



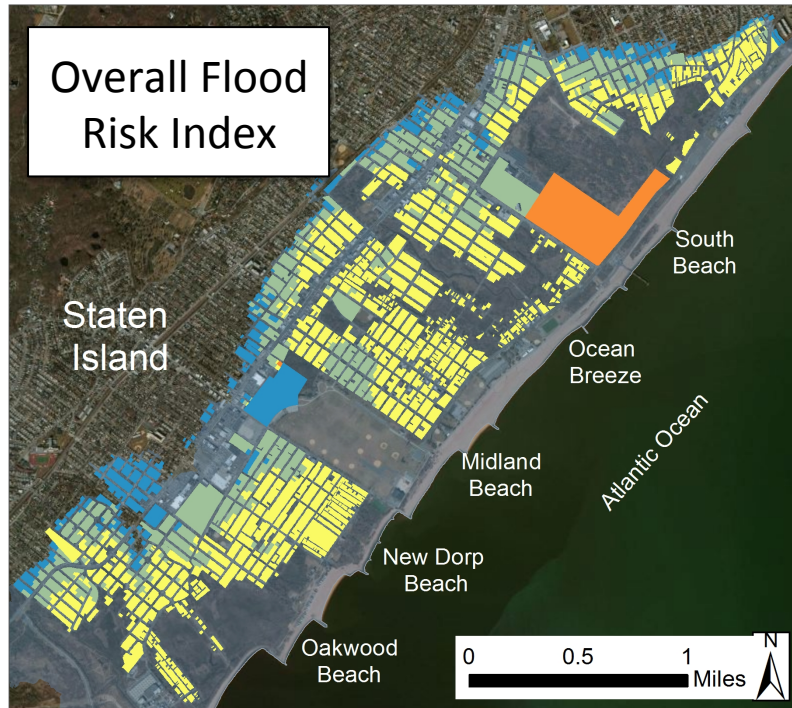
C) Social Vulnerability Index



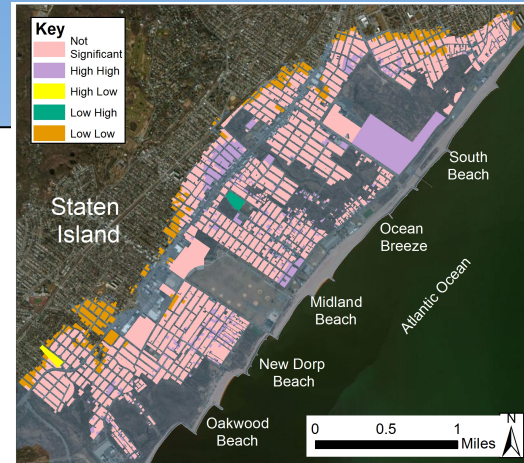
**Key**

- Low
- Low - Med
- Medium
- Med - High
- High

**Overall Flood Risk Index**



Local Spatial Autocorrelation

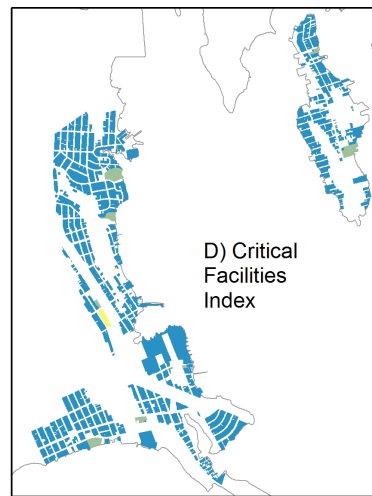
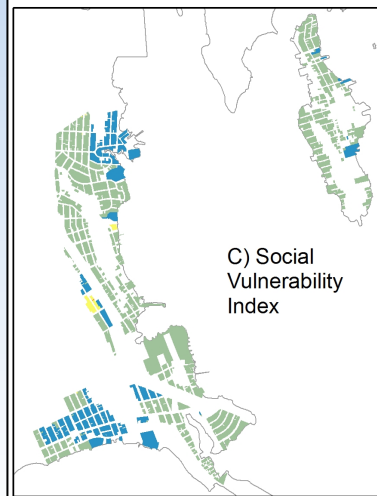
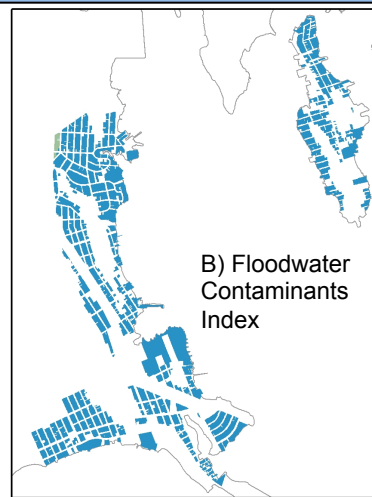
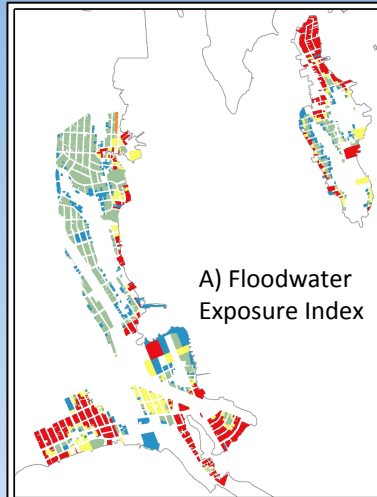
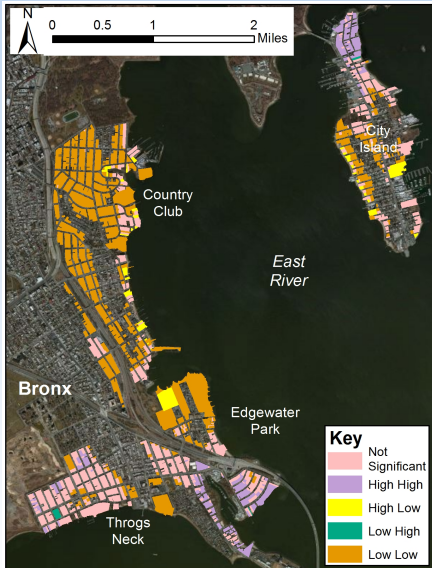




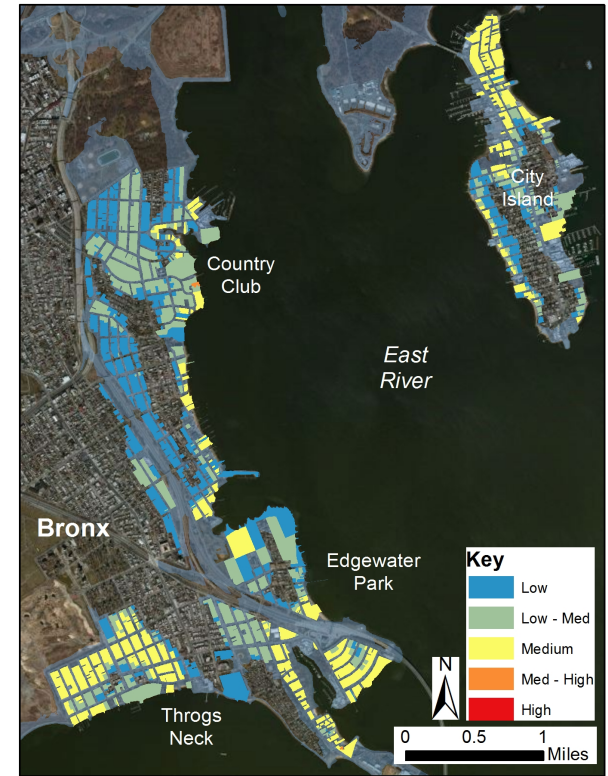
# Eastern Bronx, City Island

Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s

## Local Spatial Autocorrelation

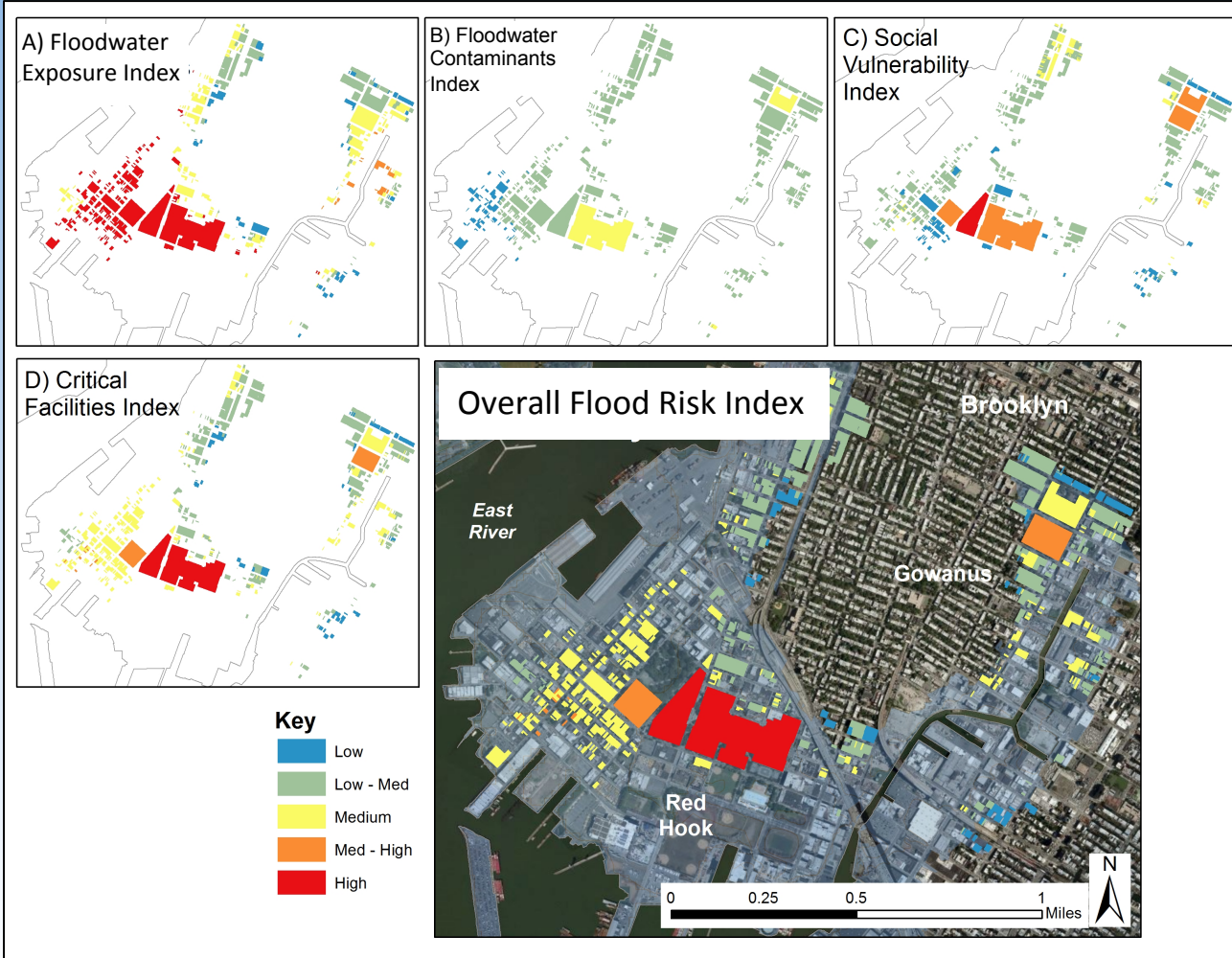


## Overall Flood Risk Index

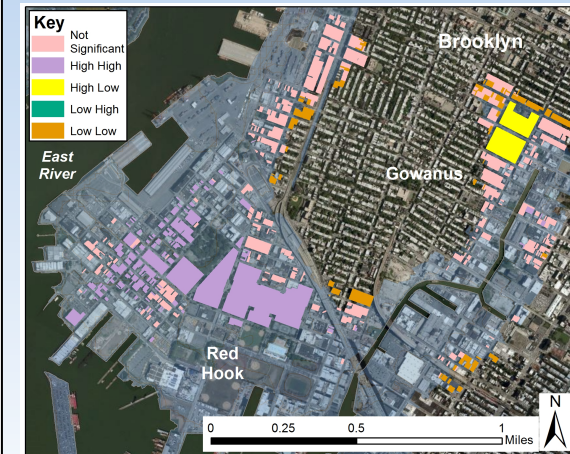


# Red Hook, Brooklyn

Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s



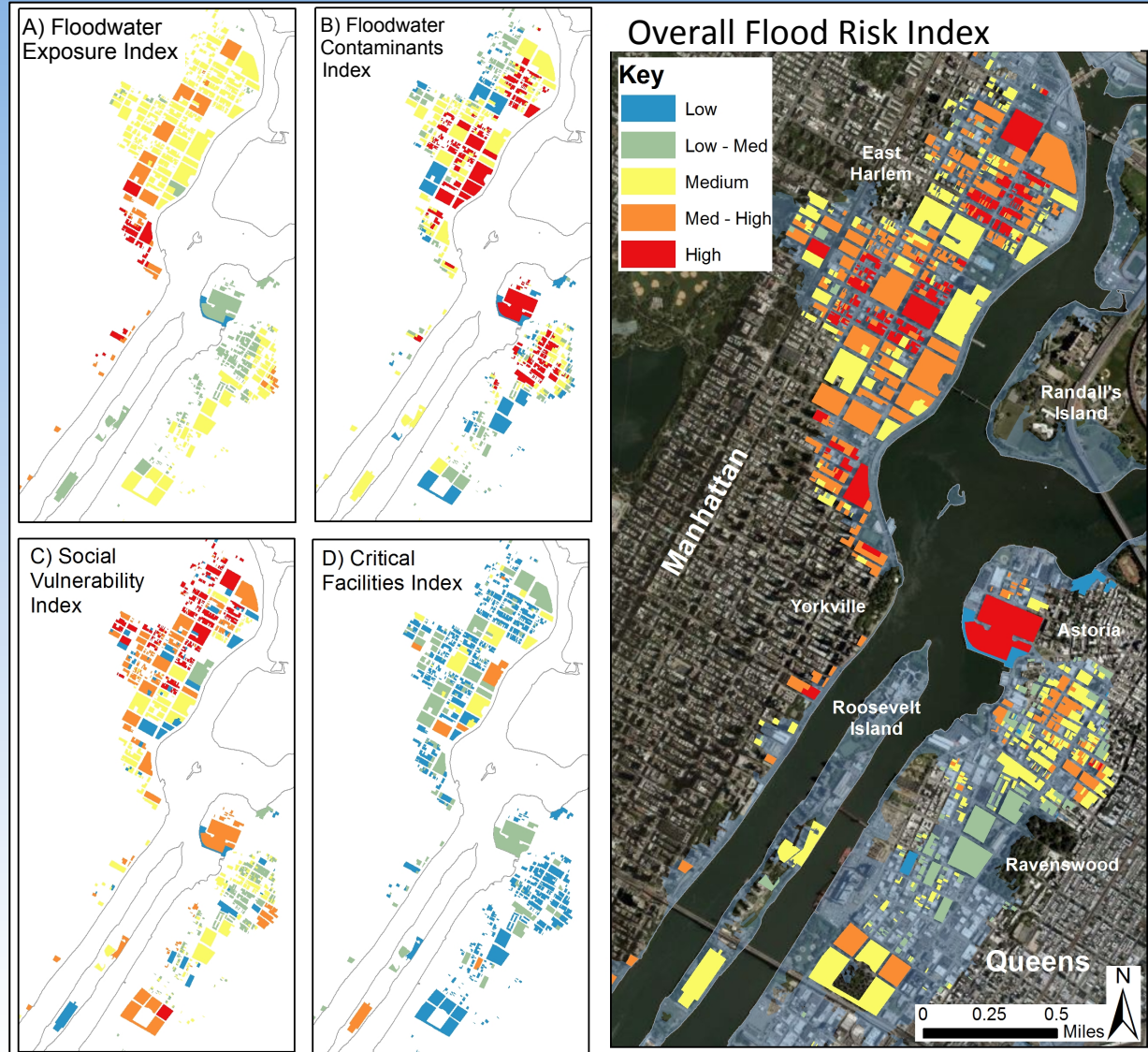
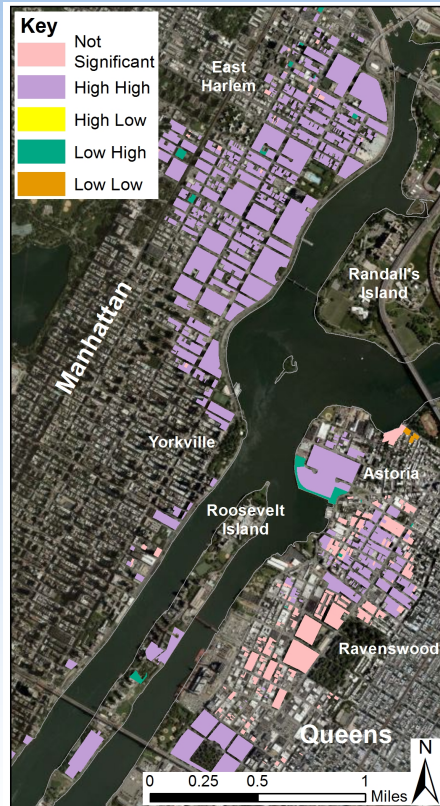
## Local Spatial Autocorrelation



# East Harlem, Roosevelt Island, and Queens

Four component indices and the Overall Flood Risk Index for the 500-year flood in the 2050s

## Local Spatial Autocorrelation



# Conclusions

- Future sea-level rise will increase the risk of the 100- and 500-year floods, particularly under scenarios of accelerated SLR and population growth and distribution in the coastal and near-coastal zones.
- Due to sea-level rise, more communities are becoming vulnerable, existing communities are becoming more vulnerable and both are becoming less disaster resilient.
- An increase in future flood extent does not always exact the same increase in population at-risk to flooding.
- In some areas, adding sea-level rise causes the flood extent for the current 500-year flood to be smaller than the future 100-year flood.
- An Overall Flood Risk Index will identify and rank the populations physically and socially at-risk due to physical exposure to floodwater and waves, floodwater contamination, social vulnerability, and compromised critical facilities.
- Understanding the spatial distribution of the components of risk can be used to develop targeted hazard mitigation and climate change adaptation strategies, inform policies and planning, and allow for better emergency preparedness and response.

# Acknowledgements

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