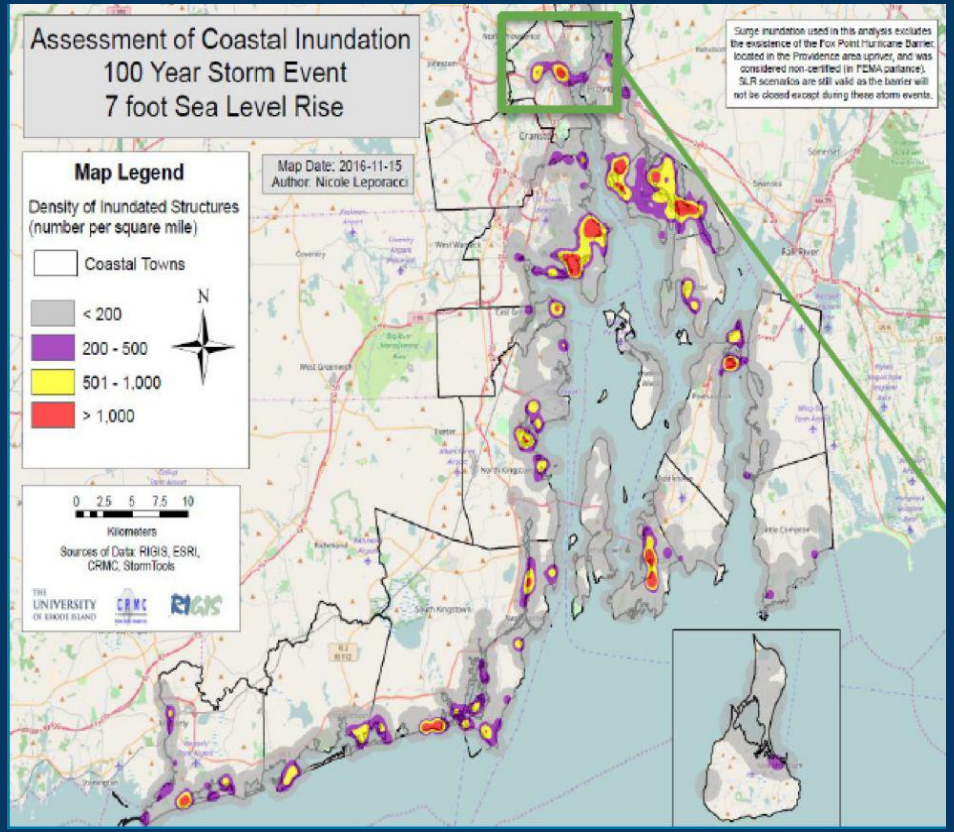
Economic Climate Vulnerability Assessment for Providence

Project Summary: Providence, Rhode Island

- Low lying city and structurally dense
- Coastal flooding has caused intense flooding and economic issues
  - Hurricane of 1938
  - Hurricane Carol of 1954
- Fox Point Hurricane Barrier
  - Prevents flooding
  - Does not account for sea level rise



Source: OCE495

Rising sea levels will cause rising concerns

Extreme Weather

+

Sea Level Rise

=

Flooding

Providence's vulnerability goes beyond the shoreline

Residents

Businesses

Port of Providence

Public Health

Public Utilities/
Transportation

Electrical Infrastructure

At-Risk Populations

- Older Adults
- Children (Specifically school-aged)
- People with Low-to no-Income
- People with Limited English Proficiency
- People of Color

Older Adults

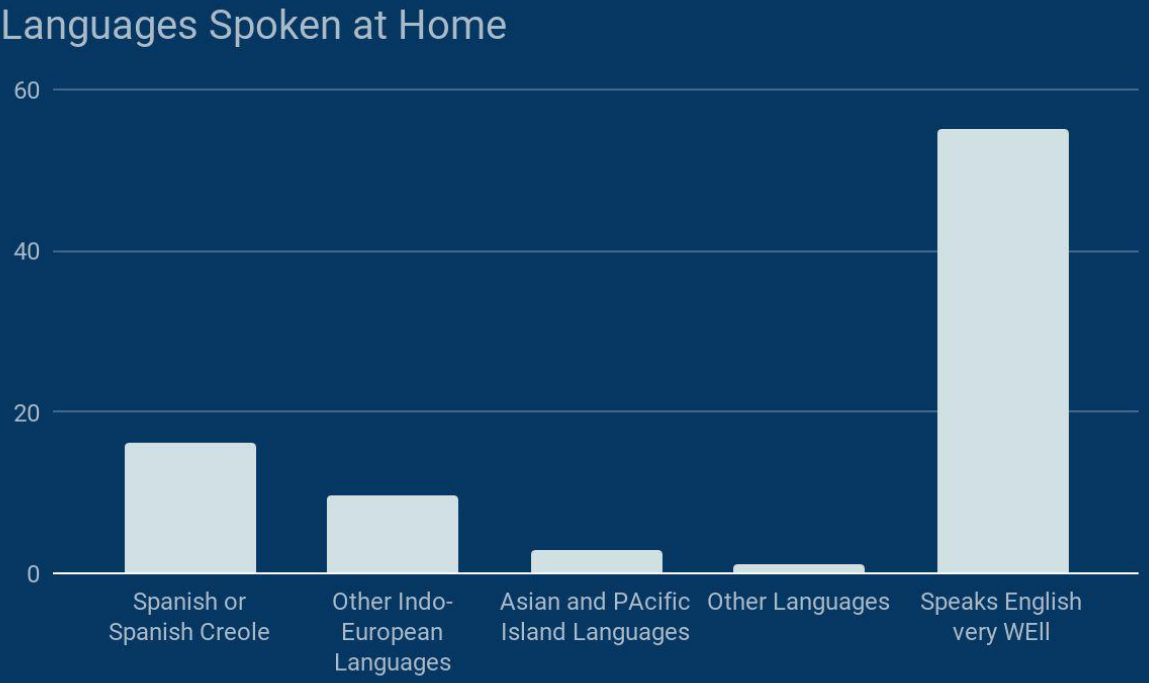
- Need different evacuation plans; may not have access to as much technology
- About 10% over Age 70
  - That's 61,000 people

Providence Public Schools

- 38 Schools
  - 21 Elementary
  - 7 Middle Schools
  - 10 High Schools
- 23,983 Students

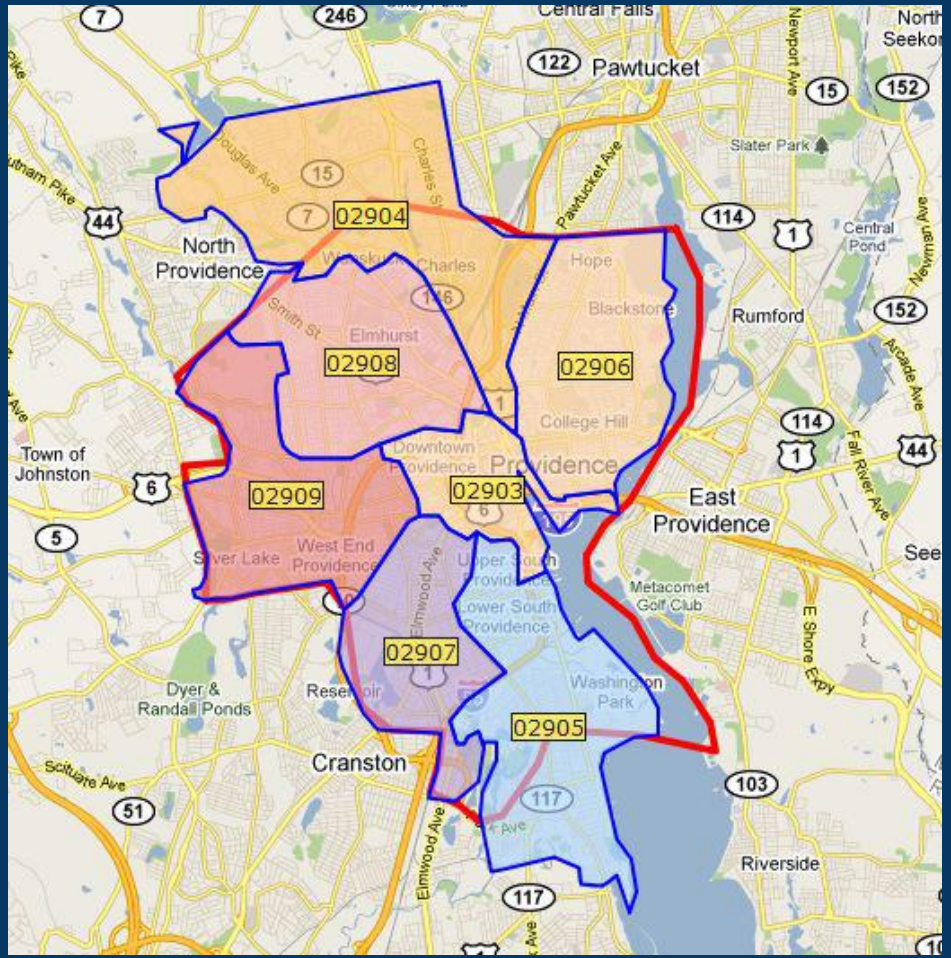
Limited English Proficiency

- Important for the city to have information accessible in other languages
- 29% of Providence speaks Spanish at home

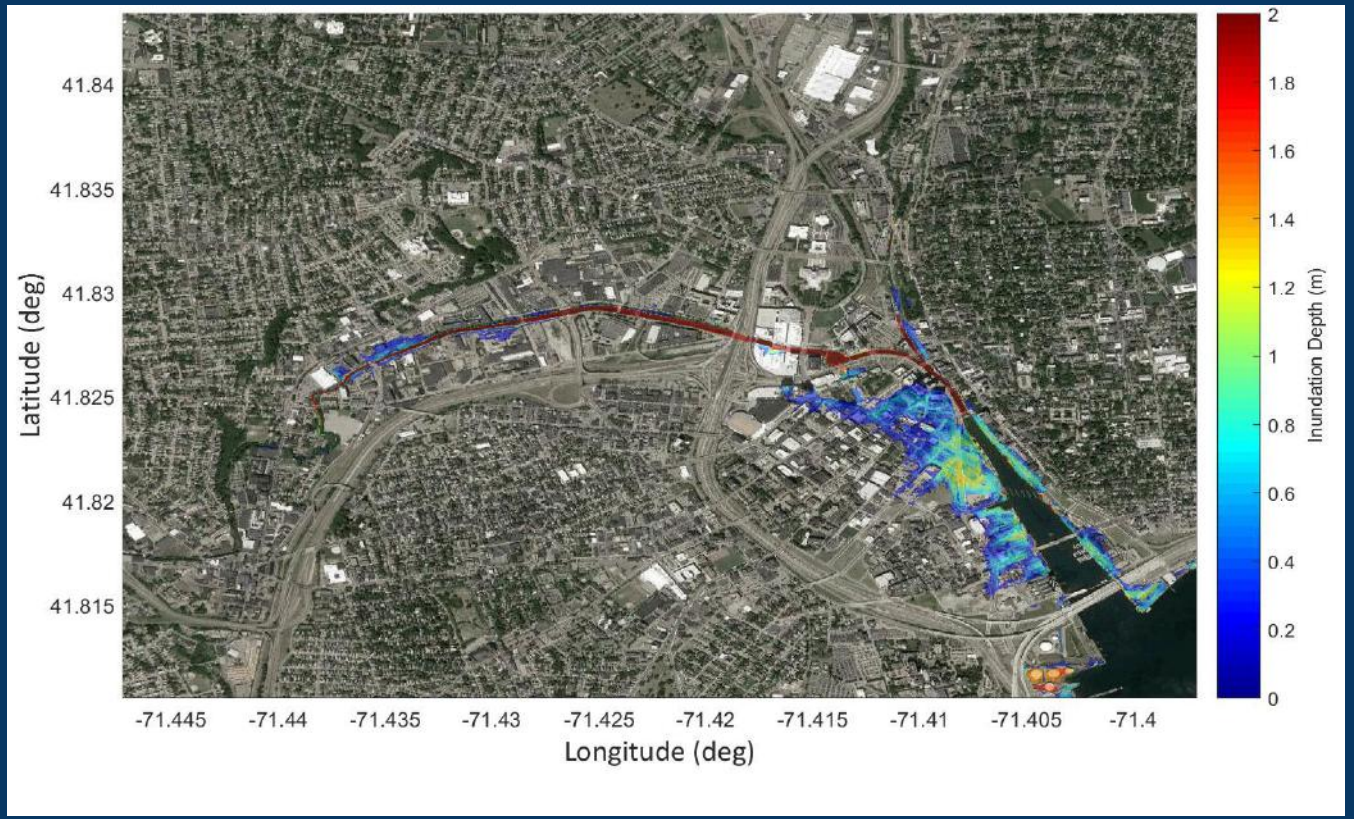


Income and Employment

46% of households make under $25,000 annually

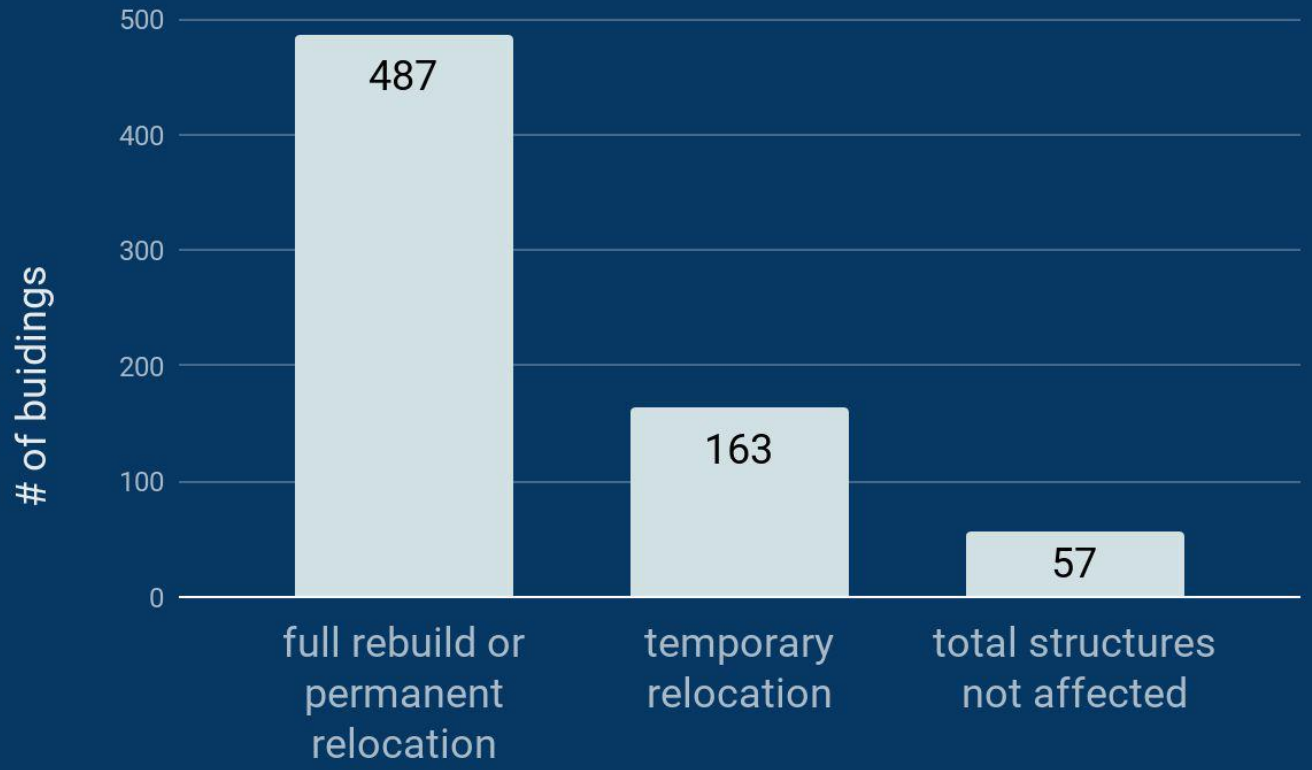


What About Business?

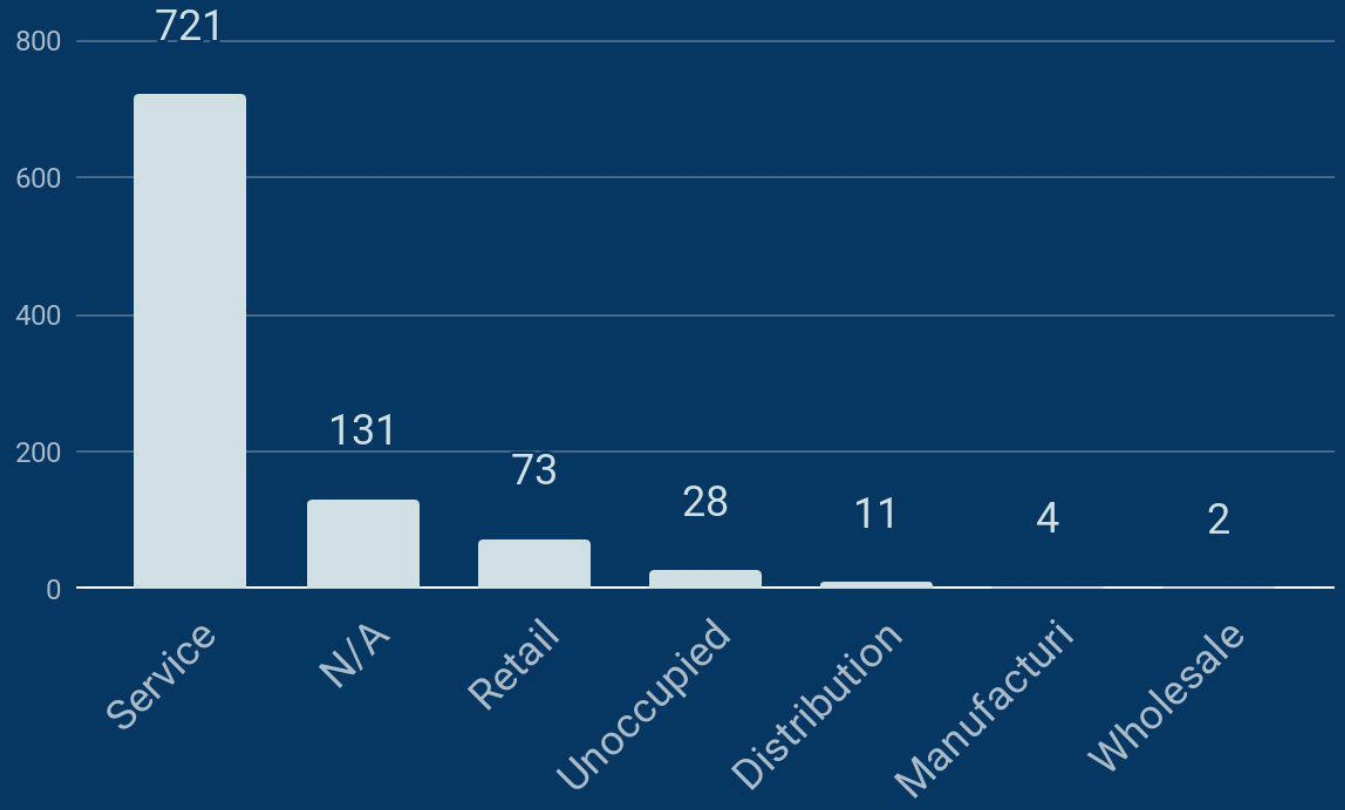


Most commercial buildings need temporary or permanent relocation

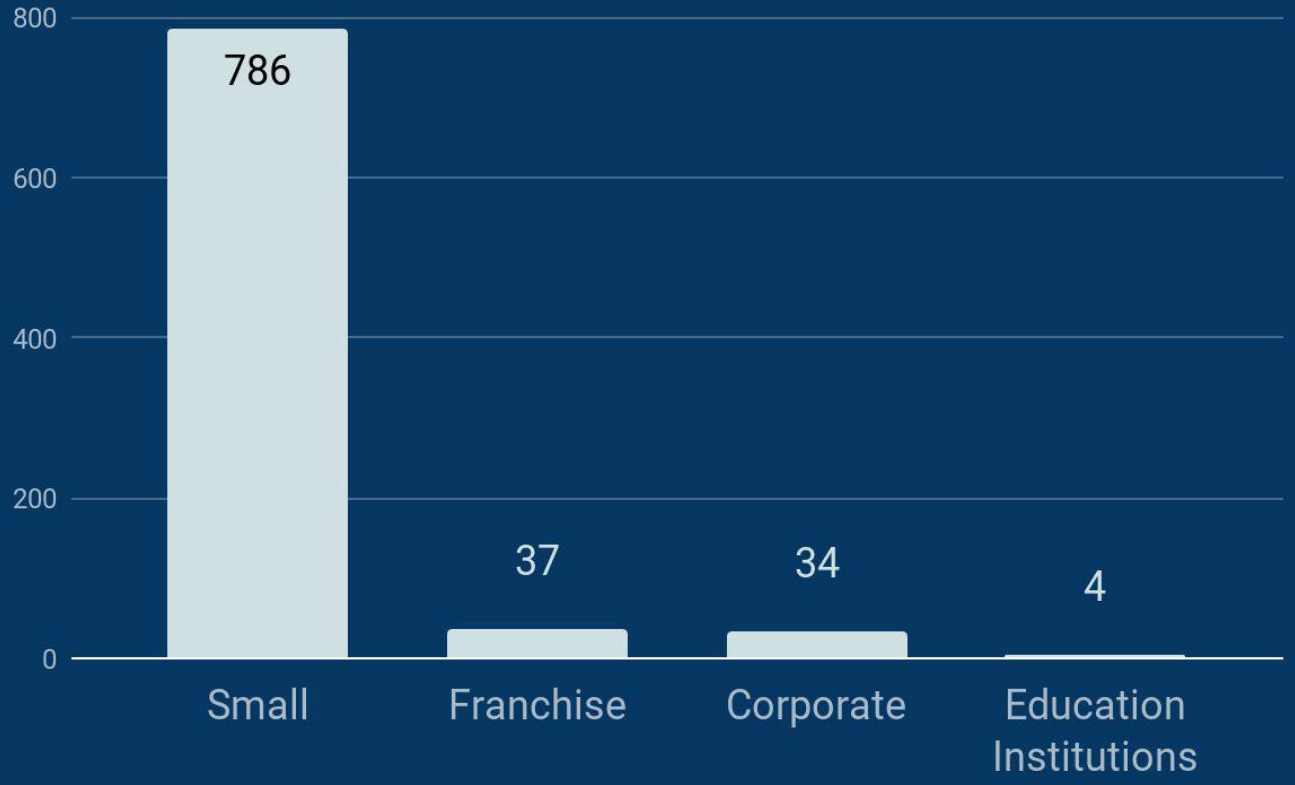
n=707



The service sector is the most affected type of businesses



The majority affected are small businesses



Survival

Or

Residential Concerns

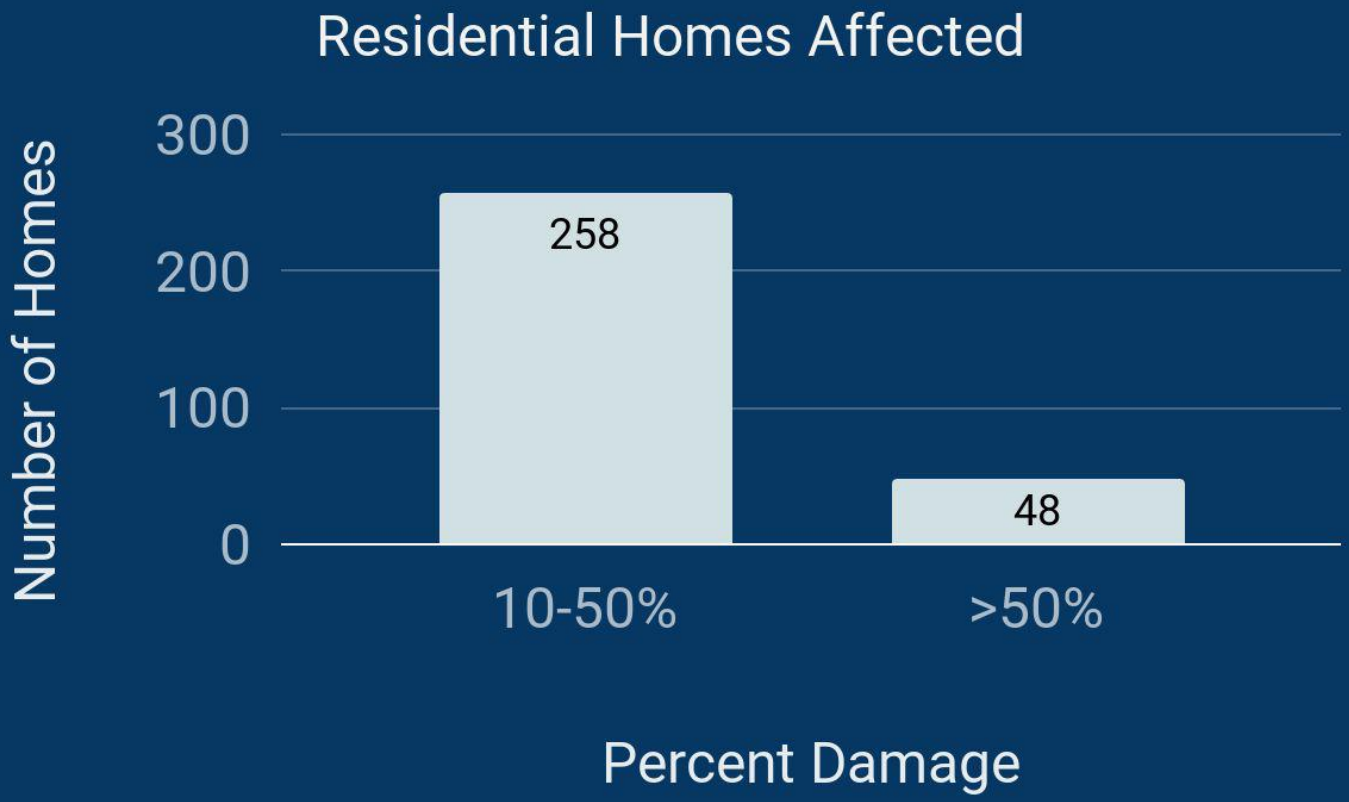
- **Displacement costs depend on:**
  - Relocating
  - Resuming activity
  - Amount of structural damage done to a building
- **Structural damage includes damage to:**
  - Foundation
  - Flooring
  - Walls
  - Etc.

Residential Concerns

- **Severity of structural damage:**
  - <10% of damage to structure household will not be displaced.
  - 10-50% of damage to building household will be displaced during renovations.
  - >50% of damage to building needs to be completely reconstructed/ relocated.

- **Displacement time:**
  - Renovations- variable
  - Reconstruction- 24 months
  - Relocation- 12 months

Residential Concerns



Port of Providence

- Economic hub throughout region
- 230 acres
- 2400 jobs attributed to port activities
- No barrier protection

Fig.1. Port of Providence

ProvPort

- 115 acre campus
- Deep water port
- Port Operator and Manager: Waterson Terminal Services LLC.

Fig.1. ProvPort campus

Port of Providence should expect

Fig.1. Bathtub inundation of Port of Providence

- 19 ft of inundation
- First level flooding of the Port infrastructure
- Hurricane Sandy Baseline

Smythe, T. C., Ph.D. (2013, May 31). Assessing the Impacts of Hurricane Sandy on the Port of New York and New Jersey's Maritime Responders and Response Infrastructure. Retrieved from https://rucore.libraries.rutgers.edu/rutgers-lib/43635/PDF/1/play/

Likely and possibly damages

- Direct, Indirect, and Intangible damages
- Structural damage is between 47.3-50%

Fig.2. Oil spill in harbor

U. (2006, March 7). DEPTH-DAMAGE RELATIONSHIPS FOR STRUCTURES, CONTENTS, AND VEHICLES AND CONTENT-TO-STRUCTURE VALUE RATIOS (CSVR) IN SUPPORT OF THE DONALDSONVILLE TO THE GULF, LOUISIANA, FEASIBILITY STUDY. Retrieved from http://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf

Costs incurred

- Direct damage: $6,285,100 (new construction) or $2,305,600 (repair)
- Indirect costs: $1,544,700
- Intangible consequences

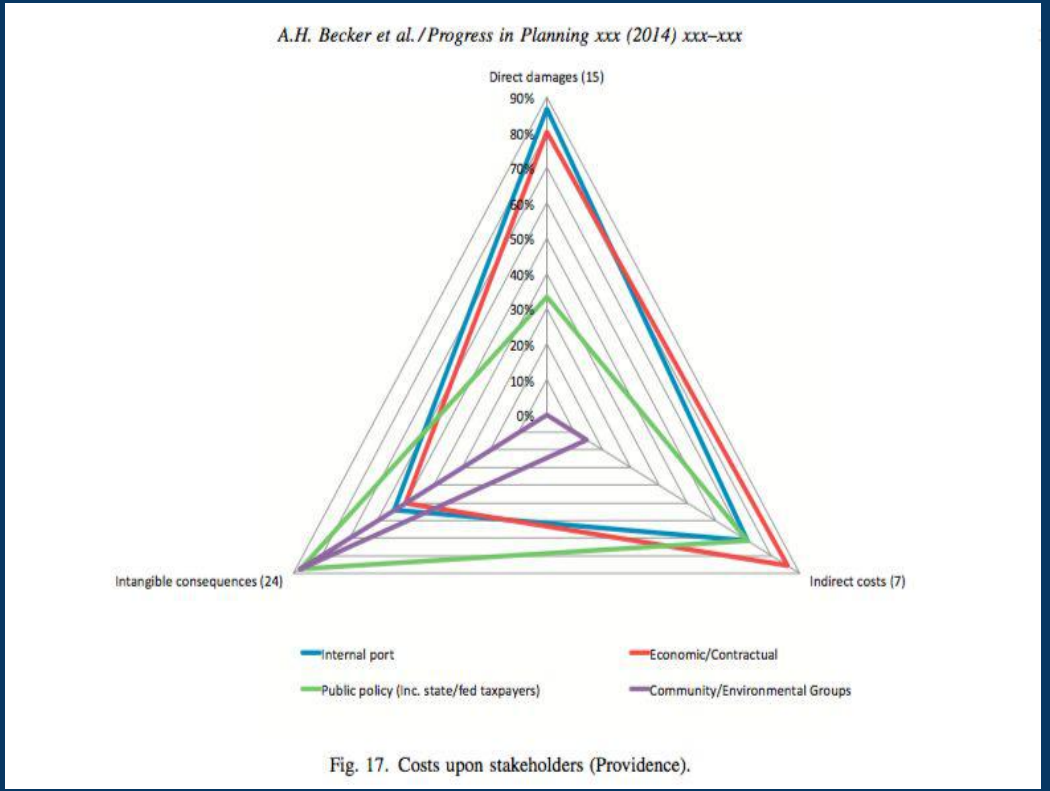


Fig.1. Costs upon shareholders (Providence)

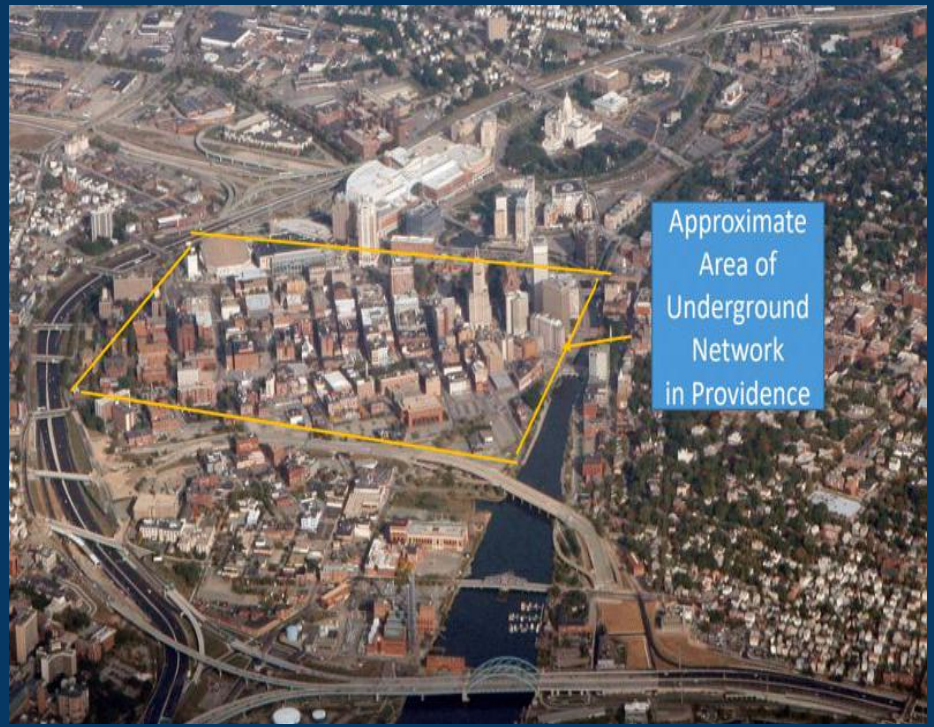
U. (2006, March 7). DEPTH-DAMAGE RELATIONSHIPS FOR STRUCTURES, CONTENTS, AND VEHICLES AND CONTENT-TO-STRUCTURE VALUE RATIOS (CSVR) IN SUPPORT OF THE DONALDSONVILLE TO THE GULF, LOUISIANA, FEASIBILITY STUDY. Retrieved from http://www.mvn.usace.army.mil/Portals/56/docs/PD/Donaldsv-Gulf.pdf

Electrical Infrastructure in Providence is at risk due to climate hazards

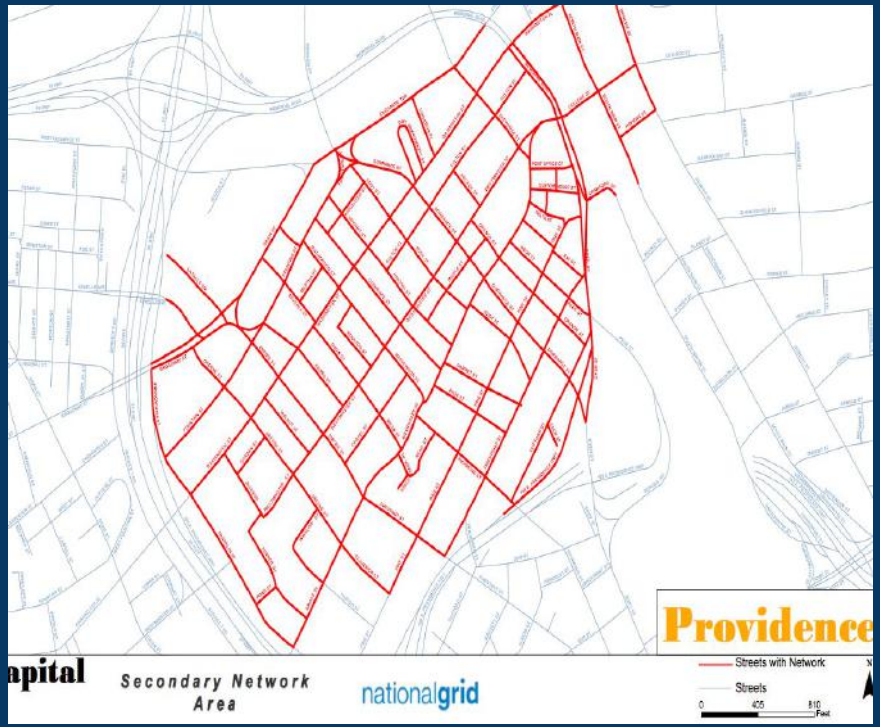
In the future:

- More intense storm events
- Stronger winds
- Increased precipitation
- Rise in temperature

Downtown Providence has a distribution secondary network



(URI Ocean Engineering)



(National Grid)

Overhead vs. Underground electrical systems

Overhead:

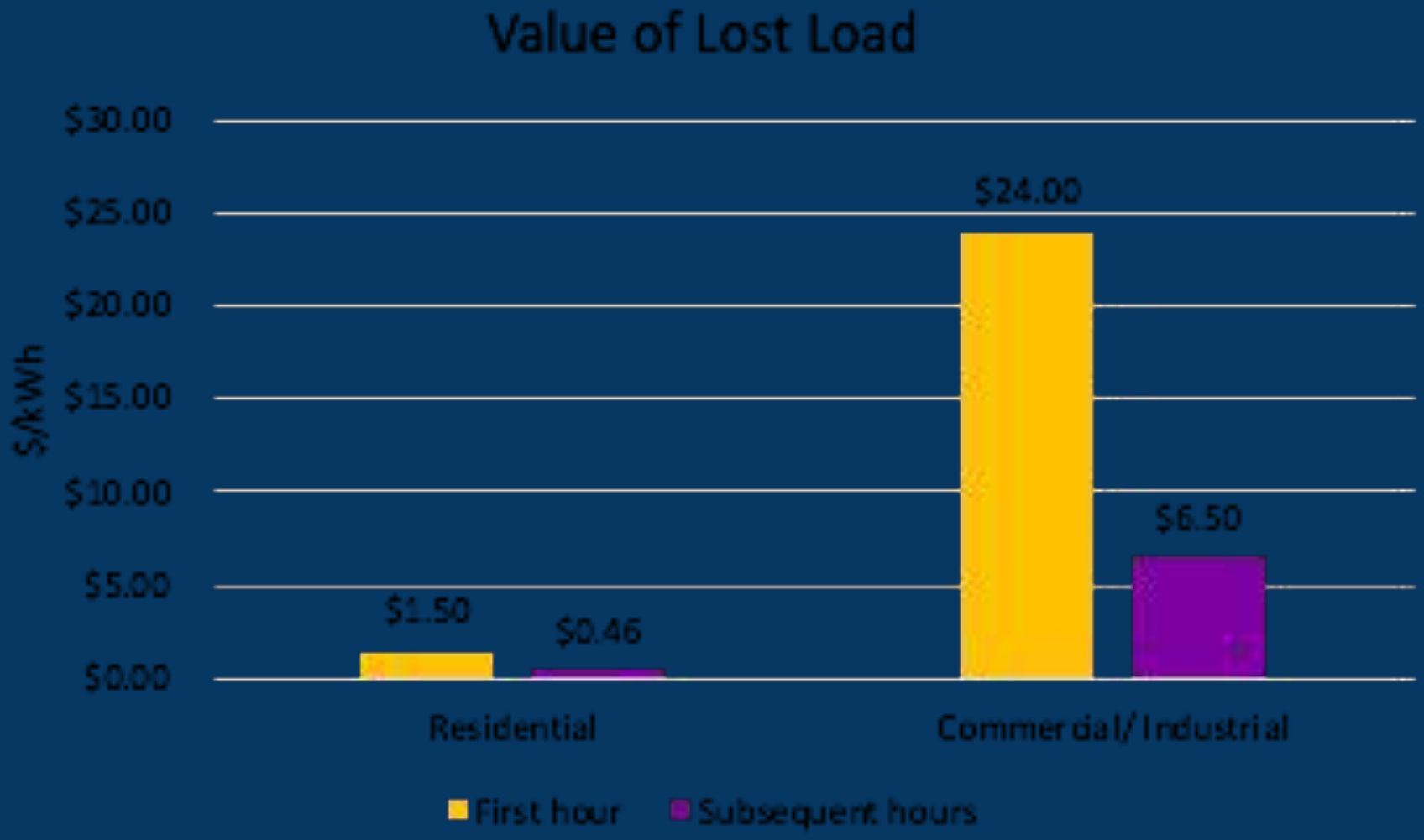
- Falling trees
- Limbs
- Telephone poles
- Live wires above ground

Underground:

- Can be vulnerable to water damage from flooding.
- Water vapor can cause problems especially if there are defects in the cables.

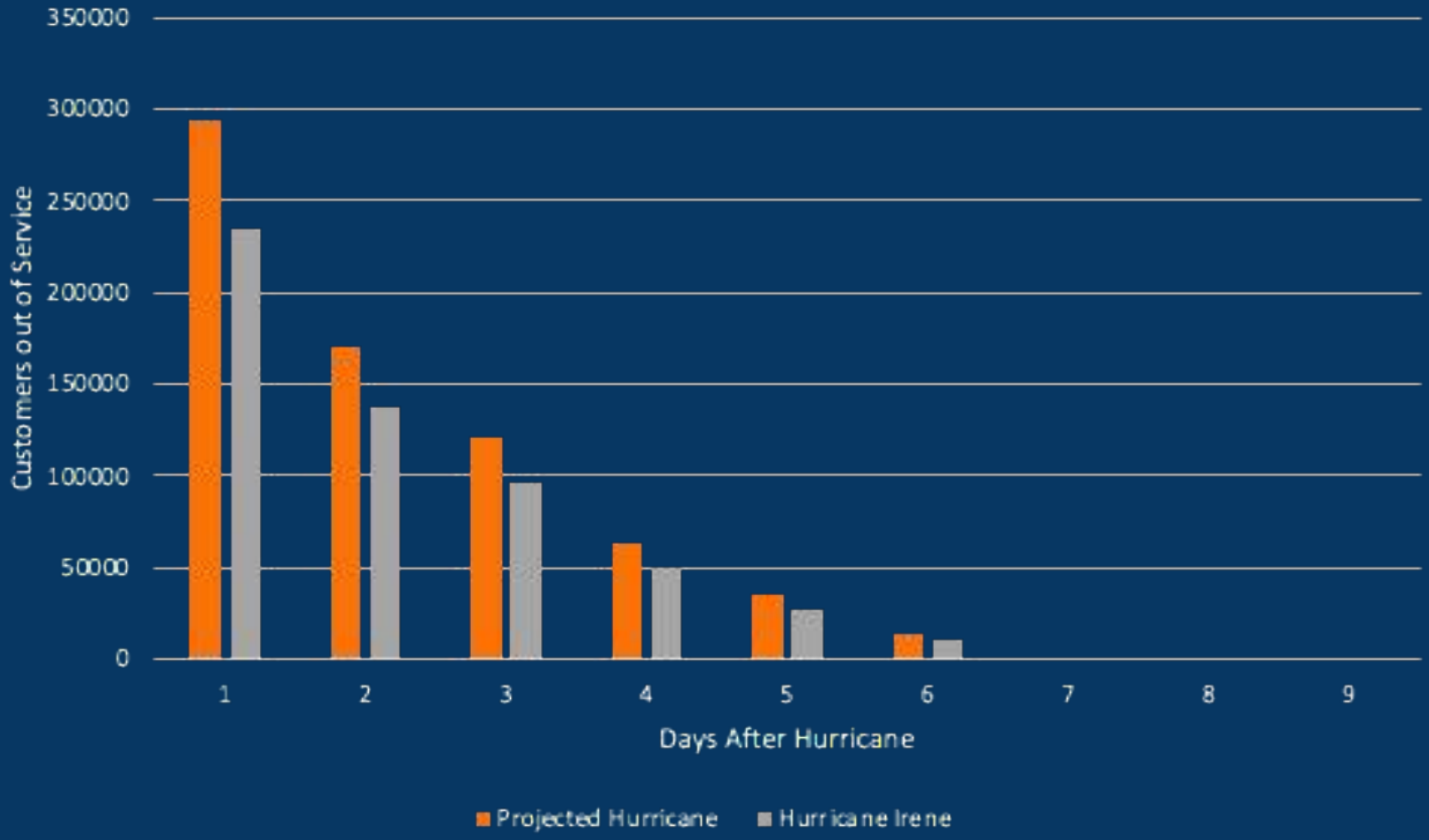
Atkinson, William. “Overhead and Underground.” Electrical Contractor Magazine, 2018

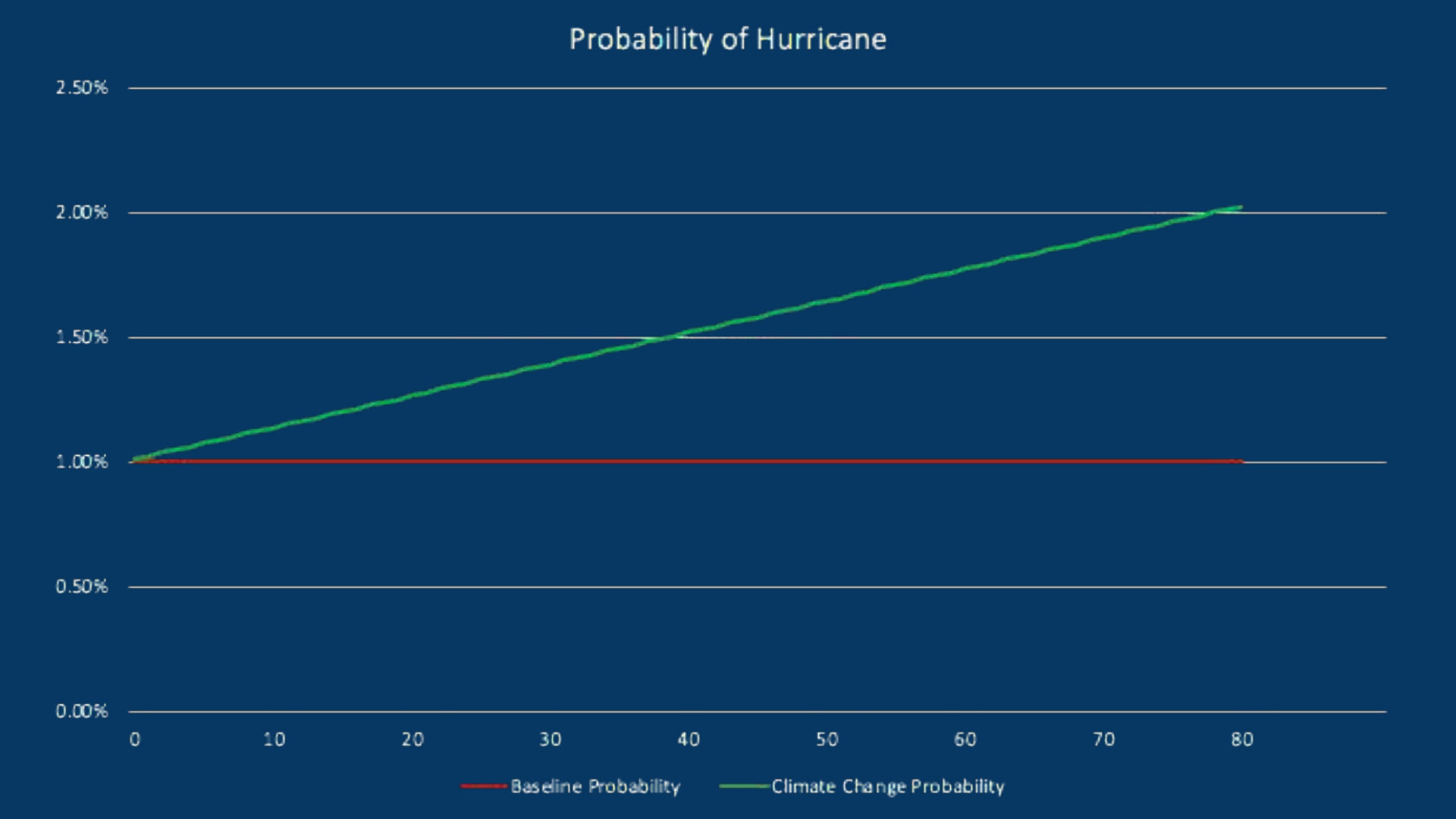
Monetization of Electricity Blackouts

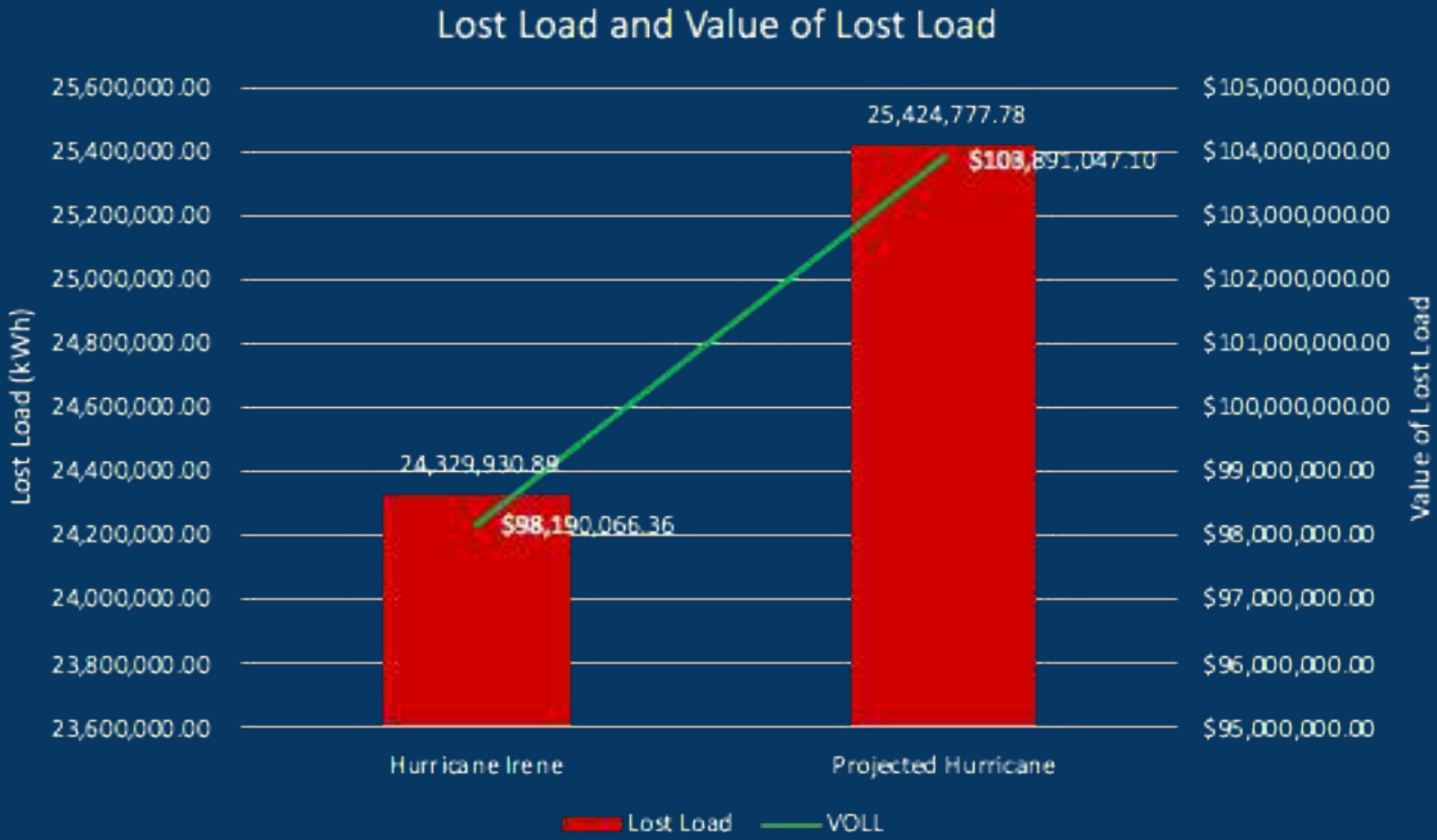

Value of Lost Load
$30.00
$25.00
$20.00
$15.00
$10.00
$5.00
$0.00
$/kWh
$1.50
$0.46
$24.00
$6.50
Residential
Commercial/ Industrial
First hour
Subsequent hours

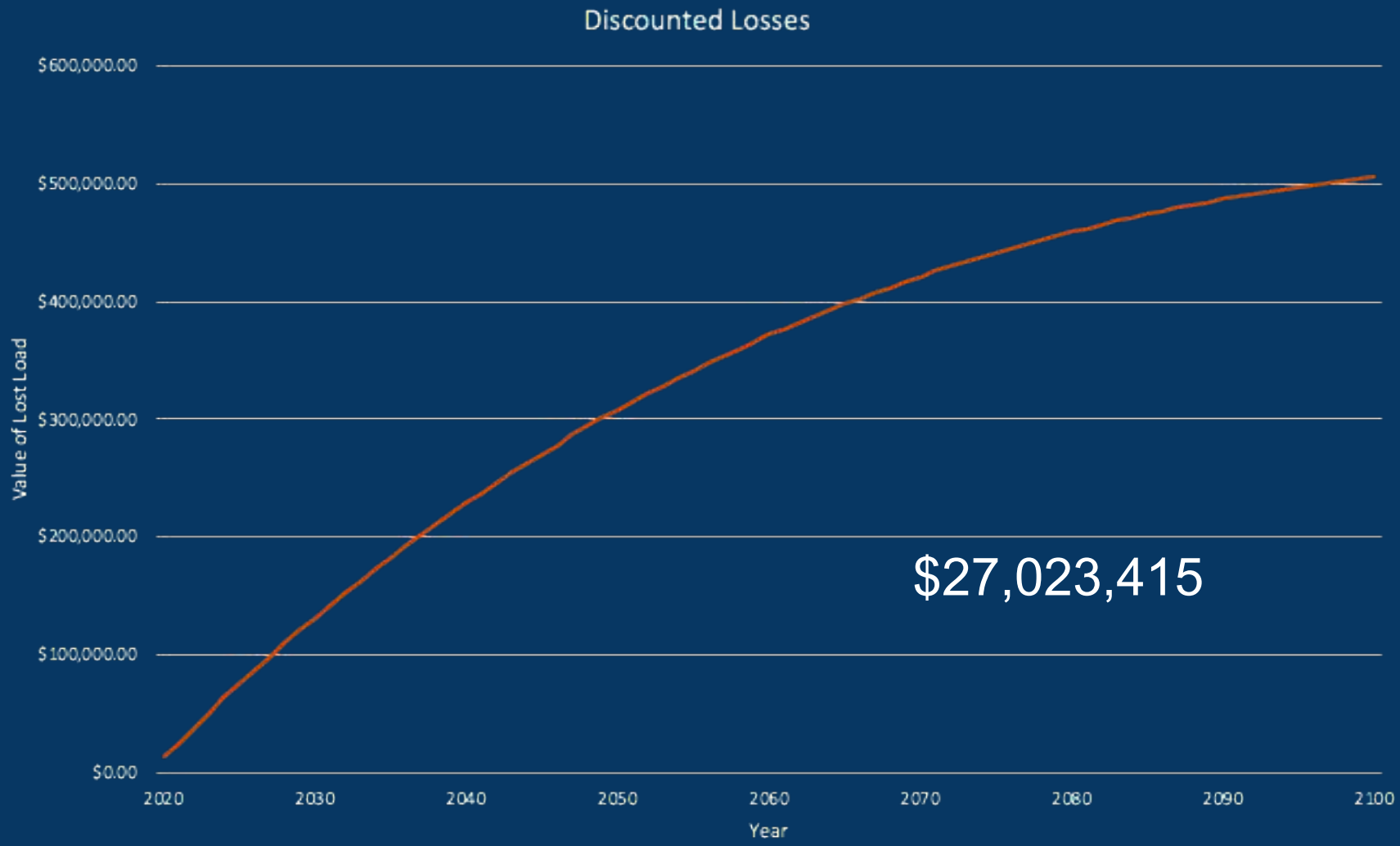

Lost Load (kWh)
Residential
Commercial/Industrial

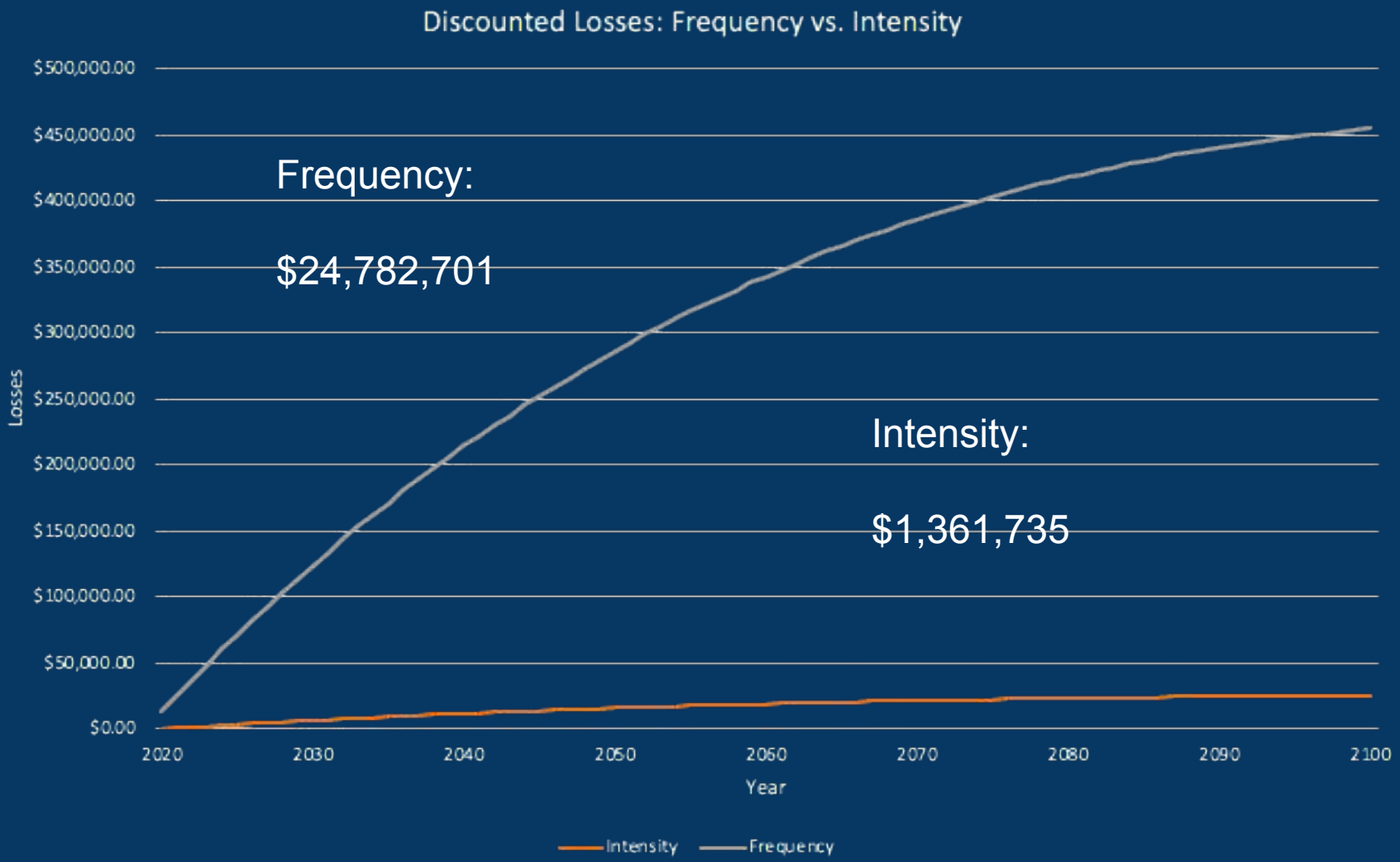

Value of Lost Load
Residential
Commercial/Industrial


Customers Out of Service: Hurricane Irene vs. Projected Hurricane
350000
300000
250000
200000
150000
100000
50000
0
Customers out of Service
1
2
3
4
5
6
7
8
9
Days After Hurricane
Projected Hurricane
Hurricane Irene


Probability of Hurricane
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
0
10
20
30
40
50
60
70
80
Baseline Probability
Climate Change Probability


Lost Load and Value of Lost Load
25,600,000.00
25,400,000.00
25,200,000.00
25,000,000.00
24,800,000.00
24,600,000.00
24,400,000.00
24,200,000.00
24,000,000.00
23,800,000.00
23,600,000.00
Lost Load (kWh)
$105,000,000.00
$104,000,000.00
$103,000,000.00
$102,000,000.00
$101,000,000.00
$100,000,000.00
$99,000,000.00
$98,000,000.00
$97,000,000.00
$96,000,000.00
$95,000,000.00
Value of Lost Load
24,329,930.89
25,424,777.78
$98,190,066.36
$103,891,047.10
Hurricane Irene
Projected Hurricane
Lost Load
VOLL


Discounted Losses
$600,000.00
$500,000.00
$400,000.00
$300,000.00
$200,000.00
$100,000.00
$0.00
Value of Lost Load
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
$27,023,415


Discounted Losses: Frequency vs. Intensity
$500,000.00
$450,000.00
$400,000.00
$350,000.00
$300,000.00
$250,000.00
$200,000.00
$150,000.00
$100,000.00
$50,000.00
$0.00
Losses
Frequency:
$24,782,701
Intensity:
$1,361,735
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Intensity
Frequency

Public Utility and Transportation: Effects of Flooding

- Storms and Flooding can require emergency relocation of vulnerable populations
- Providence population density
  - 9,720 people per square mile
  - Urban Areas Security Initiative - Tier 2
- Evacuation would overload roads & public transport
  - Further intensified by flooding
    - Road closures
      - Detours
      - Bus route cancellations

Road Flooding

- Assumes worst case scenario:
  - all roads must be repaired in event of 7 ft sea level rise and 100 yr storm
- Repairs to road could be continuous and immediate during extreme climate change
- Everyone (public) must be able to access roads:
  - Fire, EMT, and all pubic services are most important

Photo from: Flooded Roads Causing Driving Hazards (December 2015). The Lake News. Retrie ed from https://www.thelakenews.com/wp-content/uploads/images/2015-12-28/flooded-road.jpg

Road Flooding-RIDOT

- Present Value due to Climate Change discounted at 3%

Graph by: Danielle Budaj

Information from: Rhode Island Statewide Planning Program. (Jan 2016). Vulnerability of Transportation Assets to Sea Level Rise. Retrieved from http://www.planning.ri.gov/documents/sea_level/2015/TP164.pdf

RIPTA

- Assumptions:
  - 100-year storm
  - 1 ft, 3 ft, 5 ft, 7ft sea level rise
- Revenue lost each day is based off of info from planning RI:
  - Number of routes affected, number of people affected from routes, $2/rider
- Loss in revenue effects RIPTA, and the state
- Riders of RIPTA will be affected

Photo from: Rhode Island Public Transit Authority (RIPTA) Public Service Vehicles (n.d.) Retreived from https://sites.google.com/a/publicservicevehicles.com/www/ripta:

Rhode Island Public Transit Authority

Graph by: Danielle Budaj
Information from: Rhode Island Statewide Planning Program. (Jan 2015). Vulnerability of Transportation Assets to Sea Level Rise. Retrieved from http://www.planning.ri.gov/documents/sea_level/2015/TP164.pdf

Fire, EMS, Police

- Mostly all fire and police are safe from inundation of 7 ft sea level rise and 100 yr storm
  - 1 fire station is at risk
- nuisance flooding makes it difficult for first responders to adapt to reach those in need
- No monetization

Image via: Watch Dog, RI, (March 2015). Fire Data: How Do We Compare? Retrieved from http://watchdogri.org/fire/firedata1-print.html

Wastewater

- Fields Point Wastewater Treatment Facility
  - Potential environmental impacts
    - Pathogens in sewage overflows
      - Children, pregnant women, elderly particularly vulnerable
    - Aquatic ecosystem health
      - Providence River
      - Narragansett Bay

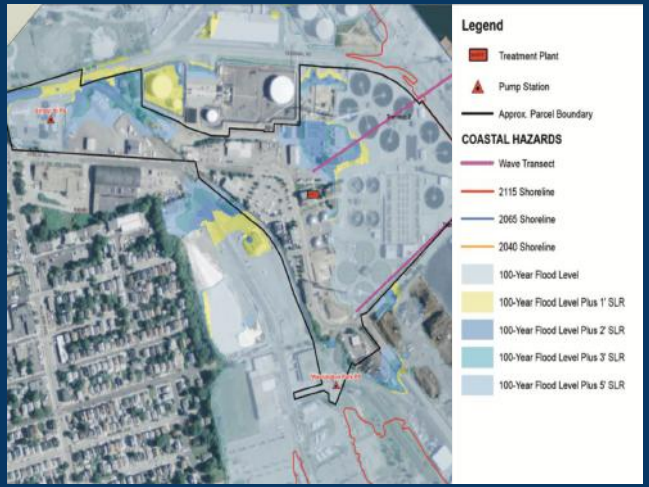
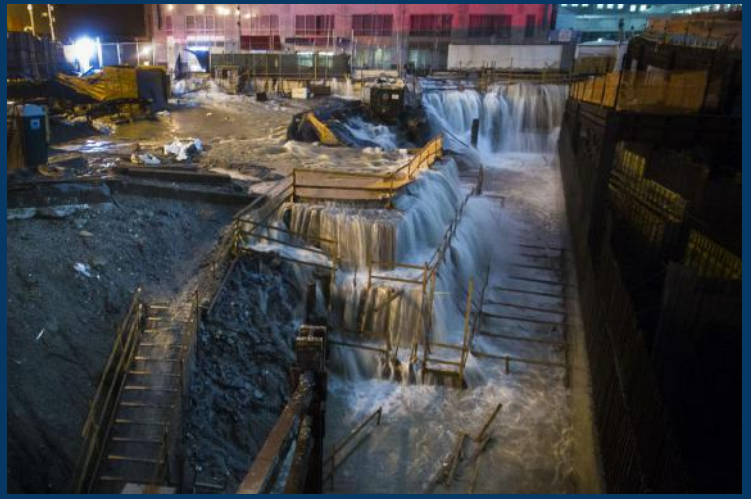


Photo provided by RIDEM

Wastewater (cont)



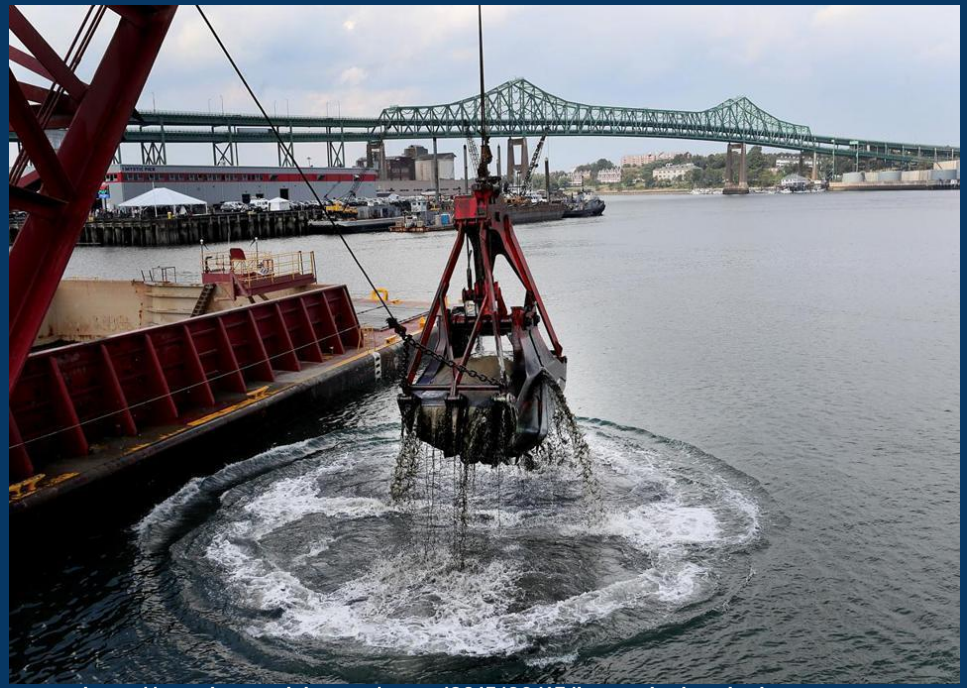
- Superstorm Sandy (from Climate Central)
  - Passaic Valley Sewerage Commision in Newark, NJ
    - Expected total cost of repairs
      - > $200 million (2013 Dollars)
  - South Monmouth County, NJ
    - Two sewage pumps inundated
      - $10 million in damages to equipment (2013 Dollars)
- Potential mitigation steps
  - Raise Elevation
  - Submersible pumps

Narragansett Bay Commission

US Army Corps of Engineers: Maintenance Dredging of Providence River

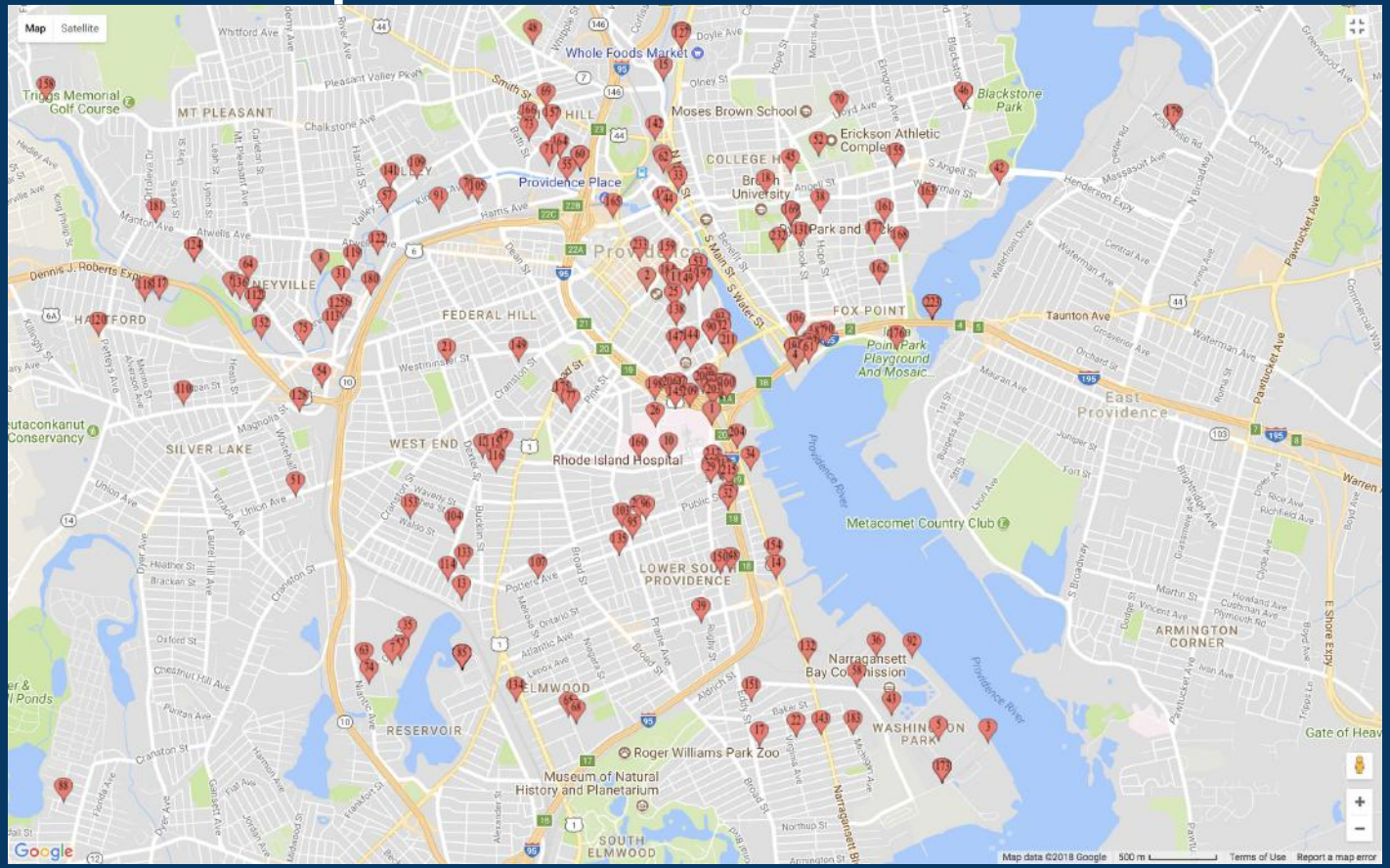
- 2003-2005: removed 1,374,851 cubic yards of sediment for $15.5 million.

- Projection: 1,500,000 cubic yards will need to be removed in the next 20 years



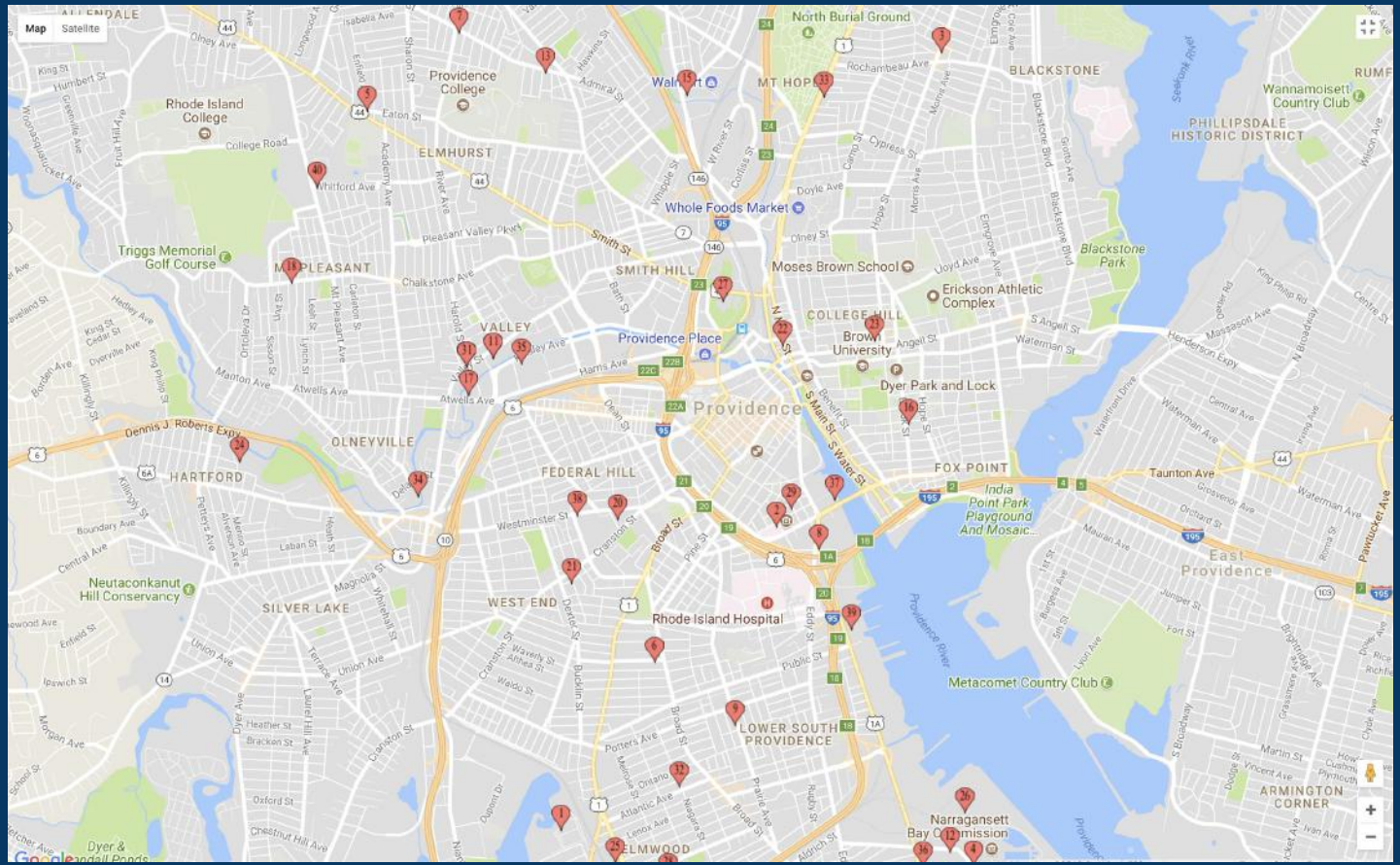
https://www.bostonglobe.com/metro/2017/09/15/boston-harbor-dredging-project-underway/SwqVFtjW8BRwQQCxrd96aP/story.html

Map of CERCLIS and State Sites



https://www.mapcustomizer.com

Map of Known LUSTs (Leaking Underground Storage Tanks)



https://www.mapcustomizer.com

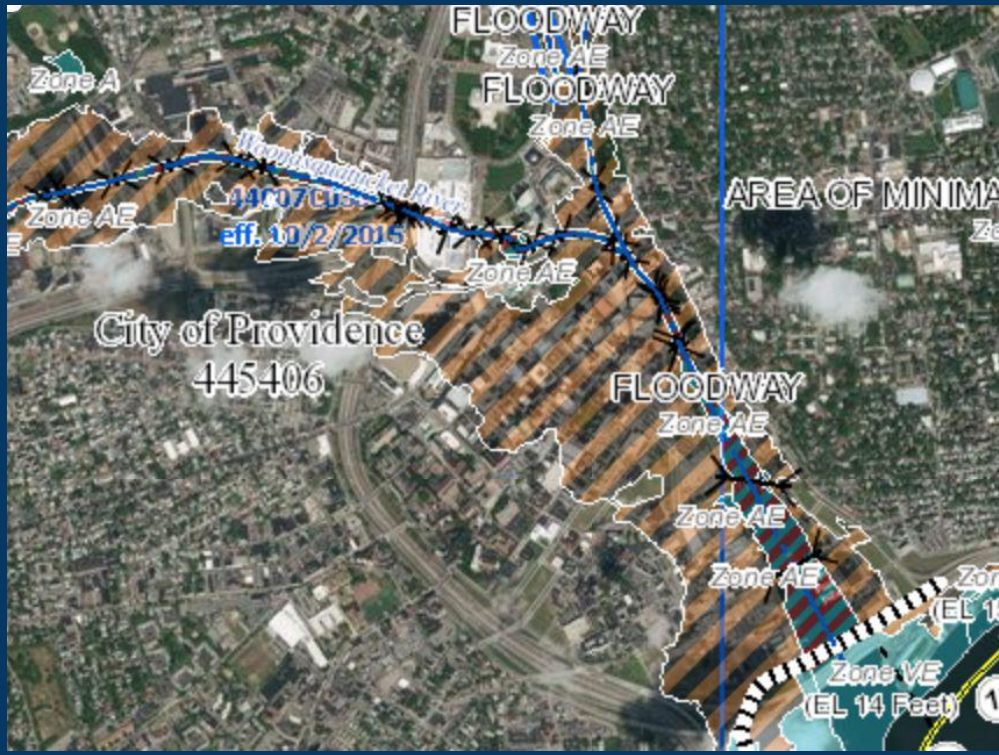
Hurricane Katrina: Effect of Chemicals on NOLA Population

Health Effects and Frequency of Frequently Reported Chemicals			
Chemicals	**Health Effect**	**Medium**	**Location of ≥2 Chemicals (%)**
B[a]P, As	Cancer	Soil	31%
Pb, Zn	Blood	Water	55%
Pb, Fe	Cardiovascular	Water	43%
Fe	Gastrointestinal	Water	76%
Pb	Kidney	Water	57%
Al, Pb, Mn	Neurological	Water	59%
As, B[a]P, B[a]A, B[b]F, I[1,2,3-cd]P	Cancer	Sediment	51%
Petroleum	N/A	N/A	N/A

Derived from Fox et. al 2009

Mitigating costs with business & residential insurance

- FEMA **National Flood Insurance Program**
  - **Flood Insurance Rate Maps**
    - High-Risk Area (A, V zones) → 1% annual chance flood
    - Low-Risk Area (B, C, X zone) → 0.2% annual chance flood
  - Community Rating System
  - Commercial coverage:
    - Buildings: $500,000
    - Content: $500,000
  - Residential coverage:
    - Buildings: $250,000
    - Contents: $100,000
- Without the barrier, the low-risk area would be a high risk area resulting in high premiums




Public Health Risk
Electricity Infrastructure
People of Providence, Rhode Island
Prov Port
Businesses and Residents
Public Utilites Transportation