Jacobs

Challenging today.
Reinventing tomorrow.

Watch Hill Sea Wall

April 8, 2021

About Me

- Bachelor's Degree in Civil Engineering from Tufts University
- Master’s Degree in Civil Engineering from Massachusetts Institute of Technology
- Professional Engineer in RI, MA
- Work for Jacobs Engineering Group, Inc (NYSE: J)
  - #1-ranked Engineering Design Firm and #1-ranked Ports & Marine Firm (ENR, 2020)
  - Lead our Ports & Maritime team and business in Northeast, Midwest, Mid-Atlantic US and all of Canada
  - Focus is on developing and upgrading marine terminals around the world

Some of Our Ongoing Resiliency Projects

Resiliency-Related Services:

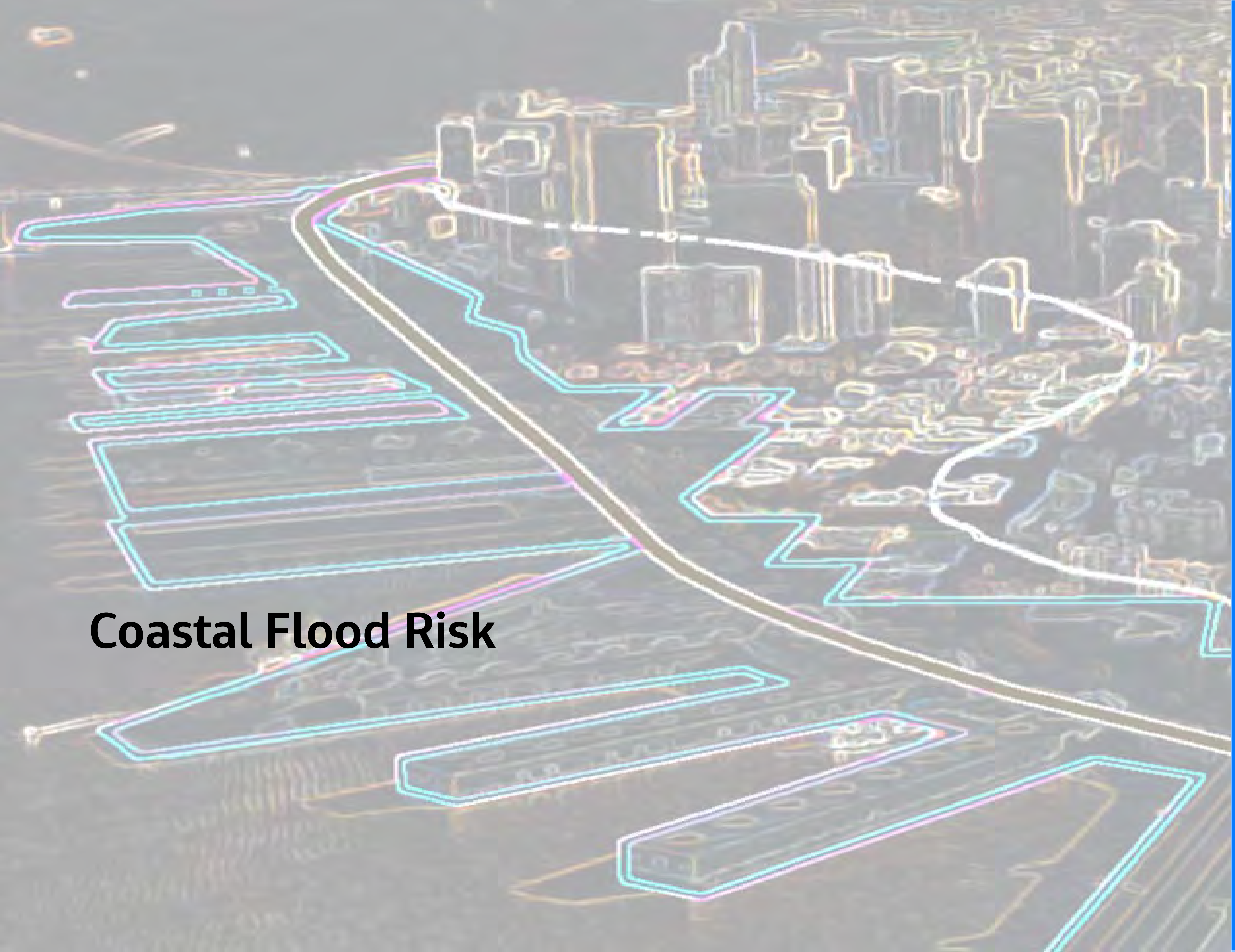
- Program management
- Flood protection engineering
- Sea level rise & storm modeling
- Asset management
- Operational planning
- Emergency response

East Side Coastal Resiliency

San Francisco Seawall Resiliency Program

NYC Harbor Barrier

USACE Galveston Flood Protection Program



Coastal Flood Risk

Coastal Flood Risk and Damage

- According to current FEMA flood maps, approx.800k residents in the NY Metro Area live within the 1% annual exceedance probability floodplain
- According to a 2018 study titled "Estimates of present and future flood risk in the conterminous United States" published in *Environmental Research Letters*, nearly 41 million people live within the floodplain nationally (https://iopscience.iop.org/article/10.1088/1748-9326/aaac65/pdf)
- In the same study, the damage estimates from a 100-yr flood is $1.2 trillion
- With sea-level rise, the impacts of flooding will continue to grow with more people getting affected and the damage estimates increasing

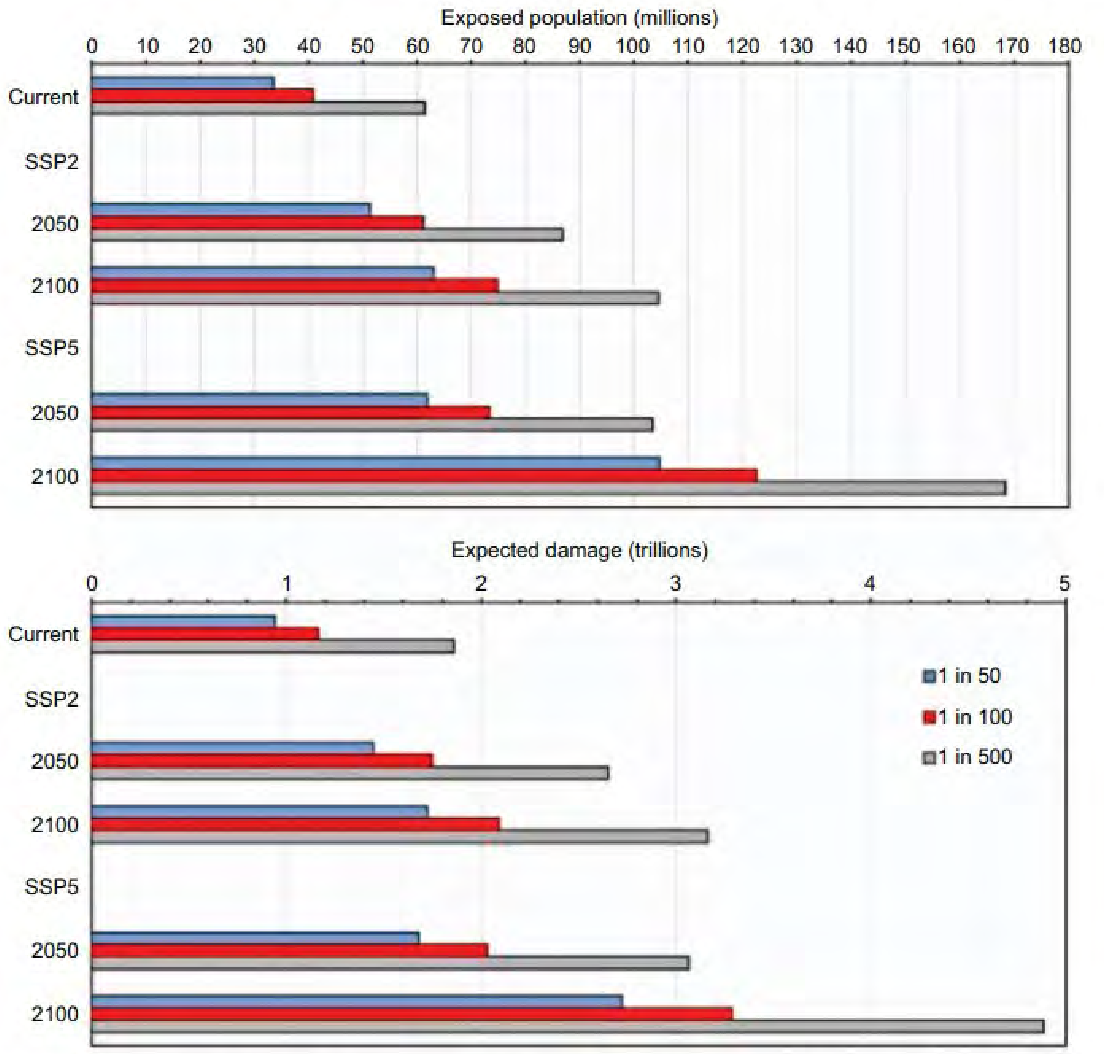


Figure 2. Selected exposure (population) and risk (damage) estimates for present and future 1 in 50-, 100- and 500 year floods. SSP2 represents a medium growth scenario, in terms of population and development, while SSP5 represents a higher one.

https://iopscience.iop.org/article/10.1088/1748-9326/aaac65/pdf

Sea-Level Rise Projections

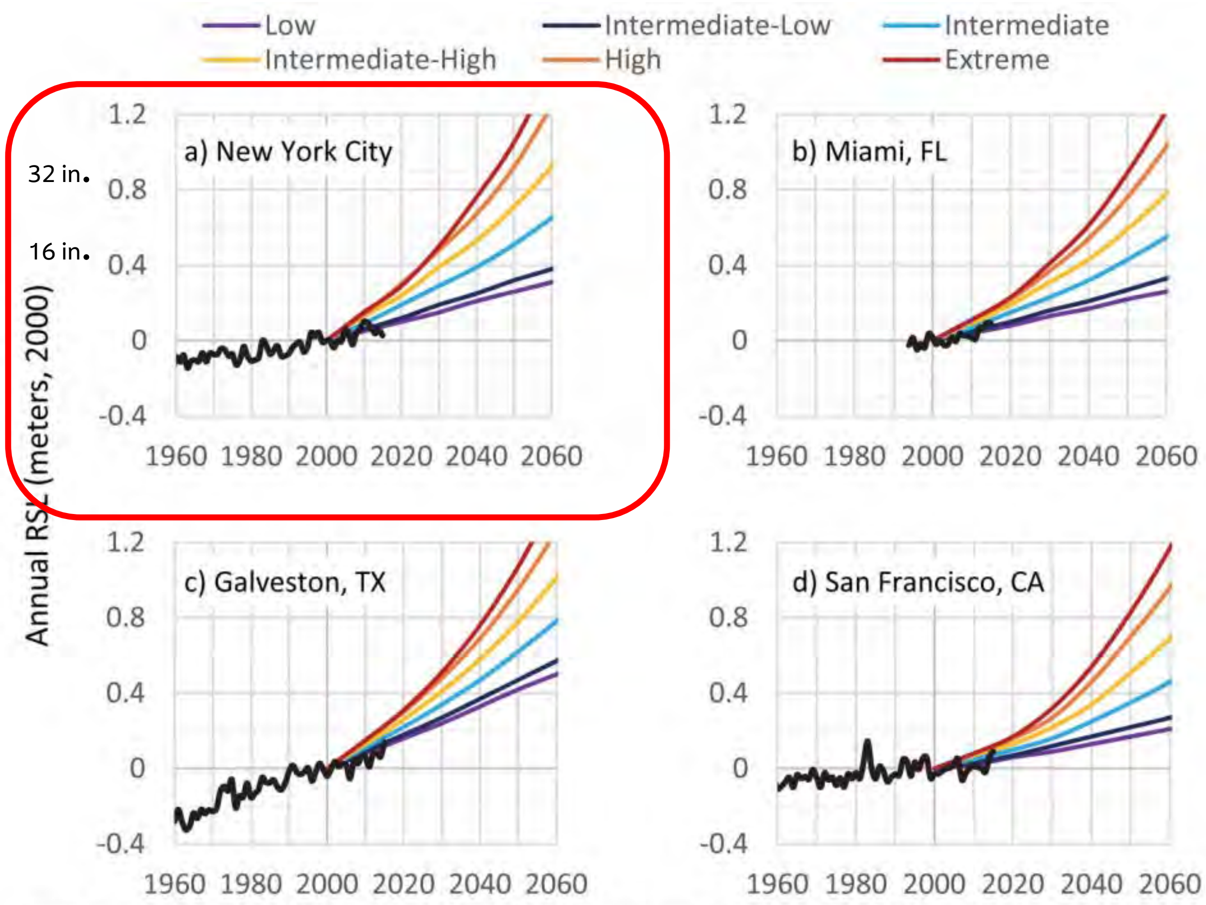


Figure 14. Average annual RSL for New York City (The Battery), Miami (Virginia Key), Fla., Galveston, Tex. and San Francisco, Calif. with their respective (median-value) RSL under the six scenarios. The NOAA RSL observations (tidesandcurrents.noaa.gov/sltrends) are shown relative to the midpoint (year 2000) of the 1991–2009 epoch (1994–2009 at Virginia Key), which is the reference level for the scenarios.

https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

NYC Mayor's Office of Recovery and Resiliency | *Climate Resiliency Design Guidelines*

APPENDIX 2 - CLIMATE CHANGE PROJECTIONS

Climate change projections are provided by the New York City Panel on Climate Change (NPCC). The full NPCC report is available from the New York Academy of Sciences.[89] Tables 8-10 (below) were reproduced directly from the NPCC report, while Table 2 (see Section II.A) was developed using the data underlying the NPCC report to inform the design of HVAC systems under warmer conditions.

Table 8 – NYC sea level rise projections[90]

Baseline (2000-2004) 0 in	Low estimate (10^{th} percentile)	Middle range (25^{th} to 75^{th} percentile)	High estimate (90^{th} percentile)
2020s	2 in	4-8 in	10 in
2050s	8 in	11-21 in	30 in
2080s	13 in	18-39 in	58 in
2100	15 in	22-50 in	75 in

Note: Projections are based on six-component approach that incorporates both local and global factors. The model-based components are from 24 global climate models and two representative concentration pathways. Projections are relative to the 2000-2004 base period.

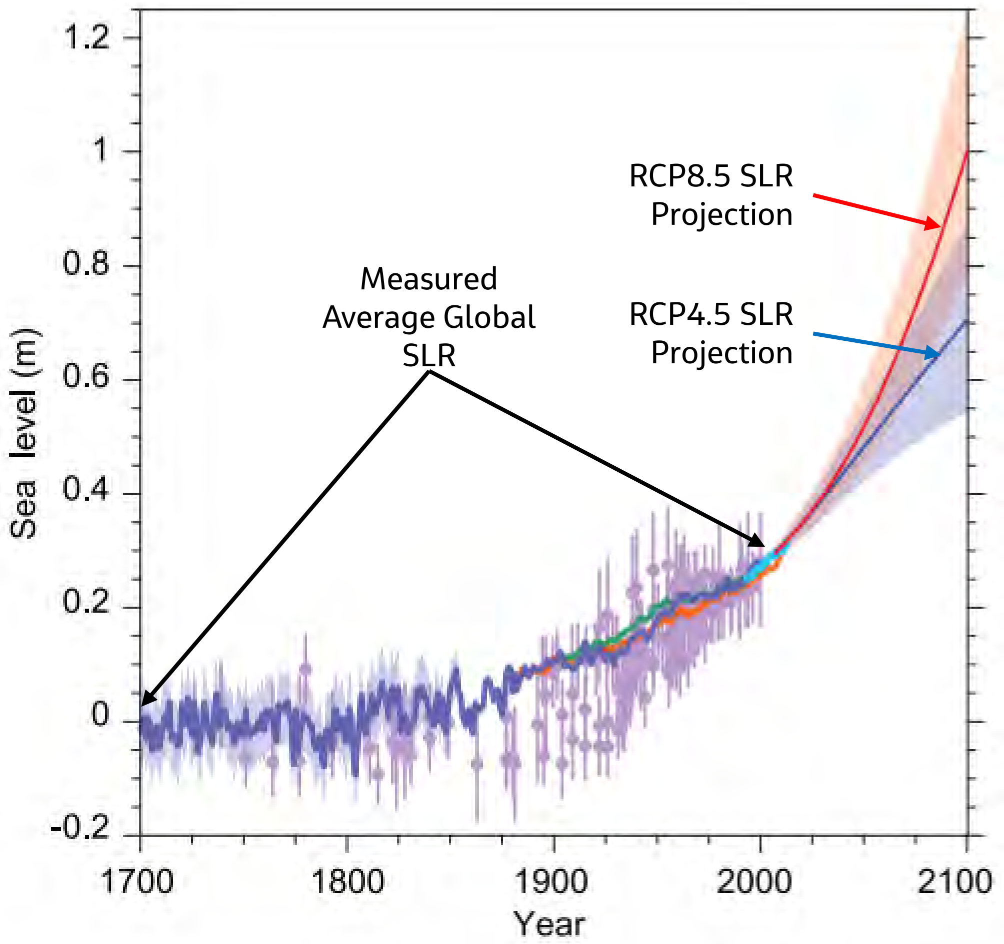
Climate Change in New England

- Temperature
- Precipitation
  - Has increased by up to 15%
  - Expected to increase further
- Sea Level Rise (SLR)
  - Expected to increase by up 3' by 2100

AR5 global warming increase (°C) projections[11]

	2046–2065	2081–2100
Scenario	Mean and *likely* range	Mean and *likely* range
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

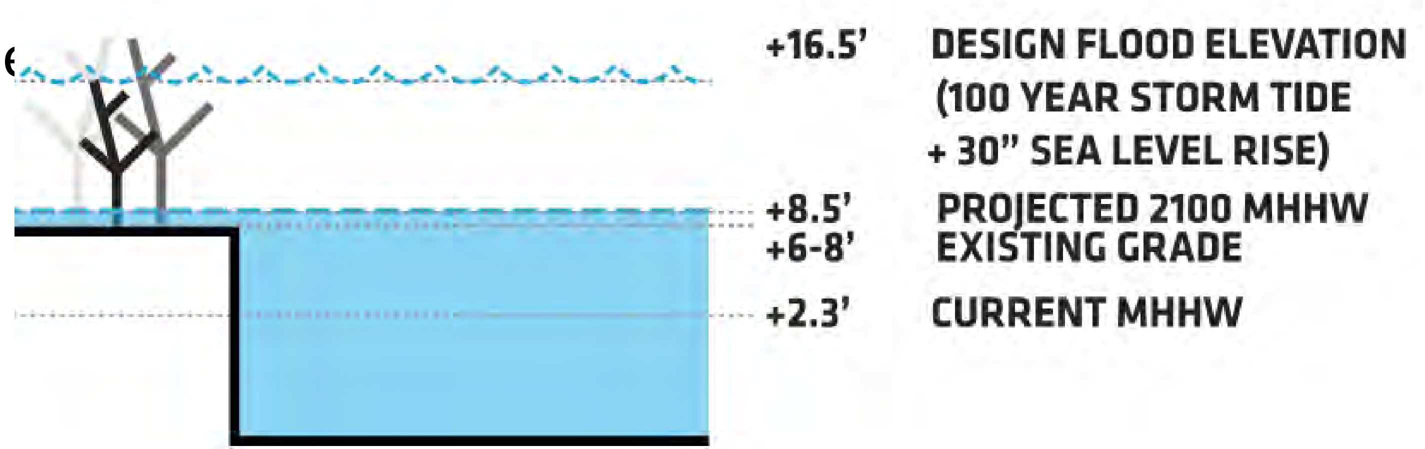
Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its fifth Assessment Report (AR5) in 2014

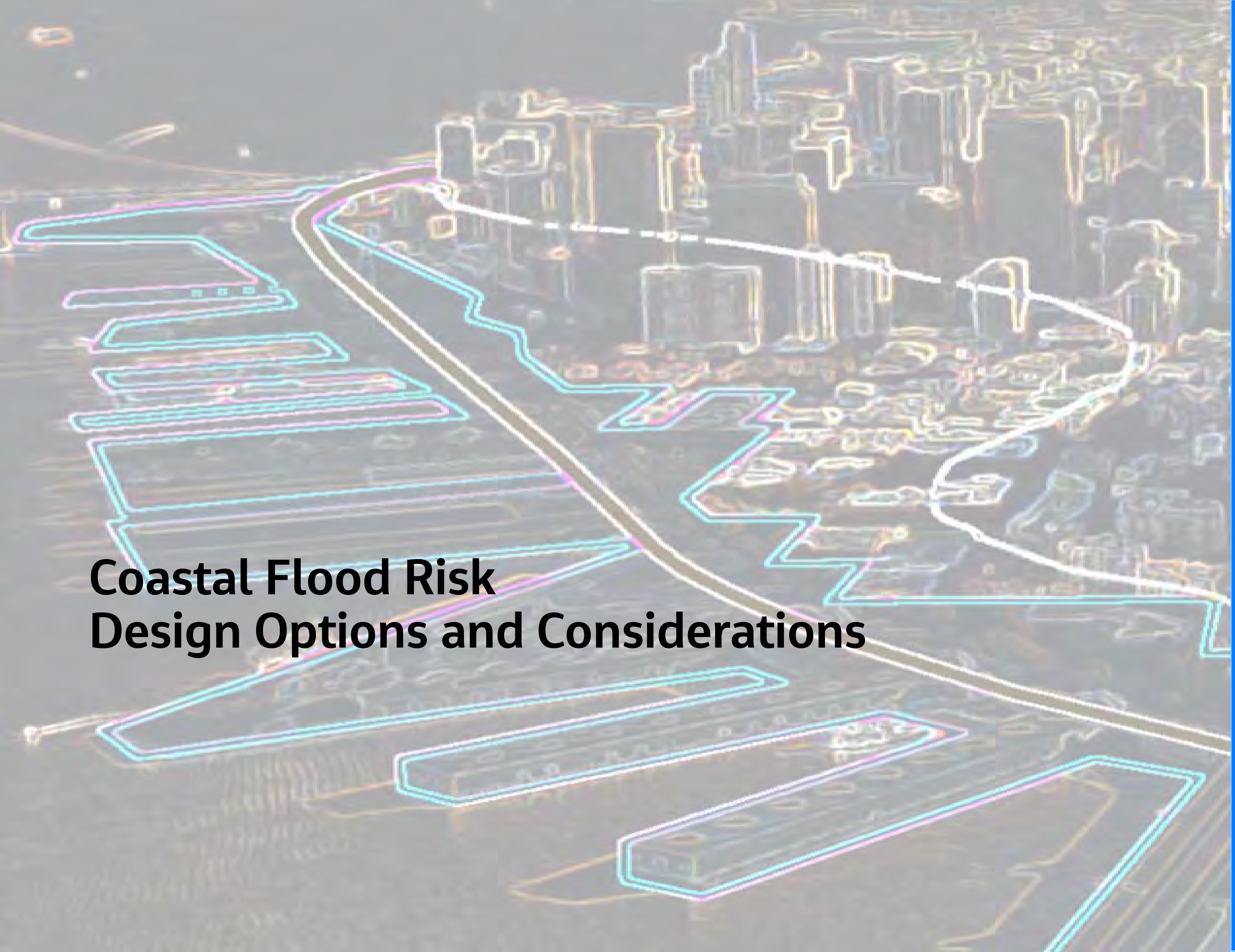


International Panel on Climate Change, Assessment Report (AR) 5, 2014

Effects of Climate Change

- Sea Level Rise
  - Daily tide fluctuations cause flooding
  - Floods go to higher elevations, further inlan
- Precipitation
  - Extreme events become common
  - Higher rainfall in extreme events
  - 500-year event becomes 100-year e
- Temperature
  - Higher & lower extremes





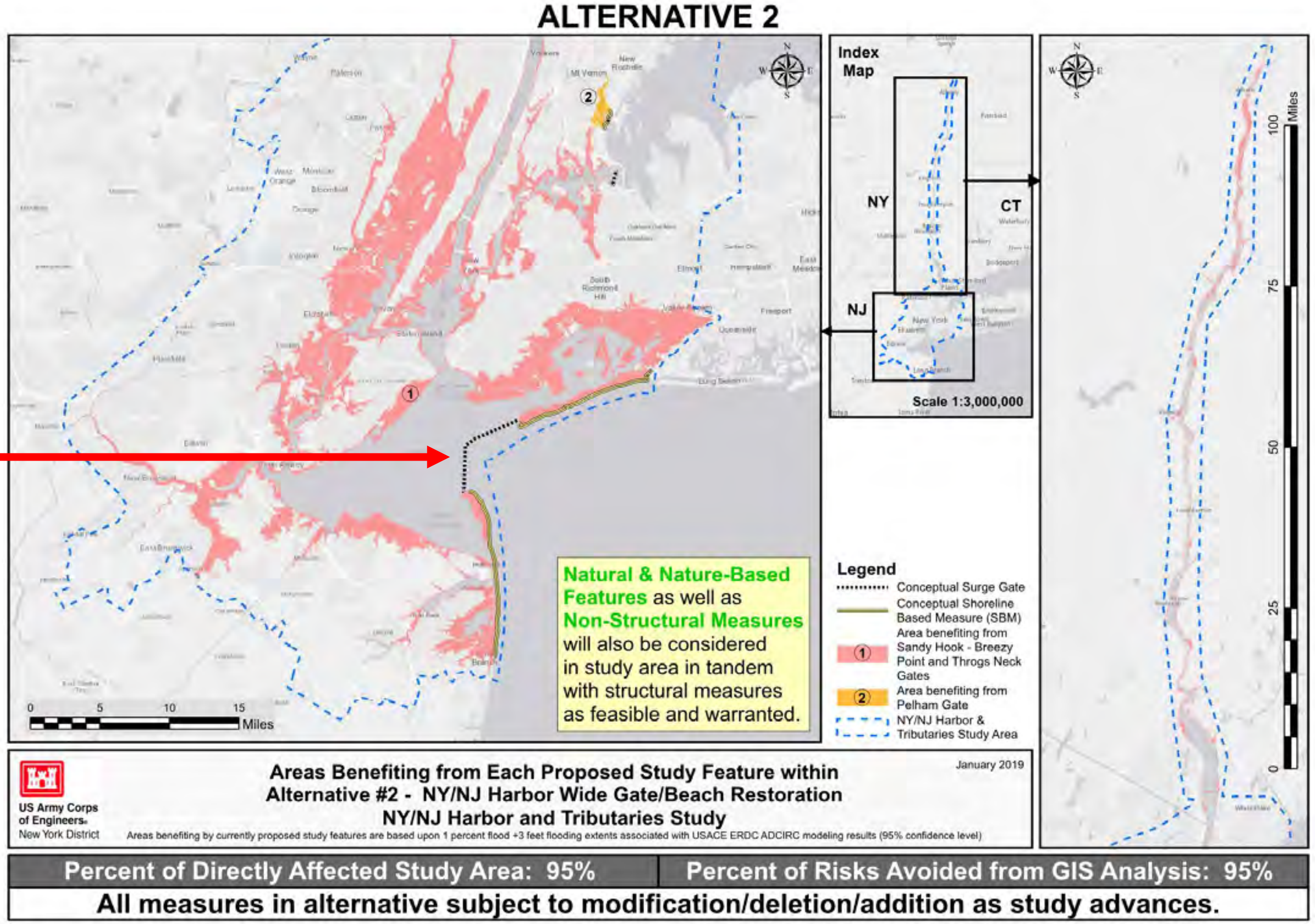
Coastal Flood Risk
Design Options and Considerations

Coastal flood risk design options and considerations

- Who do we protect?
  - Regional-based
  - Neighborhood/Community-based
  - Site-based
- What do we protect from?
  - Extreme flooding vs nuisance flooding
- How do we protect?
  - Passive vs Active measures
- When do we protect?
- How do we maintain our protection?

Who Do We Protect?

- Regional-based
- Neighborhood/Community-based
- Site-based



Who Do We Protect?

- An example of a regional scale protection system is the 25.4 km long flood protection barrier that is currently operating successfully in St. Petersburg in the Russian Federation.
- Barrier was put to the test in December 2012 and prevented a storm surge flood that, had the barrier not been in place, would have been the fourth highest flood in the recorded history of the city. The residents of St. Petersburg were largely unaware that a flood event had even occurred.

By Ssr (Thanks to N. Rublëva & A. Davydov for help & equipment) - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=35697377

Who Do We Protect?

- Regional-based
- Neighborhood/Community-based
- Site-based

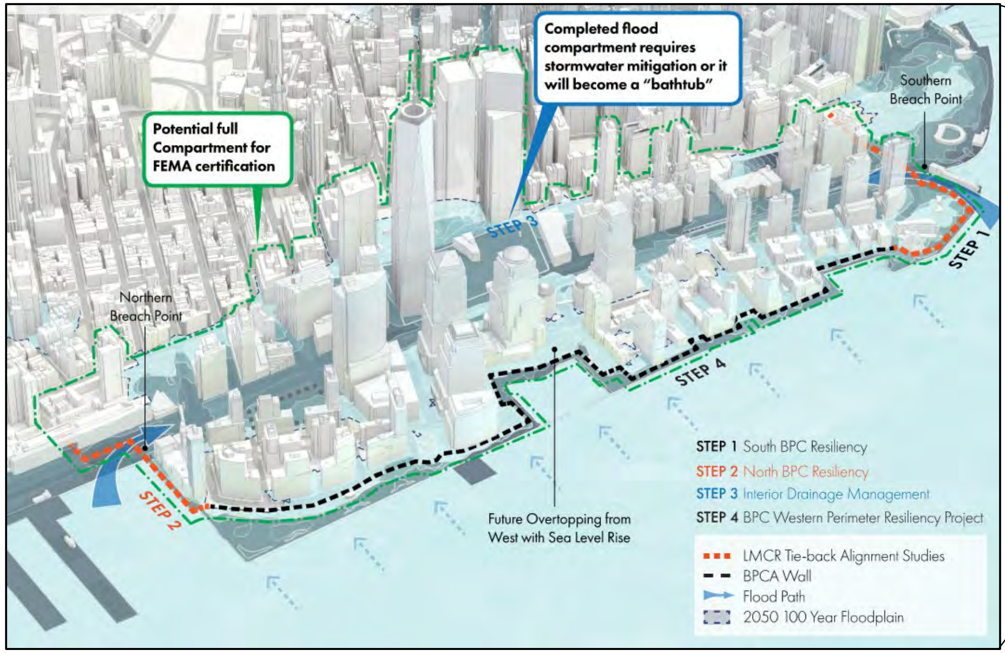
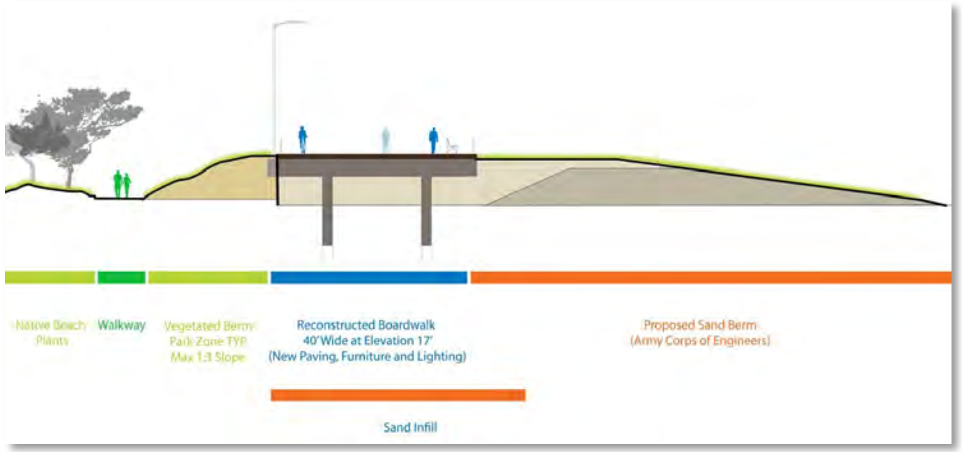


Figure taken from the Lower Manhattan Climate Resiliency Study

Who Do We Protect?

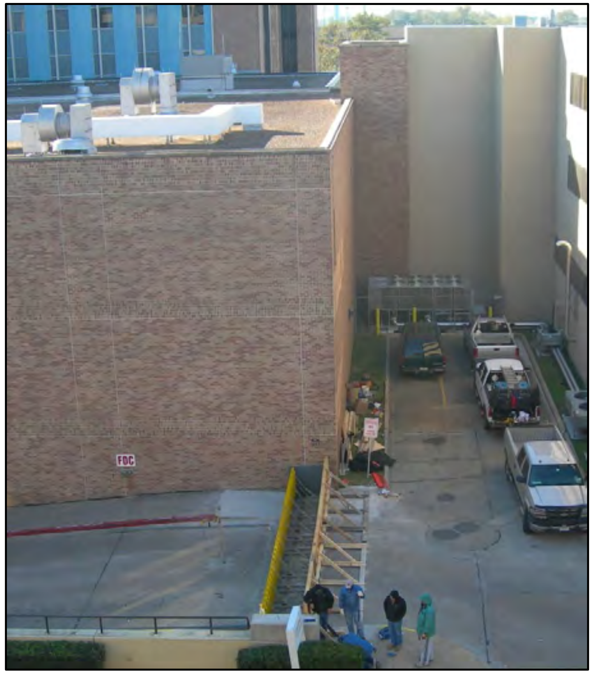
- The Rockaway Boardwalk Reconstruction project is an example of a neighborhood/community-based flood protection system.
- The project involves 4.7 miles of a reconstructed boardwalk that was heavily damaged after Hurricane Sandy. The boardwalk not only serves as a waterfront and recreational amenity, but also protects the neighborhood from a 100-yr storm event.



Rockaway Boardwalk Reconstruction

Who Do We Protect?

- Regional-based
- Neighborhood/Community-based
- Site-based



Who Do We Protect?

- The protection of the NYU Langone Hospital campus is an example of site-based flood protection system
- Perimeter floodwall was constructed to protected against a 500-yr return period flood elevation
- Combination of floodwalls and deployables
- Protection measures included raising of critical assets, installing backflow preventers on storm and sanitary connections, and developing a pumping plan and providing emergency power

https://www.health.ny.gov/facilities/public_health_and_health_planning_council/meetings/2013-06-27/docs/nyu_langone.pdf

NYU Langone Hospital

Hinged Flood Door at Ground Level

Sliding Flood Door at Cellar Level

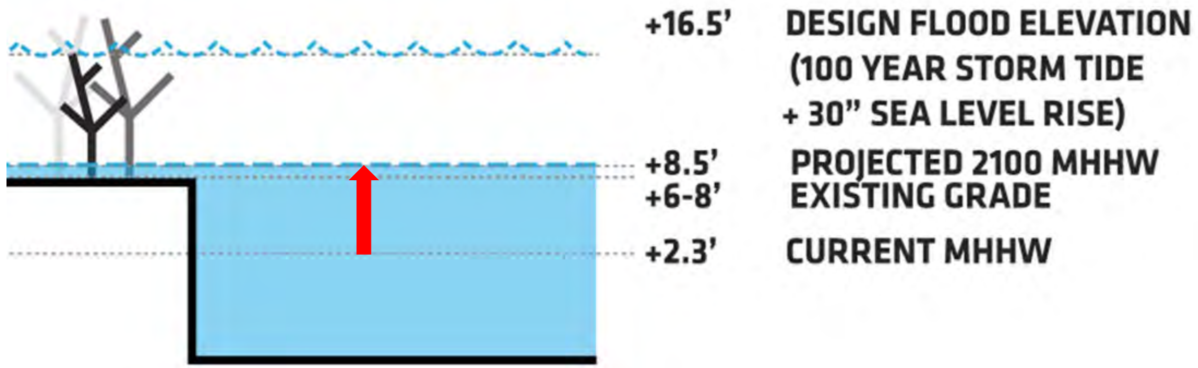
Normal Condition

Wall In Use

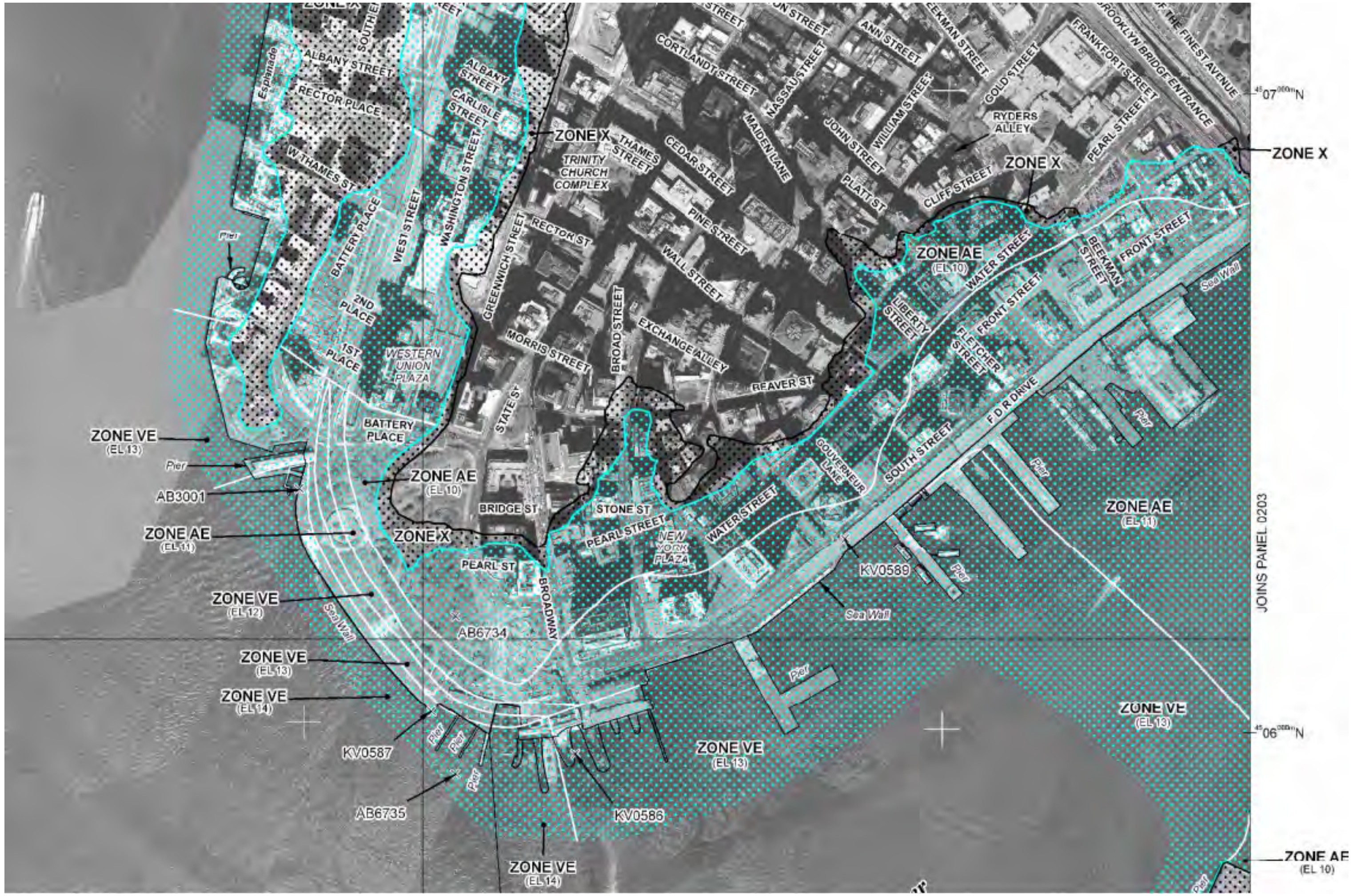
https://drii.org/downloadpresentation/c1a1716918

From What Do We Protect?

- Flooding from extreme events versus nuisance flooding
- An extreme flooding event could be from a 100-yr or 500-yr return period storm event, with or without sea-level rise (SLR)
  - The 100-yr return period flood means that there is a 1% chance of a flood event occurring in any given year.
  - The 500-yr return period flood means that there is a 0.2% chance of a flood event occurring in any given year
  - FEMA flood maps (FIRMs) show the floodplain for both of these events
- Nuisance flooding, or tidal flooding, is a condition that may occur during normal or exceptionally high tides in low-lying areas
- Future adaptability – for today, for 2050, for 2100?



Extreme Flooding - FEMA Flood Insurance Rate Map (FIRM)



LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

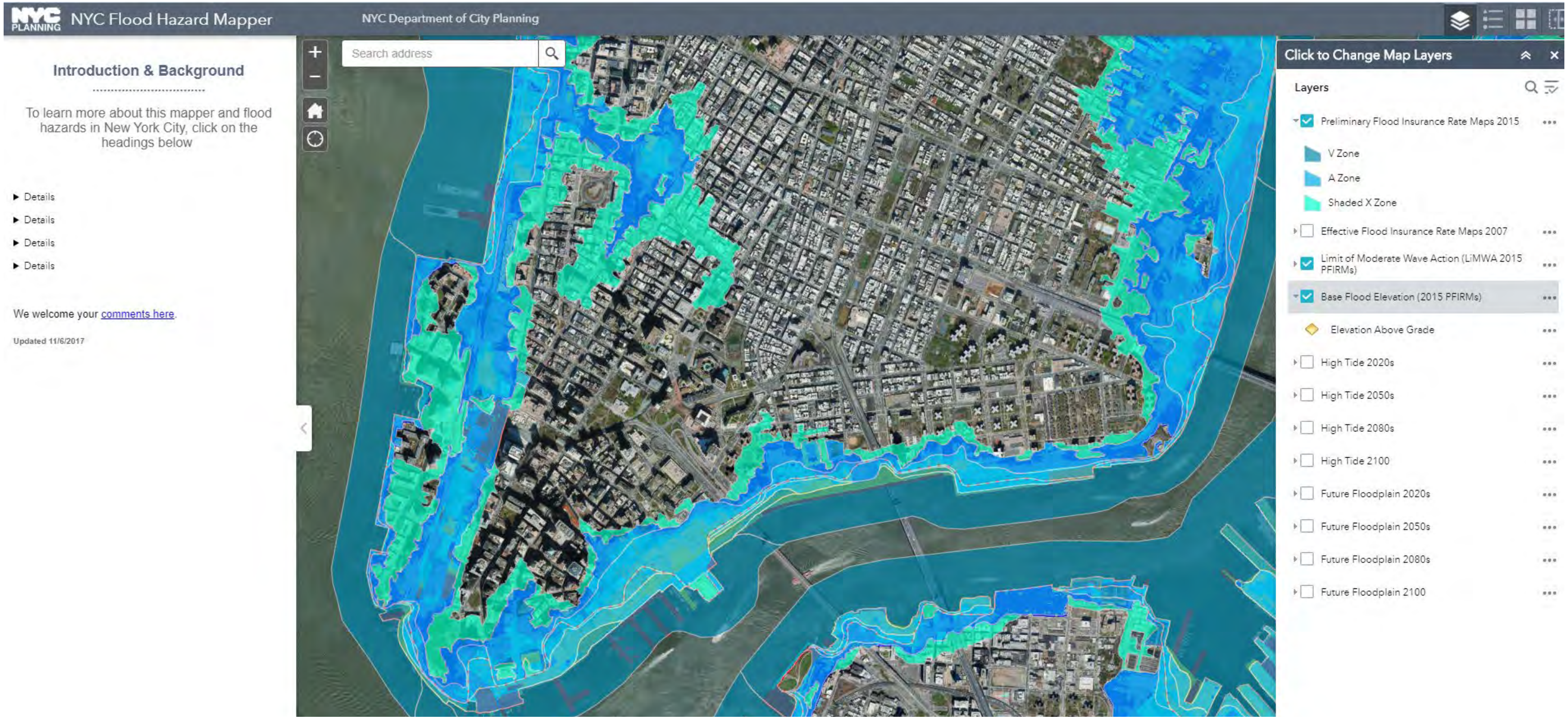
OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

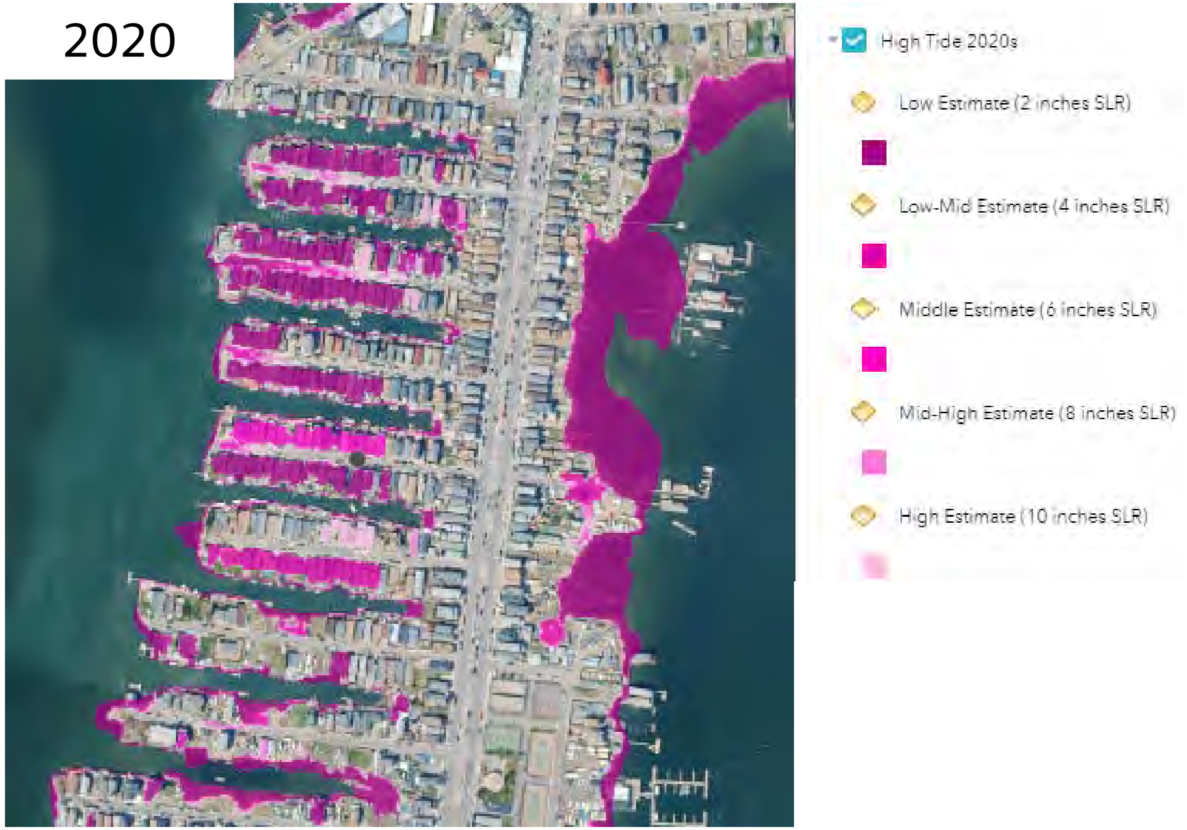
ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

Extreme Flooding – NYC Flood Hazard Mapper Tool



NYC Flood Hazard Mapper (https://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page)

Nuisance/Tidal Flooding – Flood Hazard Mapper



Cross-Bay Boulevard – 10th Road to 17th Road (Broad Channel, Queens)

NYC Flood Hazard Mapper (https://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page)

Layers showing future **high tide in the 2020s, 2050s, 2080s, and 2100** are based on NPCC's projections for SLR in New York City. Mapping of the flood inundation extents anticipated for each projection was completed by DCP based on a 2010 Digital Elevation Model for New York City using a modified bathtub approach provided by NOAA. The layers do not accurately depict inundation on over-water structures, such as docks and piers, and are not reliable for areas outside of New York City. The layers illustrate the scale of potential flooding on land, not the exact location, and do not account for erosion, rapid subsidence, or future construction. They are not appropriate for site scale planning or design.

How Do We Protect?

- Permanent barriers (Passive system)
  - Levees/dikes, floodwalls
  - Pros: Reliable, does not need to be deployed
  - Cons: Blocks access and view corridors, can take up more real estate (ie. a levee)
- Deployable barriers (Active system)
  - Gates, stop logs, flexible barriers, etc.
    - Roller gates
    - Swing gates
    - Crest/Flip-Up gates
    - Vertical lift gates
    - Miter gates
  - Pros: Does not limit access or view corridors when not deployed
  - Cons: Less reliable, requires additional resources to operate and deploy before the storm

When Do We Protect?

- Deployable barriers need to be manually or mechanically deployed prior to the flood event
- Each type of barrier requires different manpower and equipment to deploy (and remove)
- Timing of the deployment must be coordinated with the rest of the region, neighborhood, or site to ensure that the flood protection system is functioning and will perform as intended
  - How many days before the storm?
  - Will the barrier block evacuation routes?
  - What resources are available to deploy the barrier?
- Maintenance and Operations Manual for the flood protection system must be prepared and strictly followed
- Who is going to operate the barrier?
- Self-deploying barriers are available but the reliability of the system is a concern

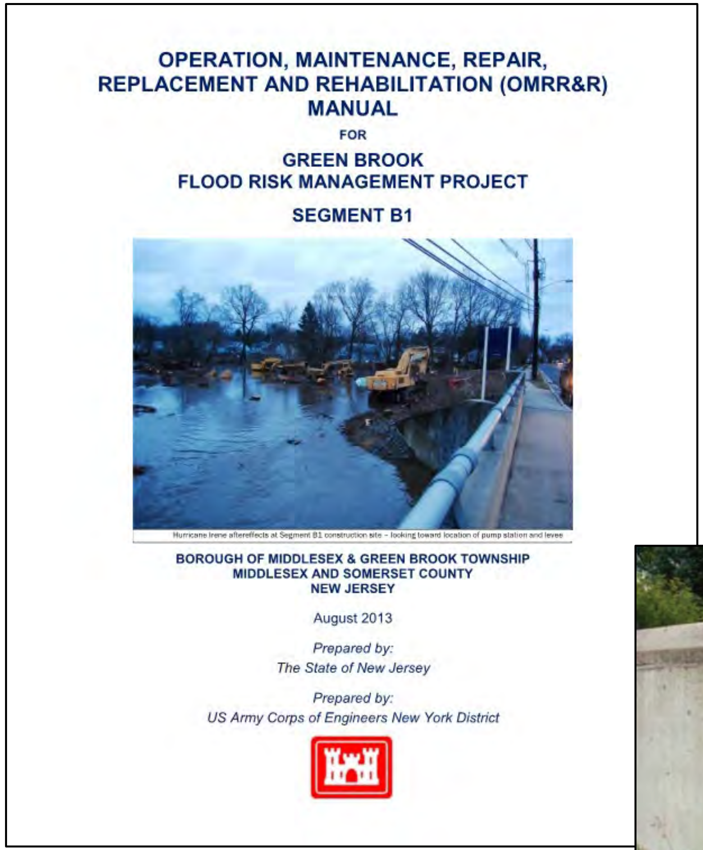
https://bismarcktribune.com/news/state-and-regional/red-river-in-fargo-now-expected-to-reach-feet-early/article_c18fcee0-6503-5fc4-921e-863e9ed4828f.html

https://wcfcourier.com/news/local/fletcher-ave-flood-gates-to-close-this-morning/article_70d14628-c2e4-11e2-b49b-0019bb2963f4.html

https://www.ny1.com/nyc/all-boroughs/news/2018/07/20/flood-barriers-completed-at-two-nyc-tunnels

How Do We Maintain Our Protection?

- Regular inspections of the flood protection system is required by FEMA as part of the certification process (quarterly and annually)
- Regular testing of the deployables is required to ensure that the system functions and can be properly deployed when needed (annually)
- Level of protection of system must be re-evaluated every 5 years to ensure that it still provides the level of protection it was designed to
  - Sea-level rise impacts
  - Land subsidence impacts
  - Impacts from changes to the topography
- Maintenance and Operations Manual for the flood protection system must be prepared and strictly followed
- Perform inspections and repairs (if necessary) after flood events


OPERATION, MAINTENANCE, REPAIR, REPLACEMENT AND REHABILITATION (OMRR&R) MANUAL

FOR

GREEN BROOK FLOOD RISK MANAGEMENT PROJECT

SEGMENT B1

Hurricane Irene aftereffects at Segment B1 construction site – looking toward location of pump station and levee

BOROUGH OF MIDDLESEX & GREEN BROOK TOWNSHIP
MIDDLESEX AND SOMERSET COUNTY
NEW JERSEY

August 2013

Prepared by:
The State of New Jersey

Prepared by:
US Army Corps of Engineers New York District

Coastal Resiliency Design Considerations

- Base Flood Elevation (BFE)
- Height:
  - Water depth
  - Retained height
  - + Sea Level Rise (SLR)
  - + Freeboard (consider Storm Surge, Wave Height, Precipitation, etc.)
  - + Curb
- Utilities
- Access and public
- Permitting and approvals

Design Flood Elevation Examples

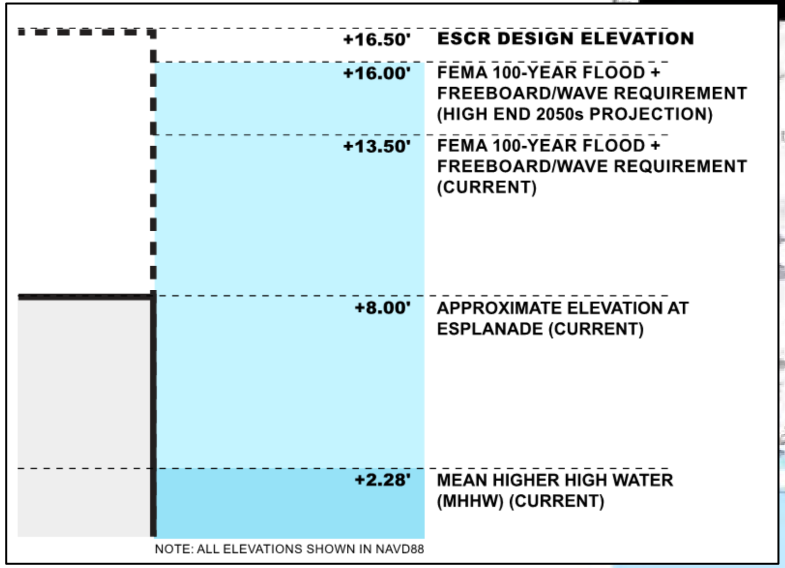
Boston, MA

CONFIDENTIAL

Agency	Flood Model	Design Flood	BFE	SLR (2070)	Freeboard	**Total DFE**
			FT NAVD88	FT	FT	**FT NAVD88**
[illegible]	FEMA FIRM (2016)	100-year	12	3.7	1	**16.7**
[illegible]	BH-FRM (2017)	100-year	9.7	3.3	1	**14.0**
[illegible]	BH-FRM (2017)	100-year	9.7	3.3	1	**14.0**
[illegible]	BH-FRM (2017)	100-year	9.6 (Confirm)	3.3	3	**15.9**
[illegible]	BH-FRM (2017)	500-year	10.7	3.3	3	**17.0**

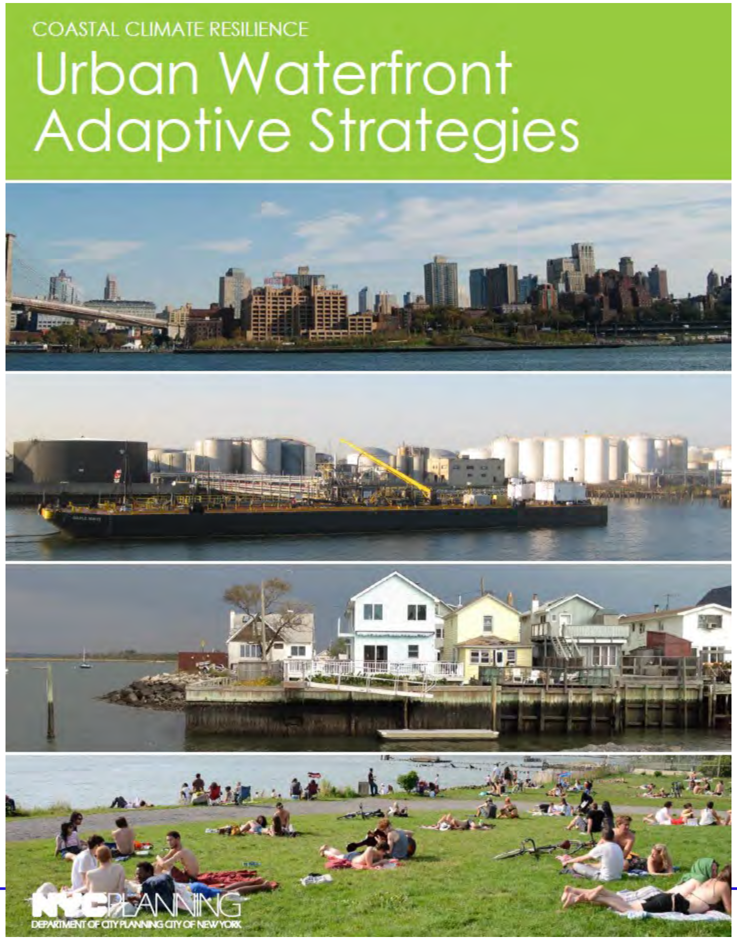
Design Flood Elevation Examples

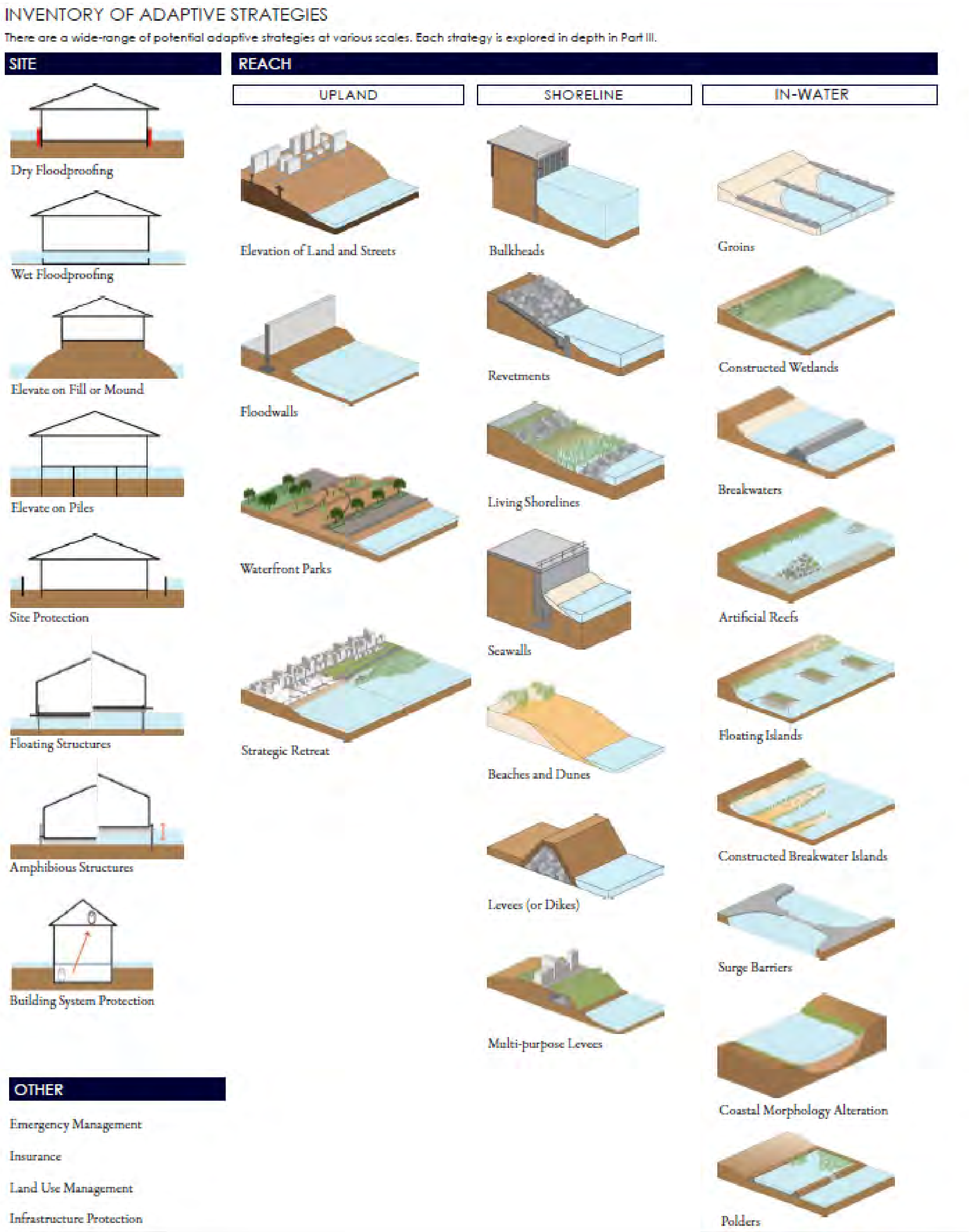
New York, NY



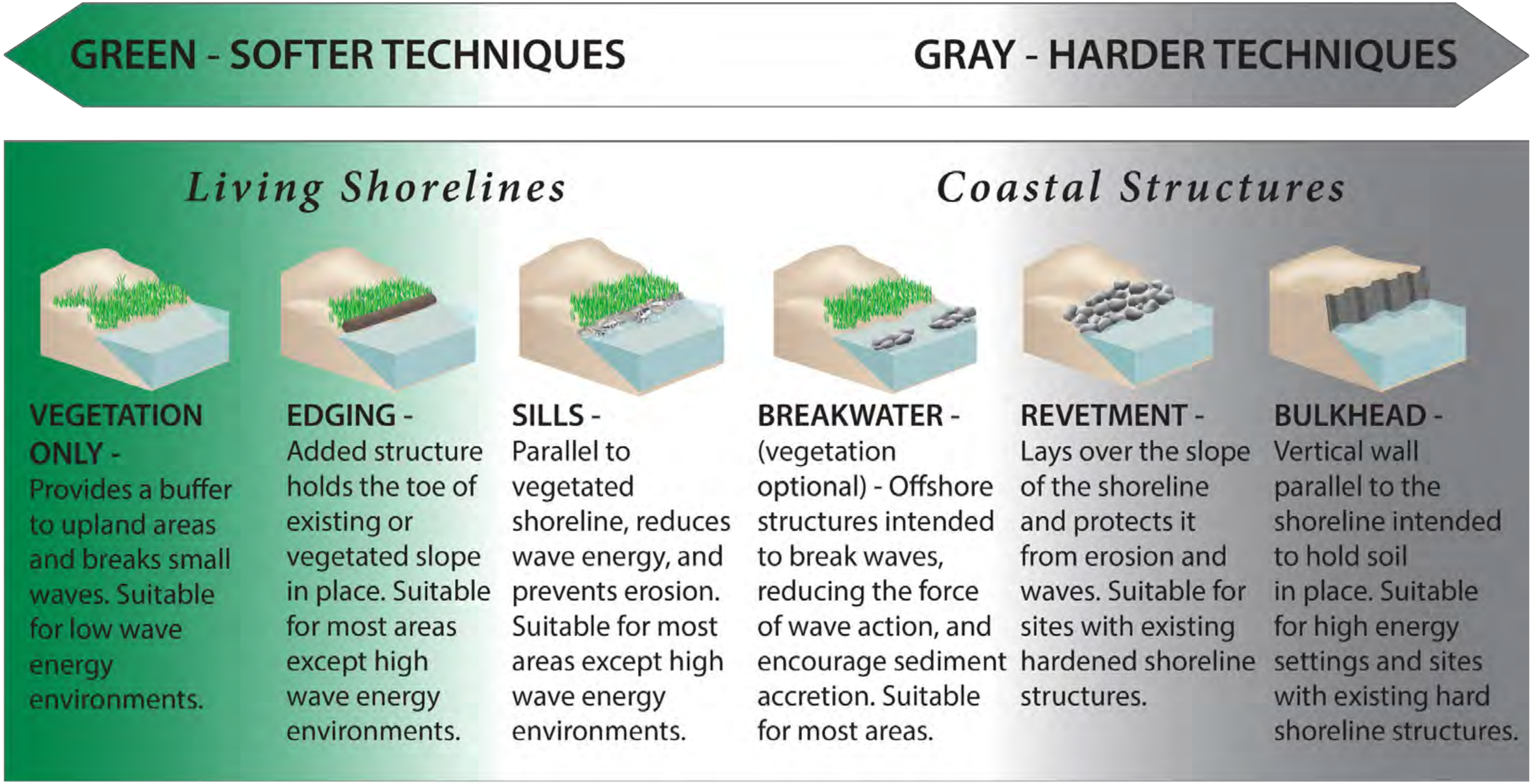
Potential Waterfront Options

- From *Urban Waterfront Adaptive Strategies* by NYC Dept of City Planning 2013.





Potential Waterfront Options



Flood Resilience: A Multi-layered Approach

Resiliency requires integrated solutions that address complex issues like social values, competing resource demands, climate change, extreme events, environmental improvements, aging infrastructure, and funding.

Watch Hill Harbor

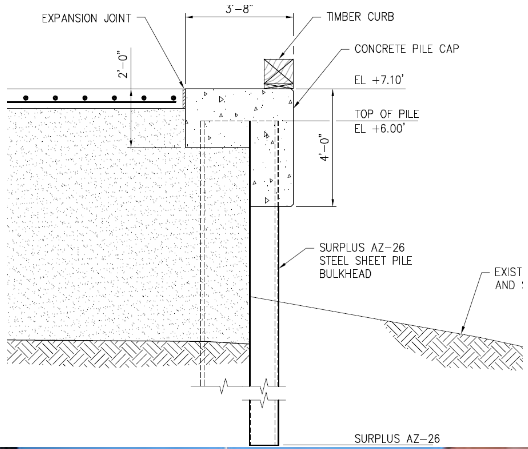
Watch Hill Harbor

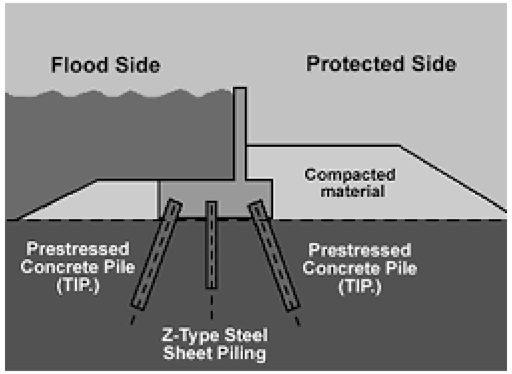
- ~1900 lin-ft of shoreline (excl. second wall on “Cabana-side” of Fort Road)
- Federally authorized channel depth of -10ft
- Various size, type, age, and condition seawalls
- Inadequate height for met-ocean conditions

Potential Options

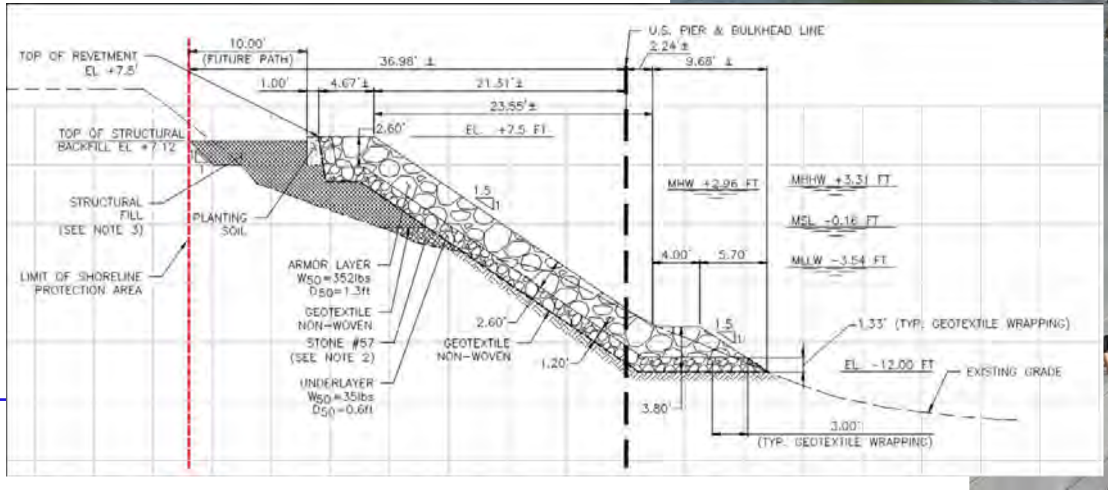
- Bulkhead/Seawall/Floodwall
  - Narrowest option (min1-2ft)
  - “Hard infrastructure

- Revetment/Rock Slope/Living Shoreline
  - Wider: ~ 2H:1V
  - Allows for green & nature-based solutions



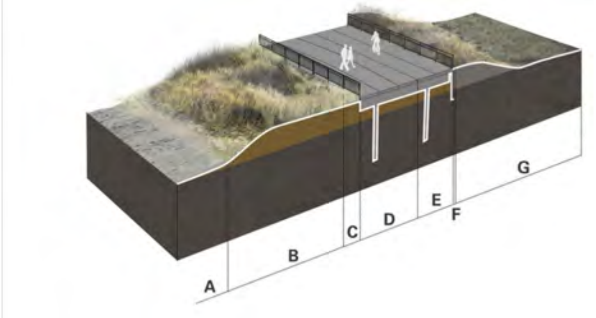


T-Wall supported on a pile foundation

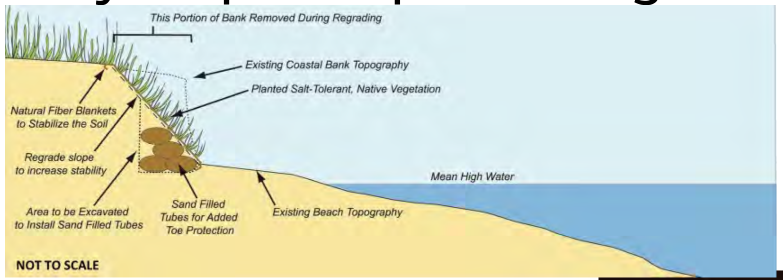


Potential Options in Watch Hill Harbor

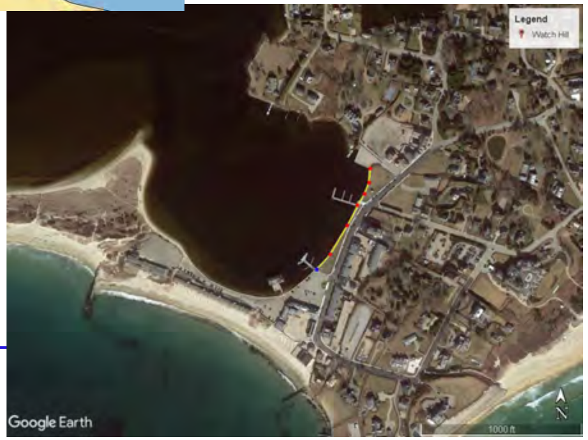
- Bulkheading/Seawall
  - 1200 lin-ft (Misq Club to Dock & Dock by Holdredges)
  - May need second wall along Cabana side



- Revetment/Rock Slope/Living Shoreline
  - 700 lin-ft with space for revetment
  - Takes up more width; approx 2H:1V
  - Likely would require cutting into land vs. pushing out into harbor
  - May help with permitting and approvals



"Living Shorelines in New England: State of the Practice, The Nature Conservancy, July 2017



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