BUILDINGENERGY BOSTON

The Power of Systems Thinking

Designing Equitable and Resilient Infrastructure

Katie Wholey, Arup

Northeast Sustainable Energy Association (NESEA) | March 20, 2024

ARUP

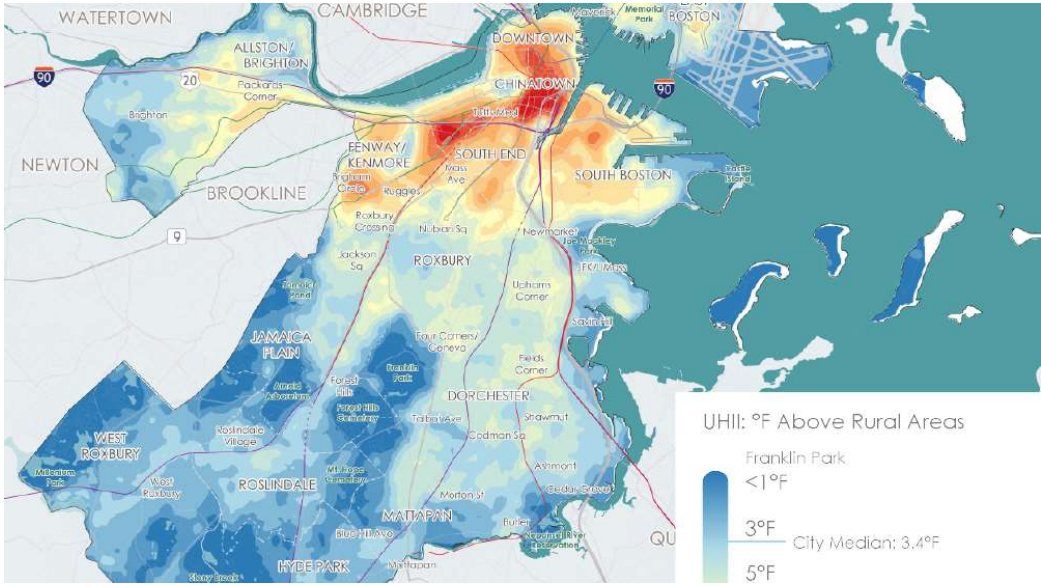
The Power of Systems Thinking

Designing Equitable and Resilient Infrastructure


Source: Chis Christo | Boston Herald


Source: Dave Thompson | MassLive.com


YIELD
TO PEDESTRIANS ON TURNS


WATERTOWN
CAMBRIDGE
BOSTON
ALLSTON/ BRIGHTON
DOWNTOWN
CHINATOWN
NEWTON
BROOKLINE
FENWAY/ KENMORE
SOUTH END
SOUTH BOSTON
ROXBURY
JAMAICA PLAIN
DORCHESTER
WEST ROXBURY
ROSLINDALE
MATTAPAN
HYDE PARK
UHII: °F Above Rural Areas
Franklin Park
<1°F
3°F
City Median: 3.4°F
5°F

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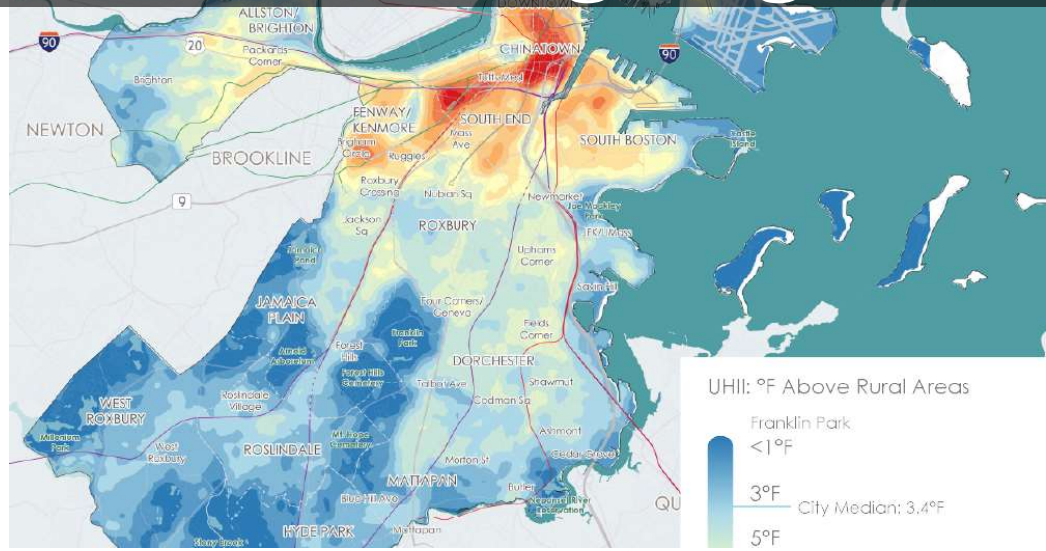
What can go wrong? → What has to go right?



Source: The New York Times

Source: Reuters, Eduardo Munoz

Do these pictures represent resilience to climate change and extreme weather?

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Do these pictures represent resilience to climate change and extreme weather?

Can a property be resilient on its own without considering the broader community?

Source: The New York Times

Source: Reuters, Eduardo Munoz

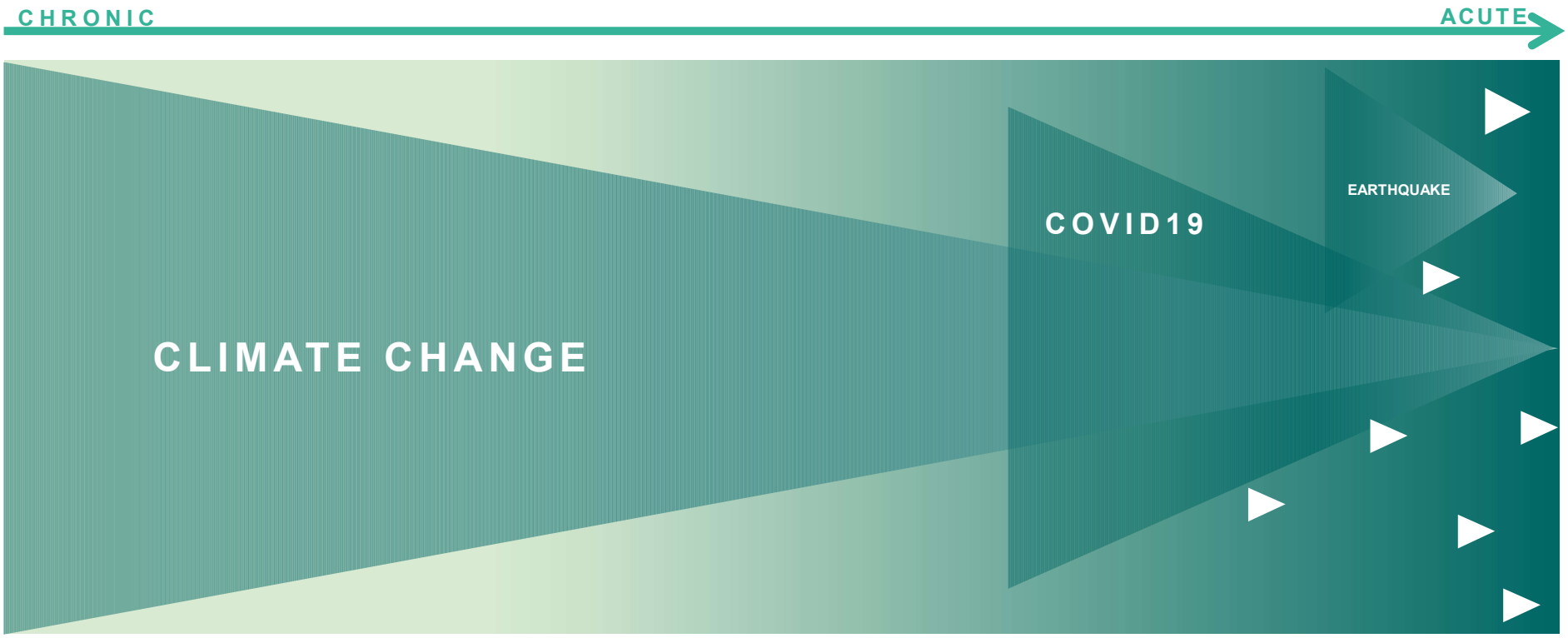
Resilience… of what?

to what?

for whom?

Resilience of what?
Building resilience of the built environment

Resilience to what?
A spectrum of shocks and stresses



Resilience for whom?
Beneficiaries of resilience

Our focus is on improving outcomes for the health, wellbeing and opportunity of people, especially the most vulnerable.

This requires an integrative approach to building resilience, working with partners and clients across sectors, from policy to design to critical infrastructure, asset management.

Policy Makers
Politicians, planners

Designers & Planners
Architects, engineers, product designers

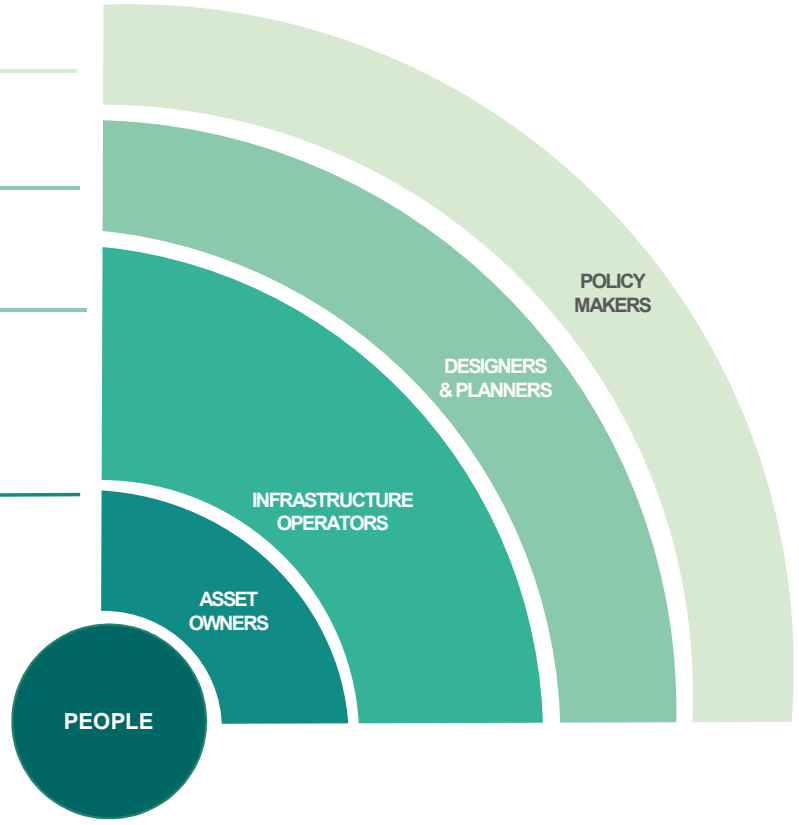
Infrastructure Operators
Transit Authorities, Airports, Ports, Utilities, Water Agencies

Investment Asset Owners
Insurers, Pension Funds, Infrastructure Funds

Real Estate Asset Owners
Retail chains, Real Estate Portfolio Companies

Sensitive / Critical Asset Owners
Hospitals, Banks, Data Centers, Tech Companies

Communities
Especially the poorest & most vulnerable



Lower Mystic Climate Vulnerability Assessment

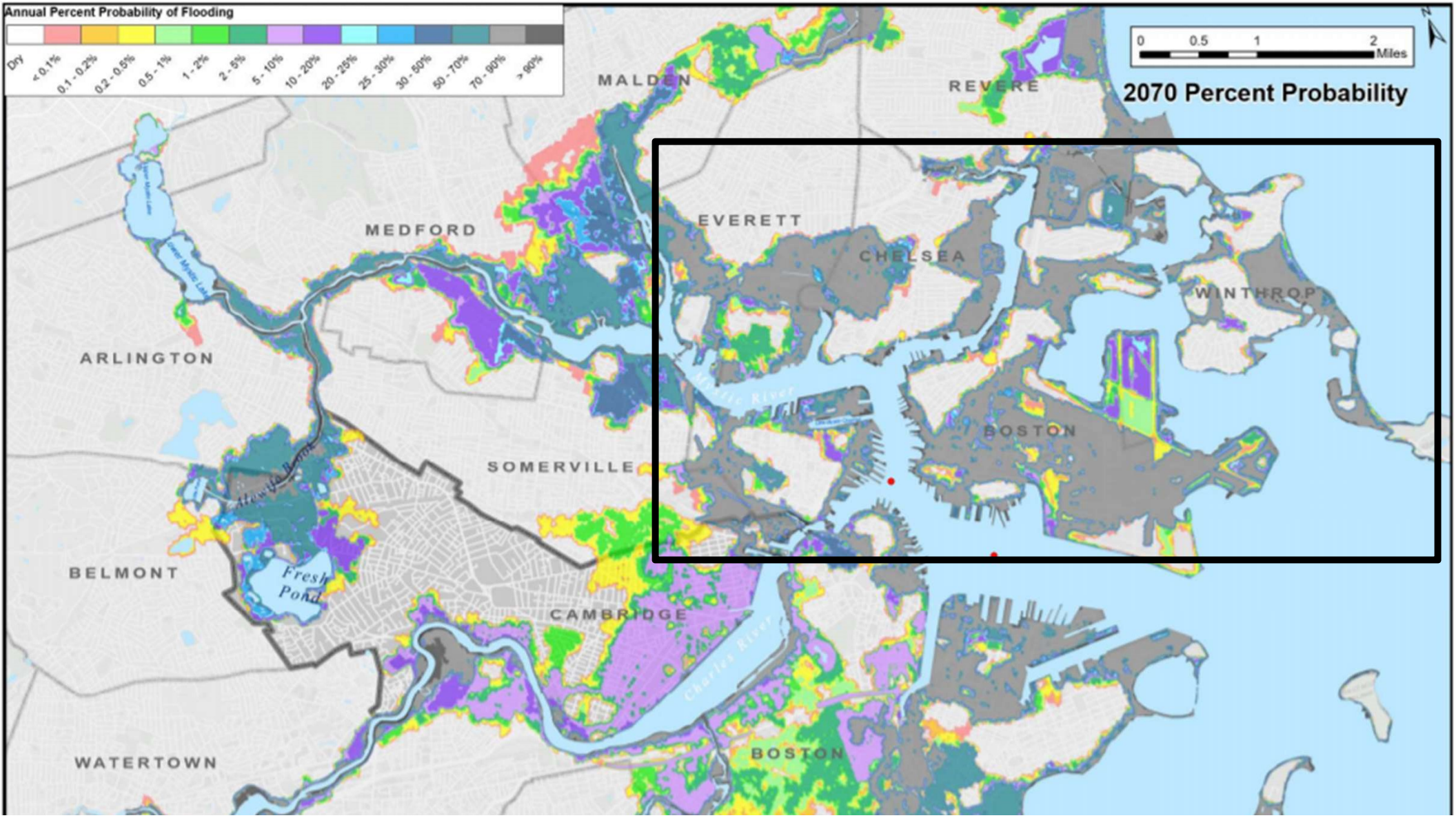
An Equity-driven Critical Infrastructure Assessment

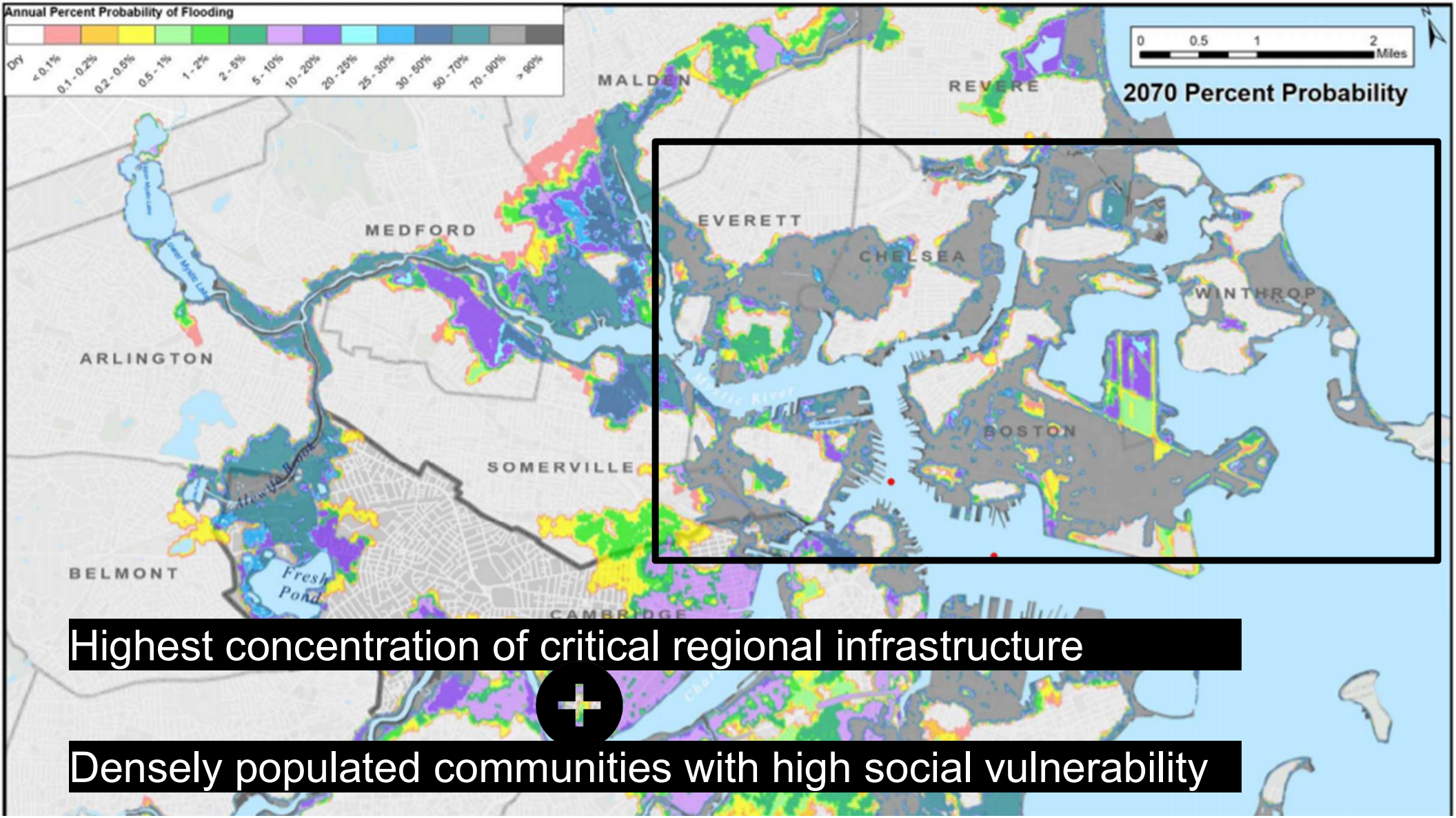
First Research Question

What critical infrastructure is at risk from a 2050 1% coastal storm?

Second Research Question

If infrastructure fails, what happens to vulnerable people?


Annual Percent Probability of Flooding
Dry
< 0.1%
0.1 - 0.2%
0.2 - 0.5%
0.5 - 1%
1 - 2%
2 - 5%
5 - 10%
10 - 20%
20 - 25%
25 - 30%
30 - 50%
50 - 70%
70 - 90%
> 90%
0
0.5
1
2
Miles
2070 Percent Probability
MALDEN
REVERE
MEDFORD
EVERETT
CHELSEA
WINTHROP
ARLINGTON
BOSTON
SOMERVILLE
Mystic River
Alewife Brook
Fresh Pond
BELMONT
CAMBRIDGE
Charles River
BOSTON
WATERTOWN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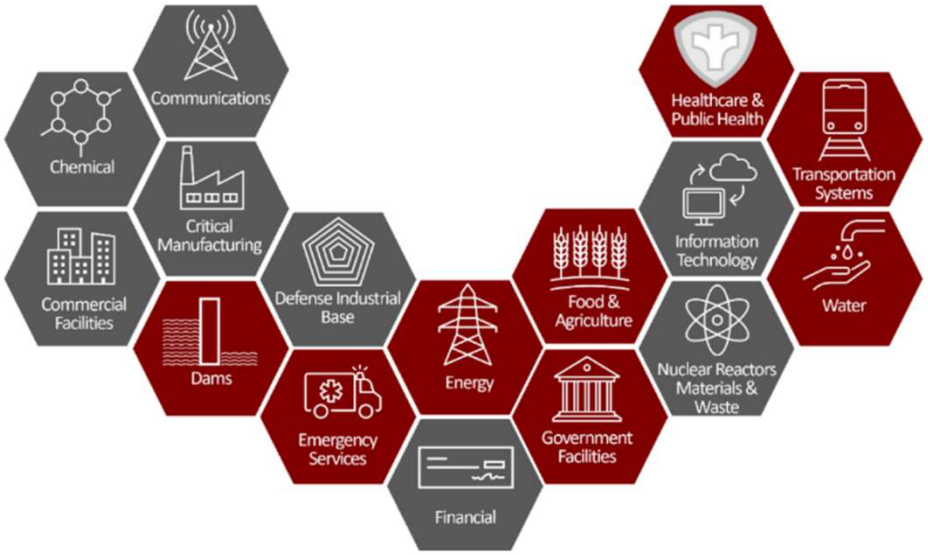
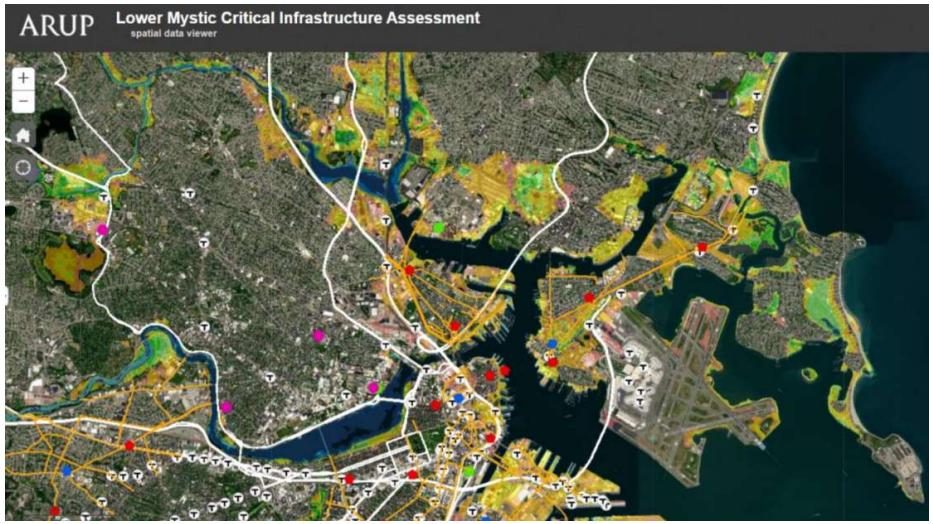
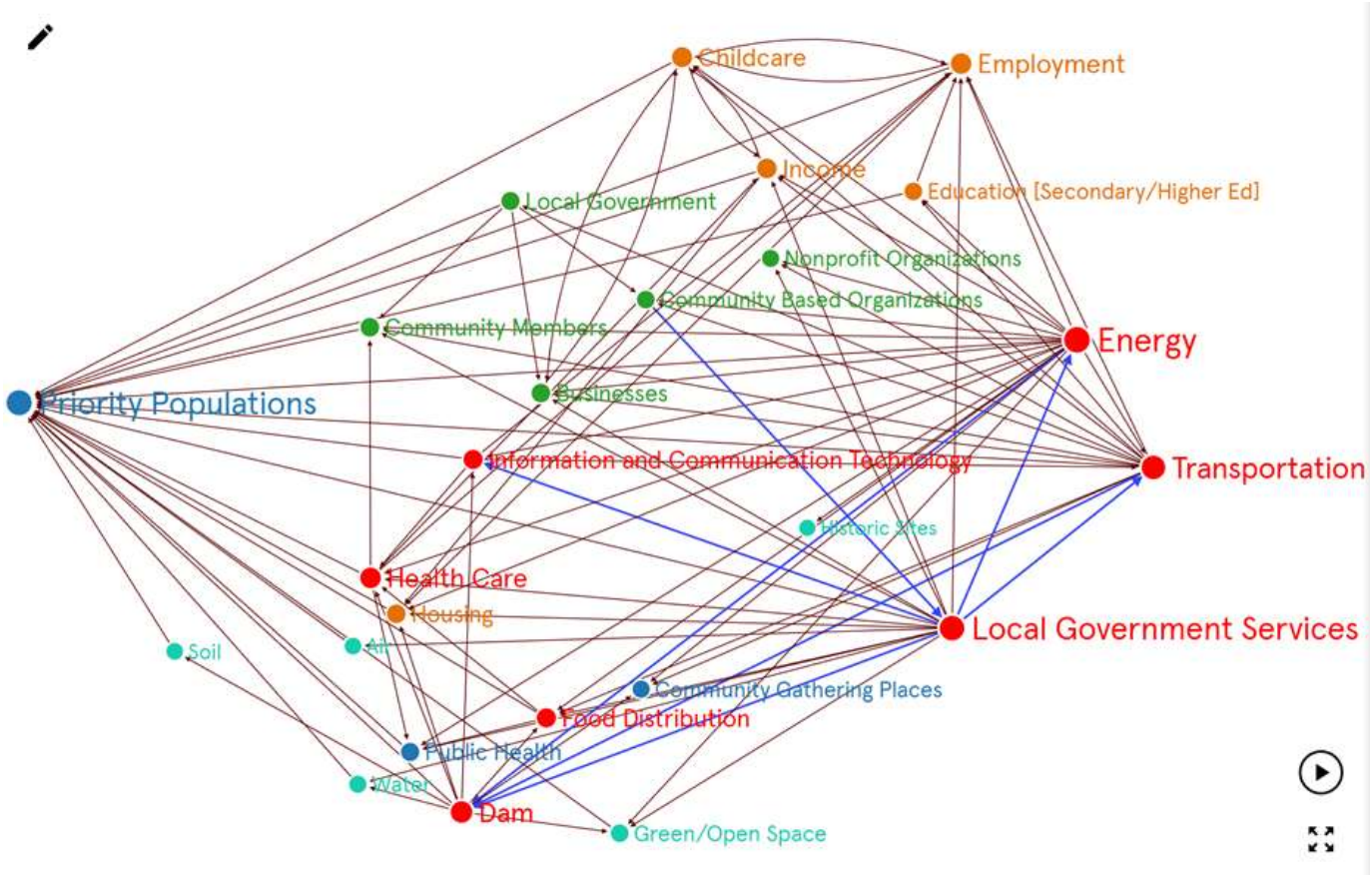
SOMERVILLE
BELMONT
Fresh Pond
CAMBRIDGE
Highest concentration of critical regional infrastructure
+
Densely populated communities with high social vulnerability

Critical Infrastructure Vulnerability



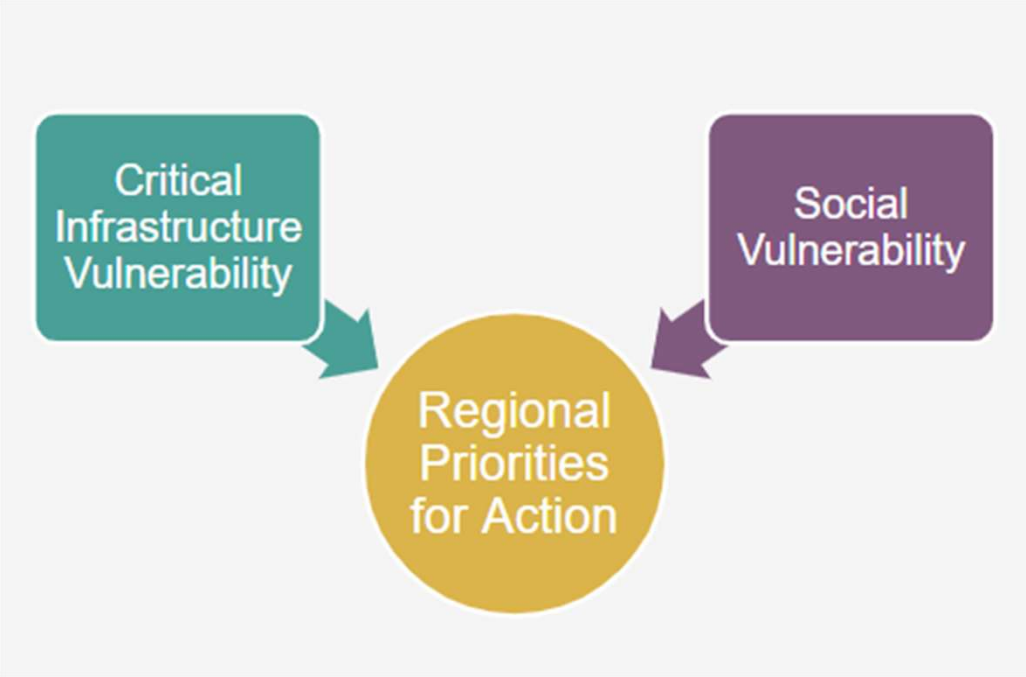


Social Vulnerability



- **Literature review** of past impacts to priority populations during extreme weather events
- **Survey of 400 community members** (supported by local Community-based Organizations)
- **Focus Groups** held in multiple languages

Key Findings



"Shovel-worthy" projects

- MassDCR Amelia Earhart Dam
- Everett/Chelsea Island End River
- MBTA Blue Line
- MassDOT Harbor Tunnels

Projects Needing Funding

- Grid/cell resiliency
- Bus/pedestrian resiliency
- Resilience hubs
- Community health centers

Lower Mystic Takeaways

- **Why this is different:** Each system is normally assessed in a silo – this assessment required consideration of interconnections and understanding of how users are impacted by failures
- **How it changes the outcome:** Changing the question from "where is the most value at risk" to "who stands to lose the most"?
- **What we learned:**
  - Expand what we consider "infrastructure"
  - Shift how we identify priorities – not just the most value at risk
  - Always keep in mind who we are designing for and don't make assumptions about what they need.

So…what does this mean for you?

Set the context early & expand your boundaries

Understand the full context of your project as early as possible

Challenge your design thinking to consider how your project fits into the larger "system"

Question "traditional" analysis

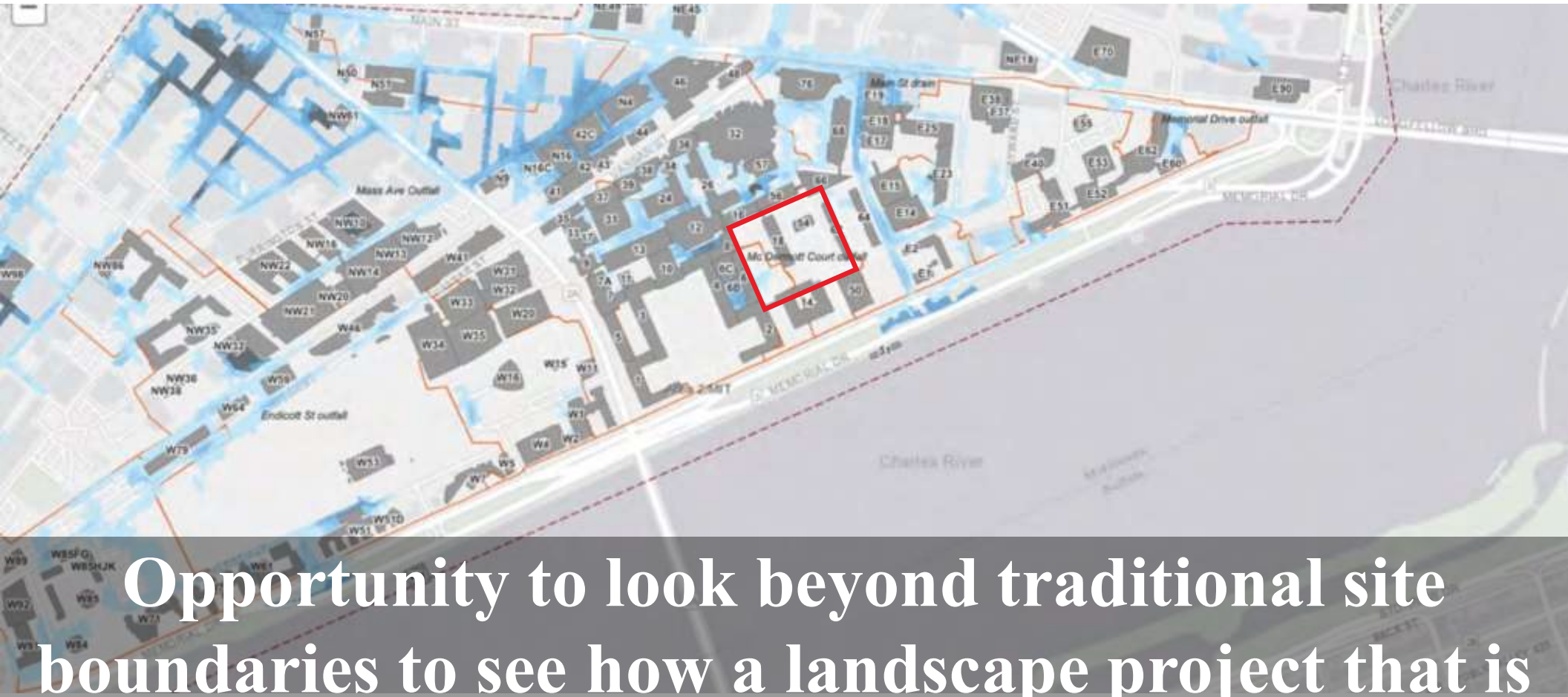
We have the data we need to change our design process. We just need to ask ourselves if our "traditional" analysis is achieving the more equitable and resilient outcome?

Design for flexibility & adaptability

The natural and social environments are not static. We need to allow for our built environment to adapt along with them.

Set the context early & expand your boundaries

Thinking of a campus as a system



Opportunity to look beyond traditional site boundaries to see how a landscape project that is NOT at risk of flooding can support flood mitigation for the broader campus

Question the “traditional” analysis

Benefit Cost Analysis


Jack Hogan
Associate
Arup


Emily Schwimmer
Senior Associate, Sustainable Economics
AECOM

Traditional BCA depends on scientific projections & $ value of losses/benefits

Hazard Modeling

- What flood depths are possible?
- How frequently does it occur?

Exposure Analysis

- What types of buildings, businesses, and critical infrastructure will be impacted?

Value of Losses/Benefits

- What is the estimated value of the impacts to buildings, structures, and businesses?

Project Prioritization & Selection

Benefit Cost Analysis

The BCA does <u>not</u> grapple with population differences or social inequities

<u>Hazard Modeling</u>

- What flood depths are possible?
- How frequently does it occur?

<u>Exposure Analysis</u>

- What types of buildings, businesses, and critical infrastructure will be impacted?

<u>Value of Losses/Benefits</u>

- What is the estimated value of the impacts to buildings, structures, and businesses?

<u>Population Differences</u>

- Who is impacted? What is their ability to recover from an event?

Opportunity

How can we augment the benefit cost analysis to account for equity?

Benefit Cost Analysis

(BENEFITS)
total avoided losses over time

minus

(COSTS)
investment requirements of project alternatives

results in

NET BENEFITS

	Levee A	Levee B
Cost	$10m	$10m
Losses Avoided	$15m	$25m
Net Benefits	$5m	**$15m**

Benefit Cost Analysis

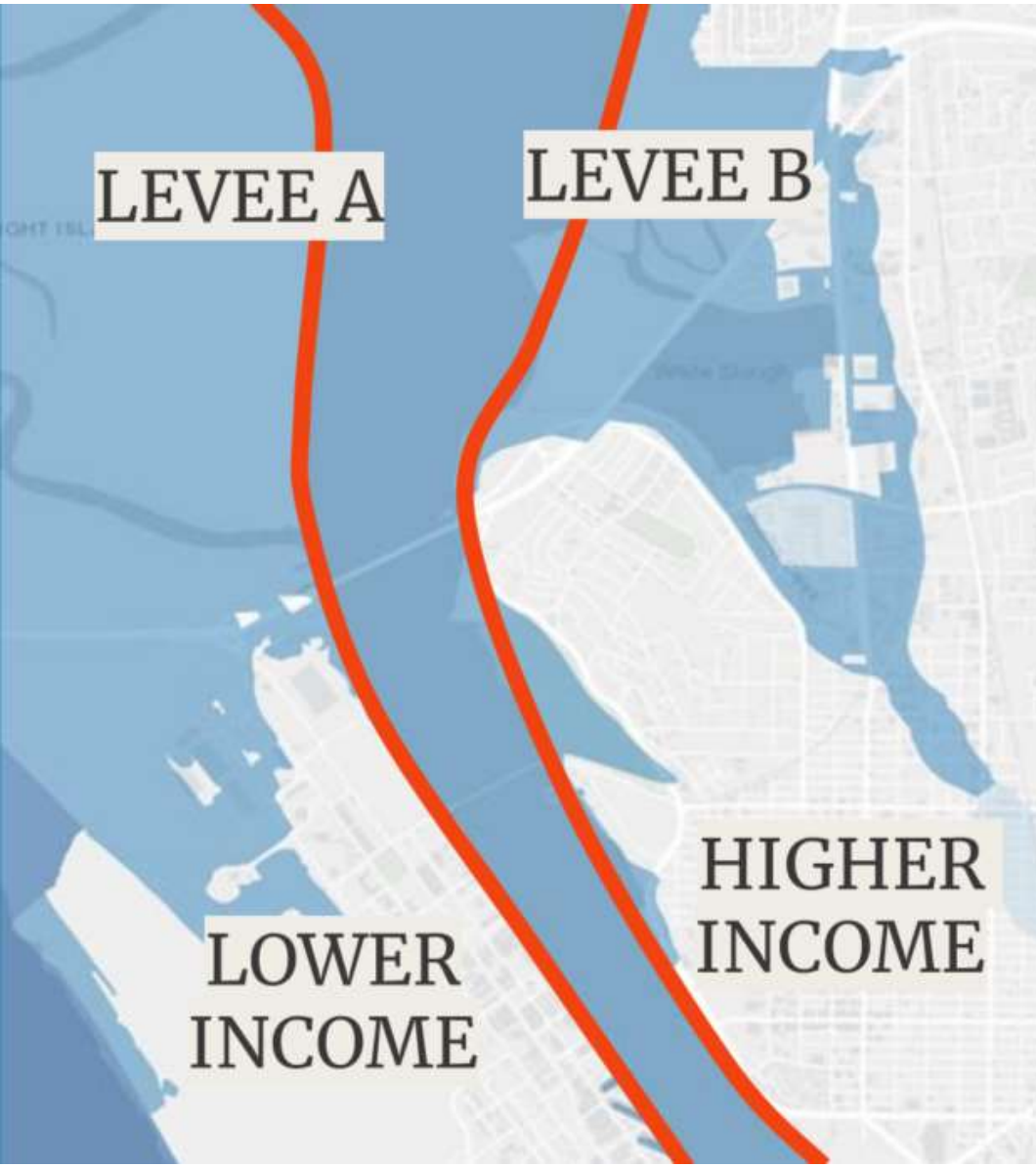
(BENEFITS)
total avoided losses over time *multiplied* by the equity weight

minus

(COSTS)
investment requirements of project alternatives

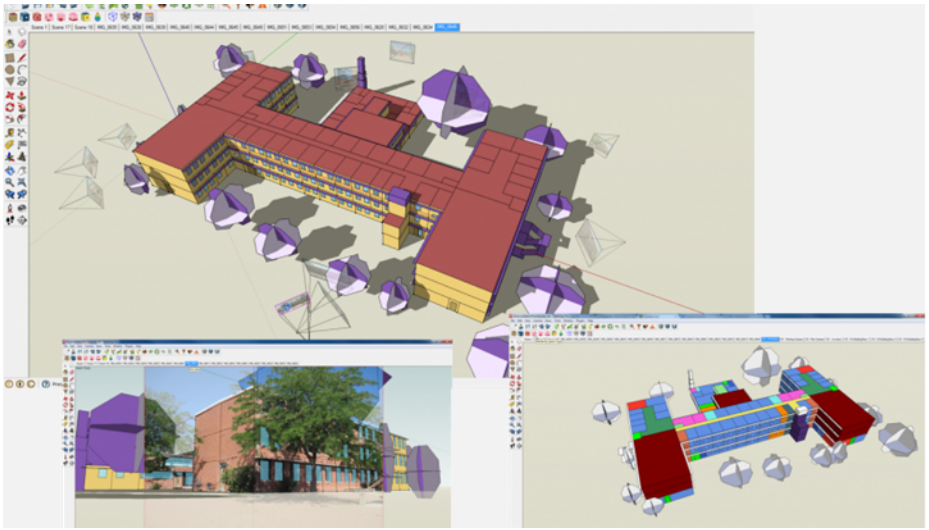
results in

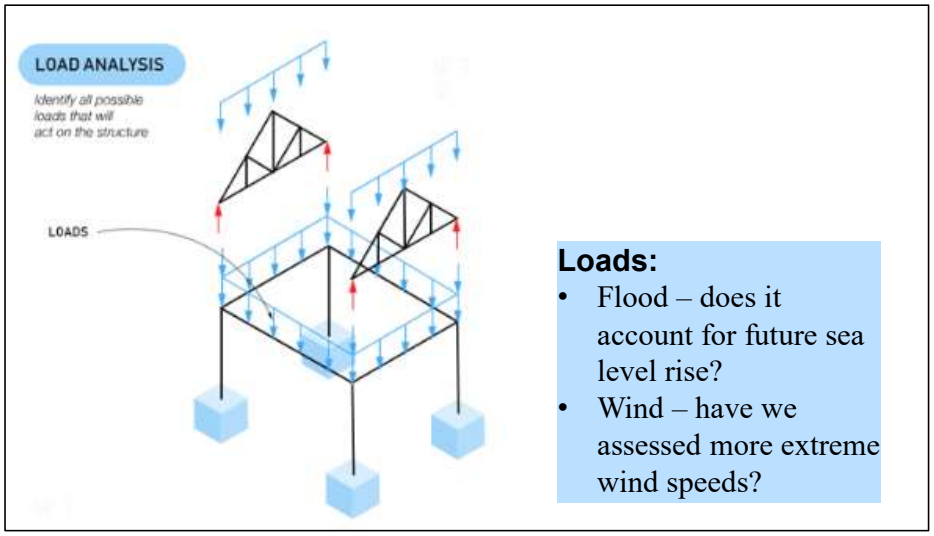
NET BENEFITS



	Levee A	Levee B
Cost	$10m	$10m
Losses Avoided	$15m	$25m
Net Benefits	$5m	$15m
Median Income	$75K	
Household Income	$50k	$100k
Weighting Factor	***1.5***	***0.75***
Value of Avoided Losses	$22.5m	$18.75m
Weighted Net Benefits	**$12.5m**	$8.75m

At a building scale, this may look like…





Loads:
- Flood – does it account for future sea level rise?
- Wind – have we assessed more extreme wind speeds?

Modifying your energy models & MEP system design

Designing more for annual extremes

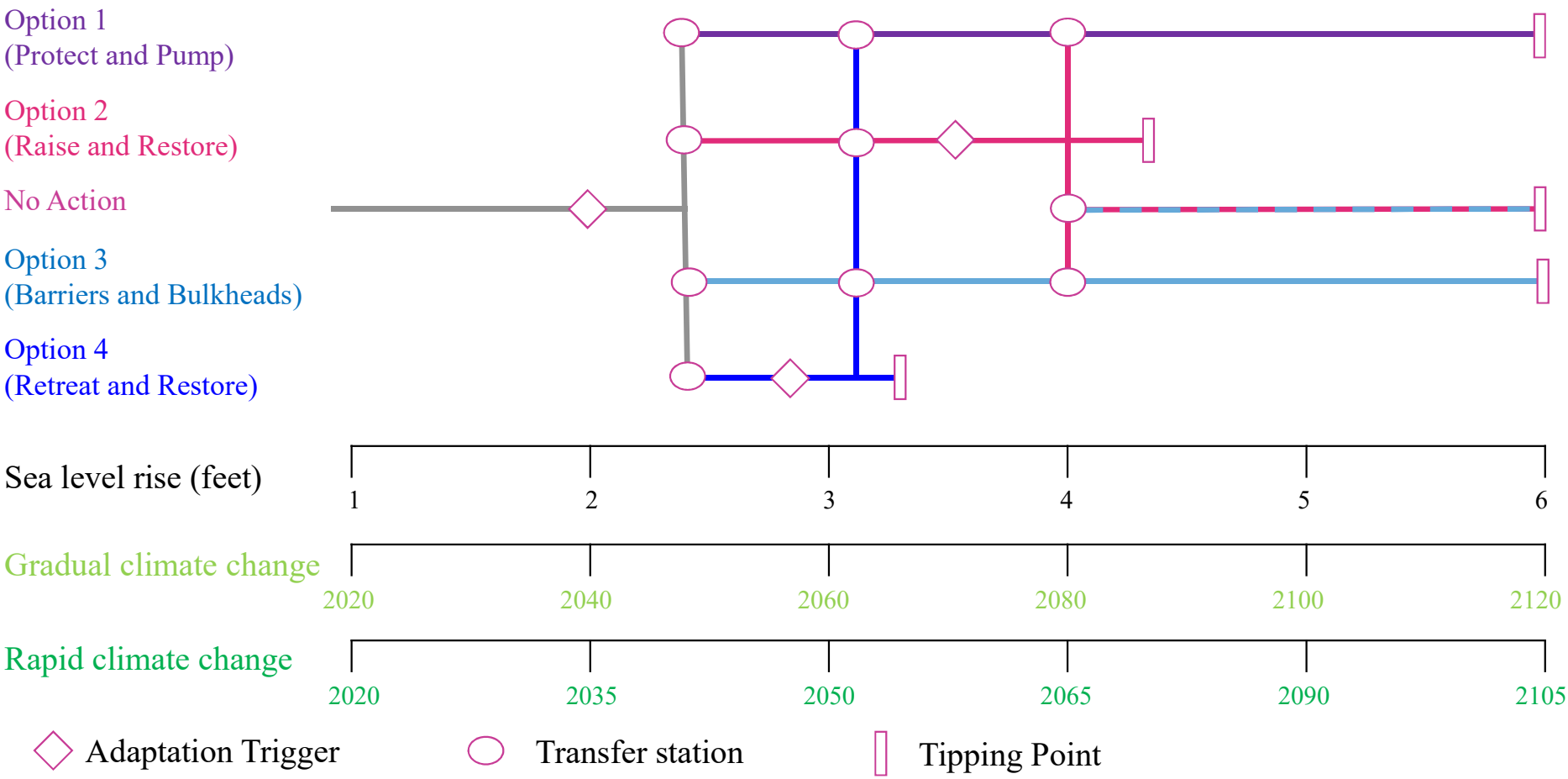
Tools for obtaining future design day conditions

Adjusting your structural loads

"Future cast" load factors to account for changing future climate conditions

Design for Flexibility and Adaptability

Adaptation Pathways



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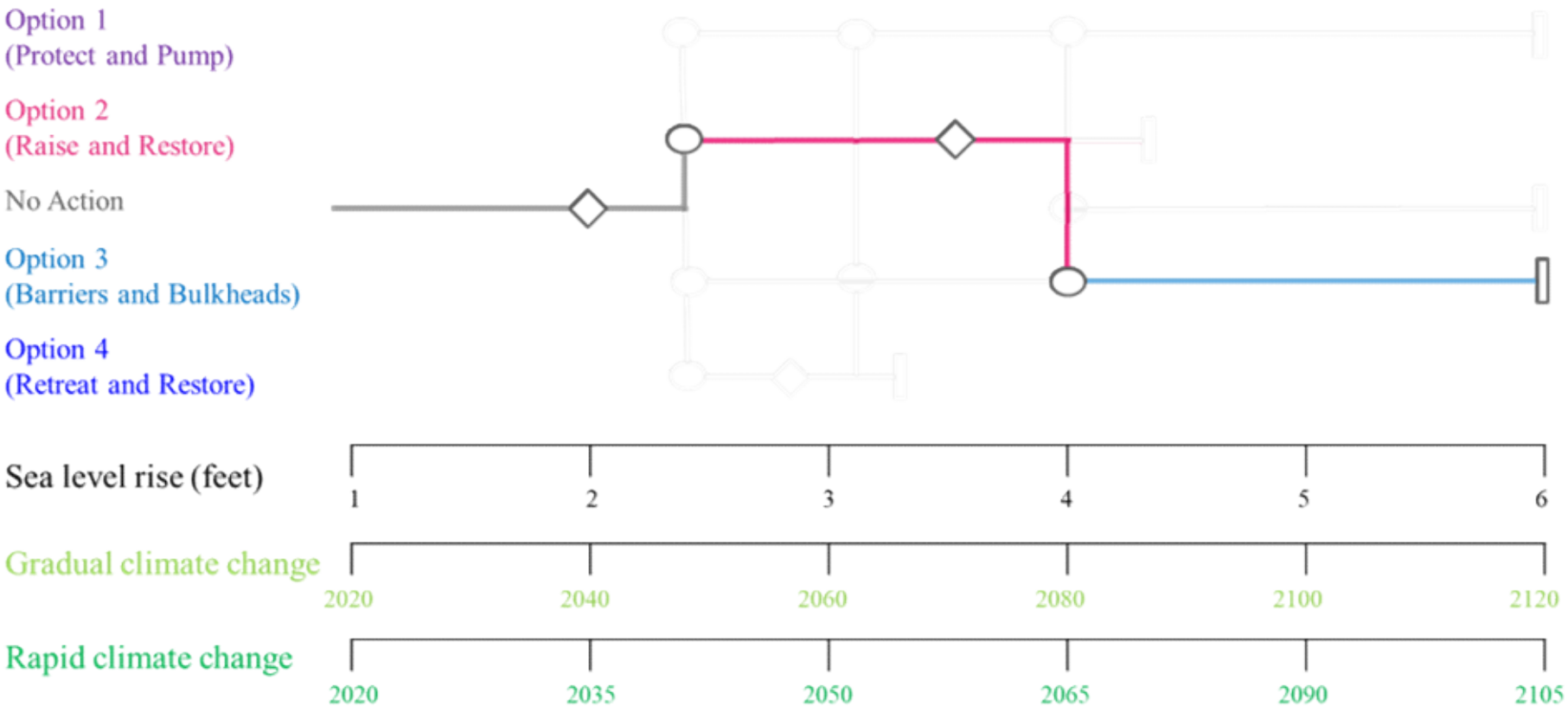
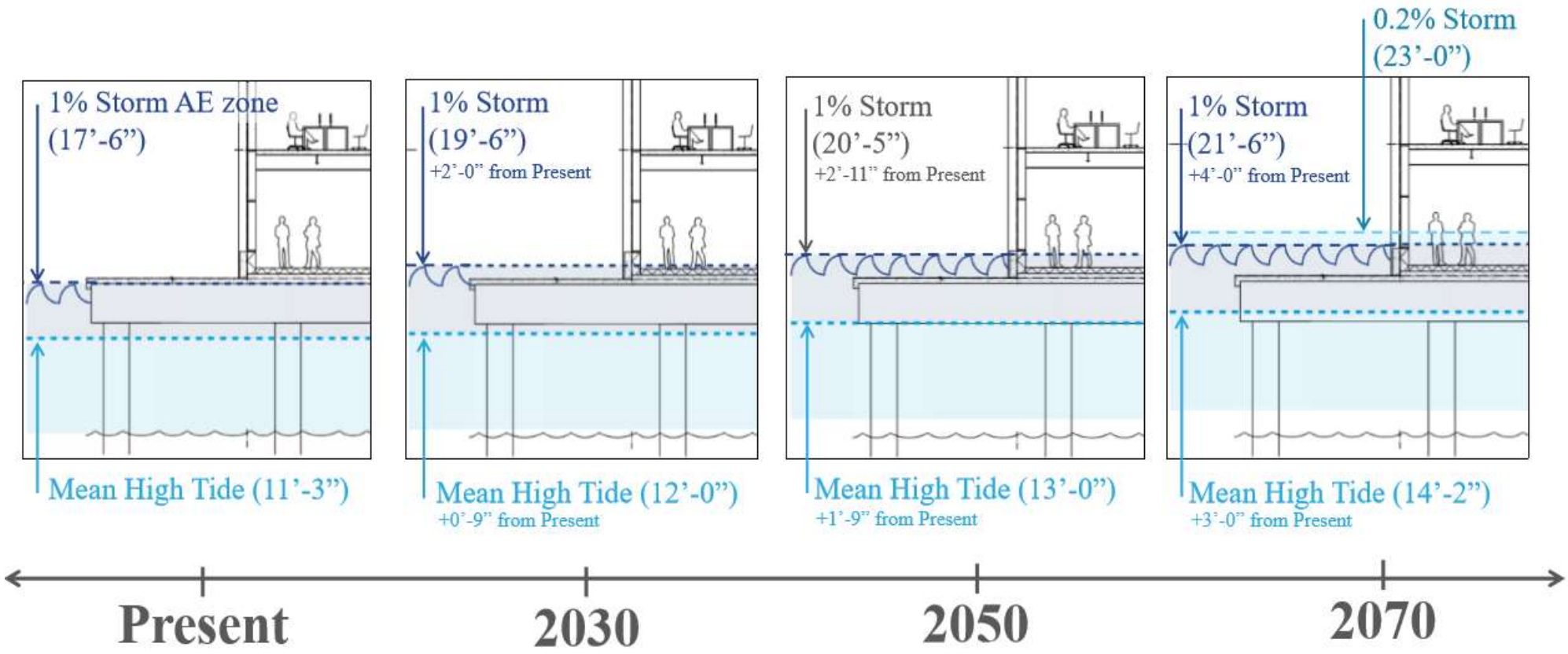


Commonwealth Pier

Future Flood Projections



Resilience Strategy

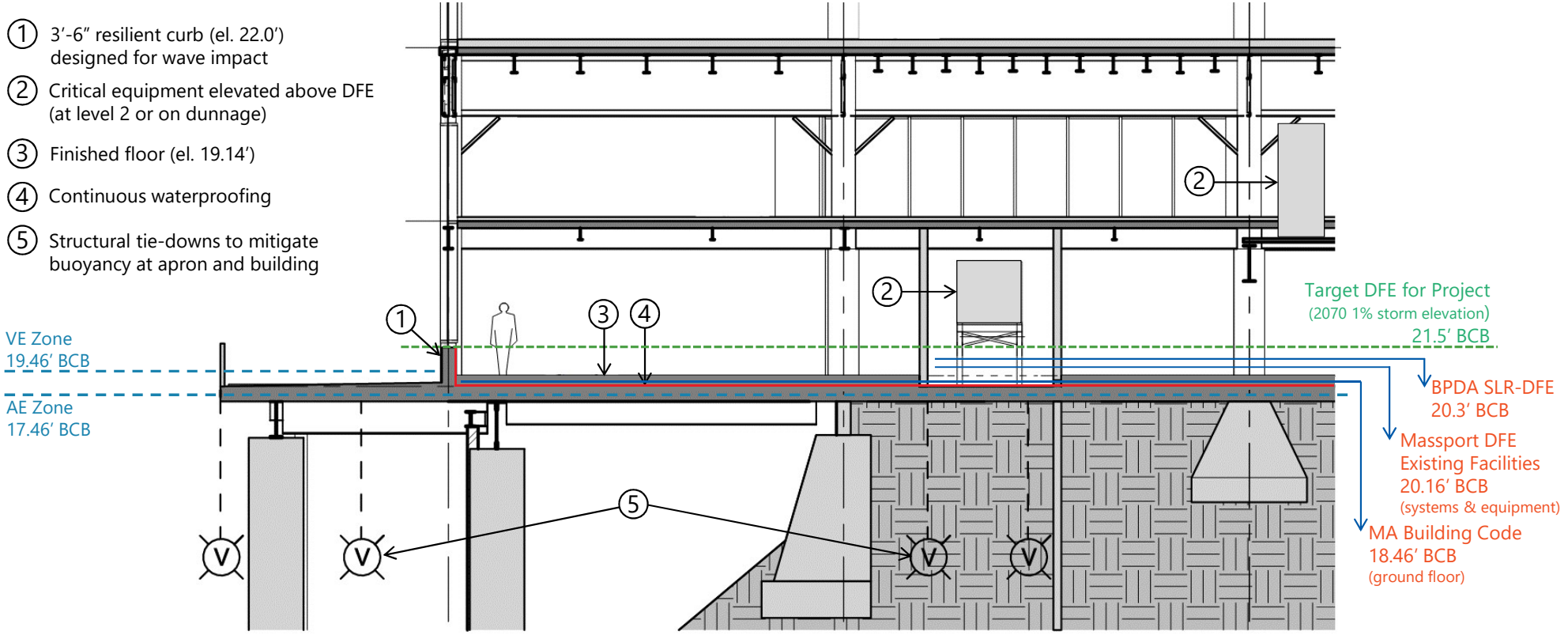
① 3′-6″ resilient curb (el. 22.0′) designed for wave impact

② Critical equipment elevated above DFE (at level 2 or on dunnage)

③ Finished floor (el. 19.14′)

④ Continuous waterproofing

⑤ Structural tie-downs to mitigate buoyancy at apron and building



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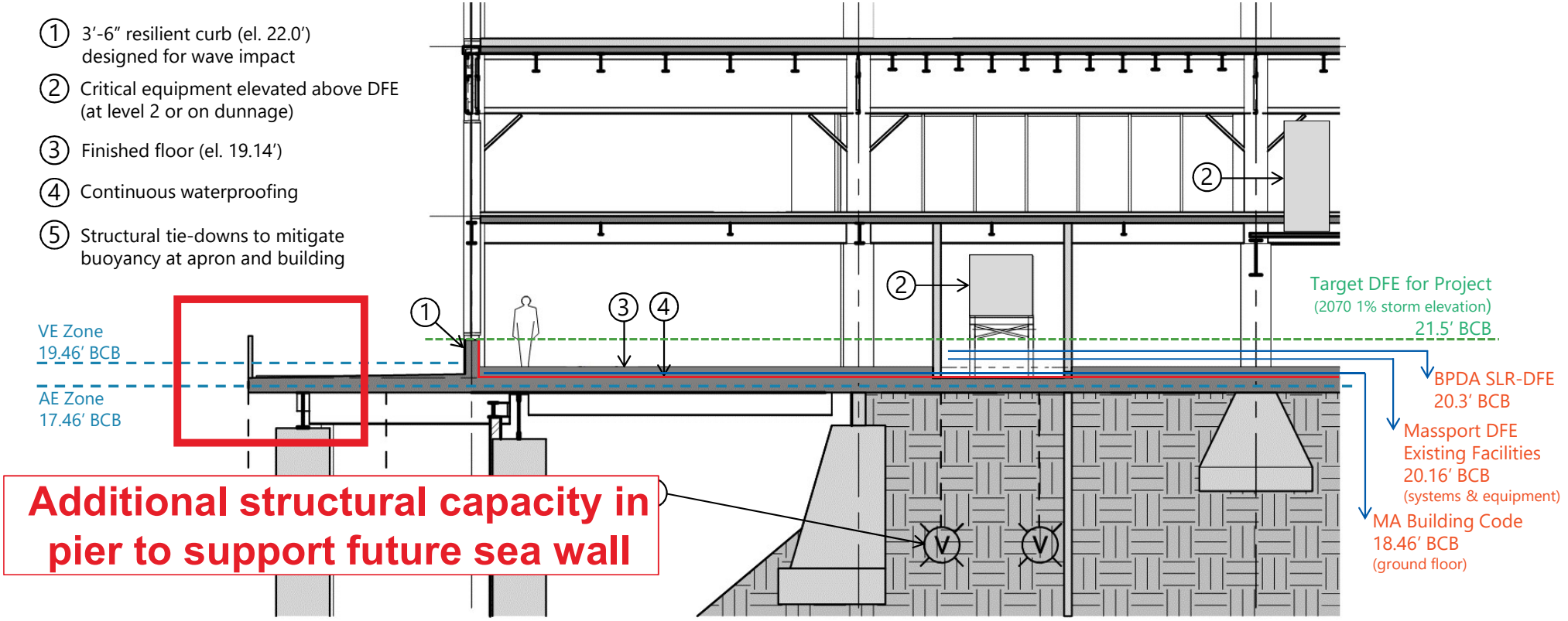
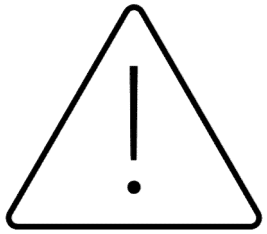
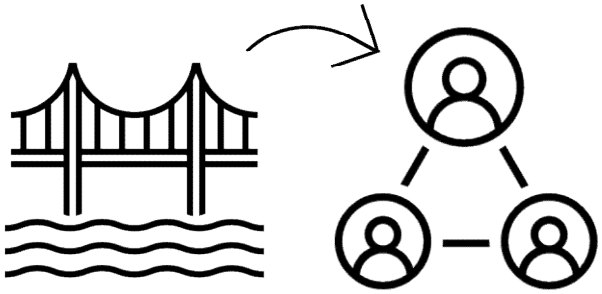


Concluding Thoughts

The past is not representative of the future – the future will be different, and we need to design for change and uncertainty.



Move away from the idea that we can engineer "out" risk. Move towards thinking about what happens if our systems fail and who stands to lose the most?



Understand that engineered systems **MUST exist within the social context.**

Thank you!

Join us for a discussion

@ 4pm in Marina 3-4

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