welcome

Weston & Sampson

Weston & Sampson[SM]

transform your environment

Implementation of Climate Adaptation Measures

Massachusetts Municipal Association

January 19, 2018

Frank Ricciardi, PE, LSP

Introduction

<u>Weston & Sampson Recent Resiliency Projects</u>

- MBTA Resiliency GEC – Ongoing services, Massachusetts
- MBTA Blue Line Flood Vulnerability Assessment (Aquarium to Maverick Portal) – Ongoing, Massachusetts
- Division of Capital Asset Management and Maintenance (DCAMM) Statewide Resilience Master Plan - Massachusetts
- Climate Change Vulnerability Assessment & Adaptation Plan – Lynn, MA
- Church Creek Drainage Study – South Carolina
- Chelsea Flood Resiliency Improvements – Chelsea, MA

Municipal Resilience Process

PHASE 1 – CLIMATE SCENARIO SELECTION

TASK 1
Map climate conditions under future conditions

PHASE 2 – VULNERABILITY AND RISK ANALYSIS

TASK 2
Identify critical assets located in vulnerable areas

TASK 3
Identify the tipping point that would damage each critical asset

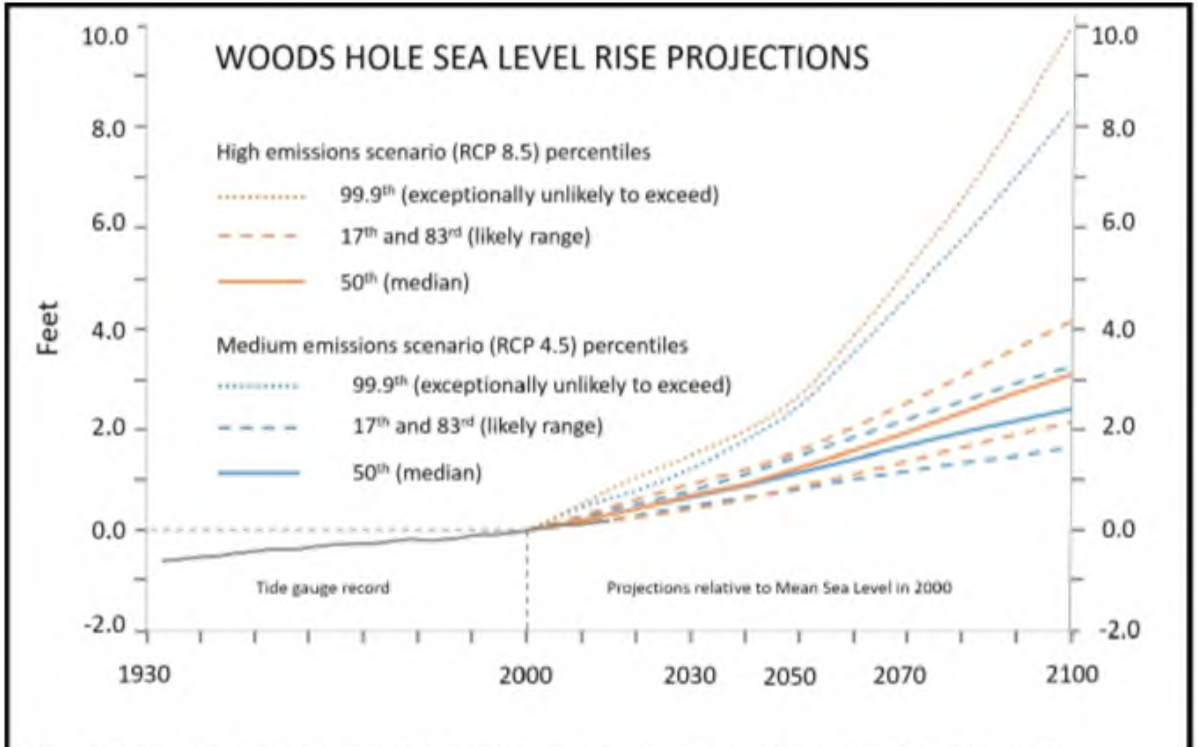
TASK 4
Evaluate risk given probability of climate scenario and consequence

PHASE 3 – ADAPTATION STRATEGIES

TASK 5
Identify and select adaptation strategies (criteria comparison)

TASK 6
Implement adaptation and preparedness plan and monitor progress

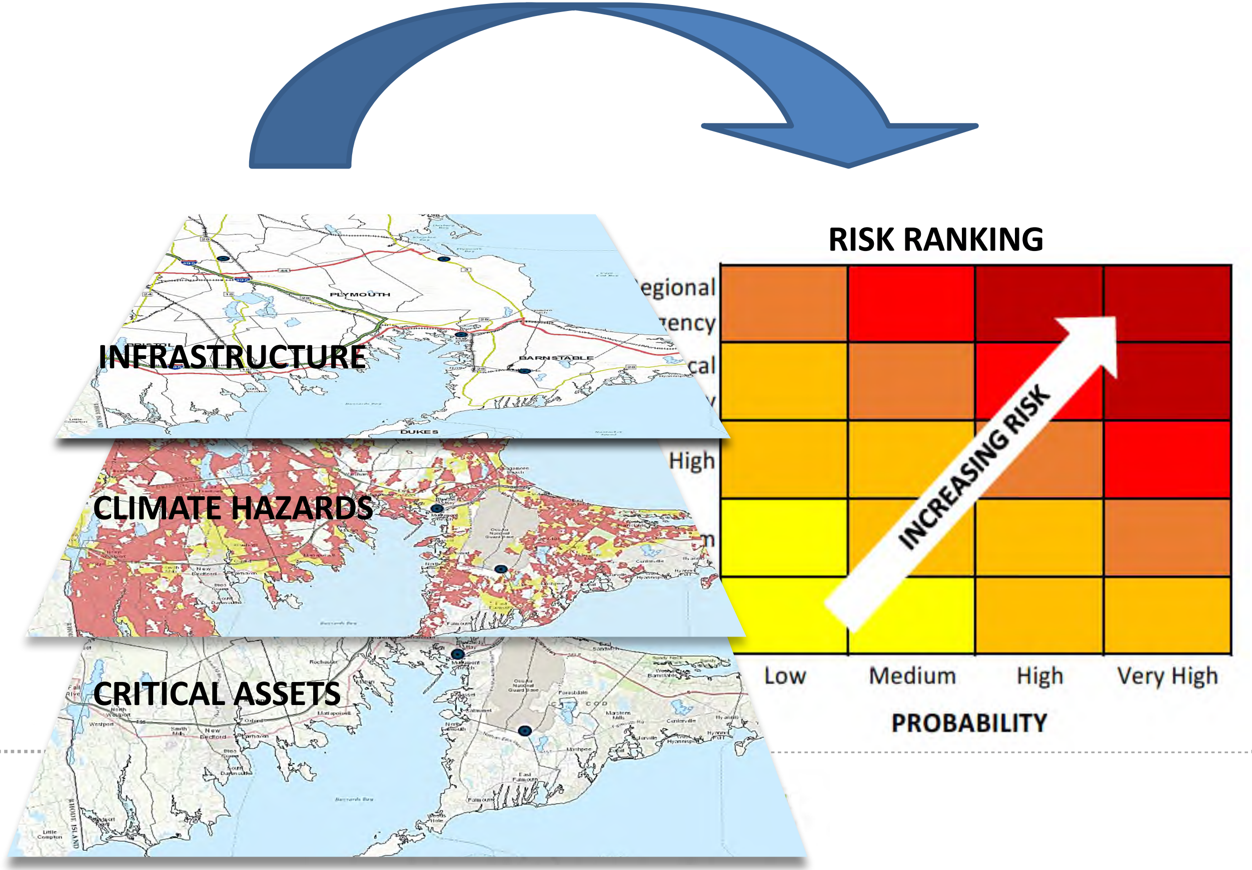
PHASE 1 – CLIMATE SCENARIO SELECTION



*These projections of sea level rise do not include potential contributions from significant losses of the Antarctic ice sheet.

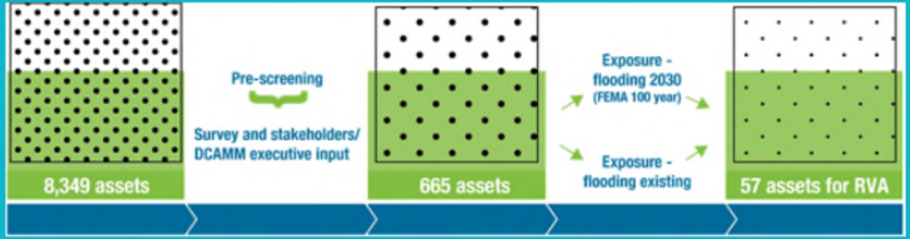
Source: EOEEA

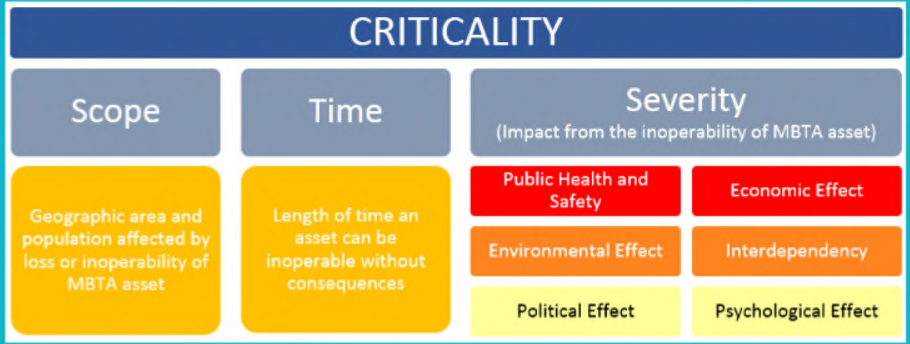
PHASE 2 – VULNERABILITY AND RISK ANALYSIS



Criticality

- Portfolio Review
- Pre-selected Assets
- Stakeholder Feedback
- Exposure
- Consequences

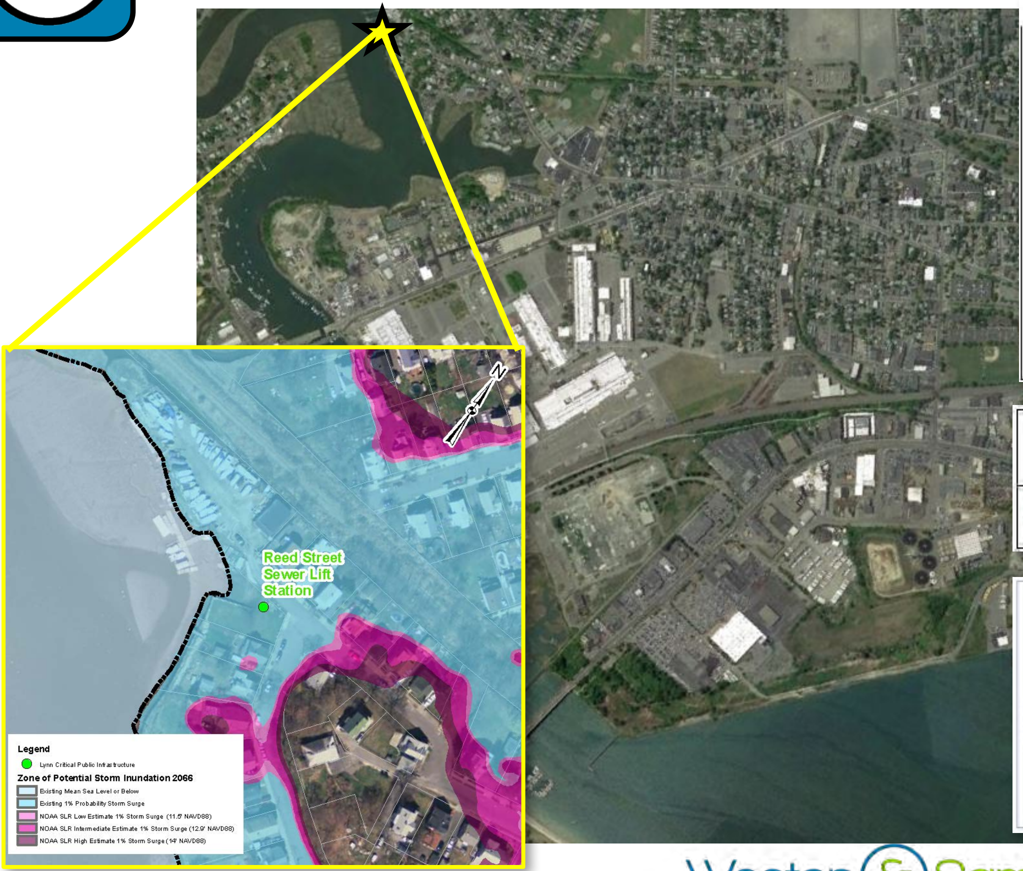




Criteria Describing Consequence

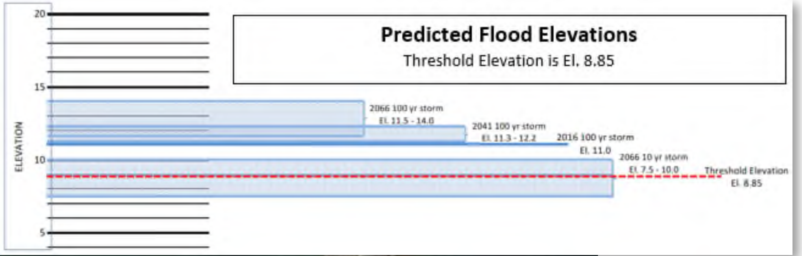
Score		Public Safety, Emergency Services	Public Health, Environment	Repair cost	Reduced Economic Activity	Public Services; Duration
Severity	5	Regional Emergency	Regional Emergency	>$20MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2MM - $20MM	City Emergency	15-30 Days
	3	High	High	$200K - $2MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Lynn EDIC – Pump Station Example



		Criteria Describing Consequence				
Severity	Score	Public Safety, Emergency Services	Public Health, Environment	Repair Cost	Reduced Economic Activity	Public Services; Duration
	5	Regional Emergency	Regional Emergency	>$20 MM	Regional Emergency	>1 Month
	4	City Emergency	City Emergency	$2 MM - $20 MM	City Emergency	15-30 Days
	3	High	High	$200 K - $2 MM	High	7-14 days
	2	Moderate	Moderate	$20K - $200K	Moderate	1-6 days
	1	Low	Low	<$20K	Low	< 1 day

Facility	Consequence Score	Probability 2016	Probability 2041	Probability 2066	Weighted Risk Score
Reed Street Sewer Lift Station	64	0.01	0.01	0.1	2.37



Weston & Sampson

FACILITY CHECKLIST

	Features	Observations (Pre-existing Problems)
PAGE 4	EXTERIOR AND GROUNDS (vegetation, drainage, slopes)	evidence of pooling, erosion, trees
PAGE 5	ARCHITECTURAL (windows, doors, louvers)	glazing type, operability, impact resistant
PAGE 6	STRUCTURAL (roofs, foundations)	skylights, snow drift areas, drainage, cracking, mold
PAGE 7	BUILDING SYSTEMS (mechanical, electrical, HVAC)	location, utility ports, temperature control, redundancy
PAGE 8+	OTHER (generators, server rooms, user groups, etc.)	location, fuel type, vulnerable populations

Climate Parameters (Tier 1)
- FLOOD
- EXTREME PRECIPITATION
- HEAT

Climate Parameters (Tier 2)
- WINTER STORM
- WIND
- DROUGHT
- FIRE
- LANDSLIDE

Facility Manager Input

Adaptive Capacity	Consequence Rating
Rate the site feature's ability to withstand the climate parameter	Rate the consequence of damage or inoperability to site feature
1. EXCELLENT very unlikely to result in damage	1. LOW minor injuries and/or <$5k
2. GOOD unlikely to result in damage	2. MODERATE moderate injuries and/ or <$250k
3. SATISFACTORY may result in damage	3. HIGH severe injuries and/or <$1M
4. FAIR likely to result in damage	4. VERY HIGH possible loss of life and/or <$10M
5. POOR very likely to result in damage	5. EMERGENCY local or regional emergency and/or loss of life expected

Weston & Sampson

iDataCollect℠
a Weston & Sampson solution

CAMIS ID #: 531TRC1001

INSPECTOR: Weston & Sampson

EXTERIOR

SITE FEATURE	OBSERVATIONS	YES	NO	COMMENTS	CLIMATE PARAMETERS	SENSITIVITY	ADAPTIVE CAPACITY*	VULNERABILITY RATING	CONSEQUENCE RATING**	RISK RATING
PRE-EXISTING	Existing problems and/or concerns?	x		Drainage by loading dock reportedly inadequate, increased size (1)	FLOOD/EXT. PRECIP	1	3	High	1	Low
	Water staining/mold/algae as flooding evidence?		x		FLOOD/EXT. PRECIP	1				
GRADING	Located downgradient of surrounding areas?	x		Surrounding grades higher at Federal street, lower at bridge street	FLOOD/EXT. PRECIP	1	1	Low	1	Low
	Grades slope towards building?	x		Yes	FLOOD/EXT. PRECIP	1	1	Low	1	Low
	Slopes steeper than 2H:1V present?		x	Footpath connecting Bridge to Federal eroded	LANDSLIDE					
DRAINAGE	Existing drainage problems? Flooding? Puddles?	x		Drainage pipe on canopy becomes disconnected and drips (2)	FLOOD/EXT. PRECIP	1	2	Low	2	Low
	Stormwater retention on-site?	x		2 tanks, in unknown condition	FLOOD/EXT. PRECIP	1	3	High	3	Low
	70% or more of site impermeable surfaces?		x		FLOOD/EXT. PRECIP					
	Bioswales or rain gardens present?		x		FLOOD/EXT. PRECIP					
VEGETATION	Multiple trees on site (>5)?	x		Landscaper maintain branches regularly	WIND/FLOOD	1	1	Low	2	Low
	Visible signs of erosion?	x		Footpath connecting Bridge to Federal eroded	EXT. PRECIP/LANDSLIDE	0	3	Low	3	Low
	Vegetation providing shade?		x	Not much shade provided onsite	HEAT	1	1	Low	1	Low
OPEN SPACE	Area to store snow on site?		x	Snow removal agency takes offsite	WINTER STORM	1	1	Low	1	Low
	Objects on site that could become debris?	x		Cars	WIND/FLOOD	1	1	Low	2	Low
	Below ground parking?		x		FLOOD					
	Shaded parking lot?		x		HEAT	1	1	Low	1	Low

NOTE: REFER TO STRUCTURAL SECTION FOR EXTERIOR BUILDING WALLS AND FOUNDATIONS

ADDITIONAL COMMENTS:

(1) no longer problem with flooding

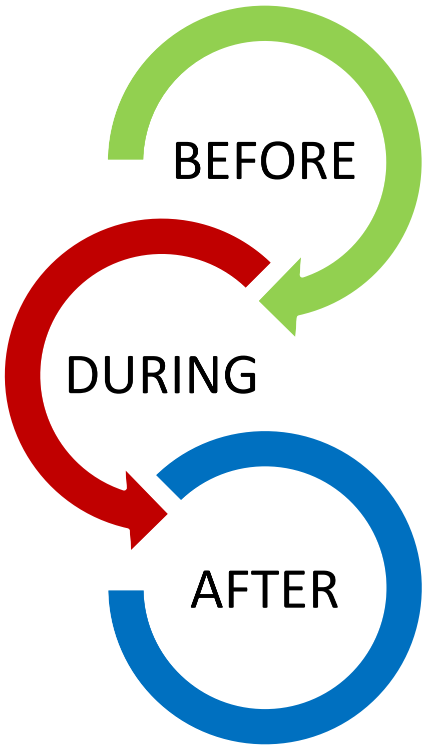
(2) puddles observed along bridge street (historically) and tidal flooding near the F.Webb building further down bridge street. The MBTA parking lot has tidal flooding too.

The generator and transformer are located along bridge street

Weston & Sampson℠

PHASE 3 – ADAPTATION STRATEGIES

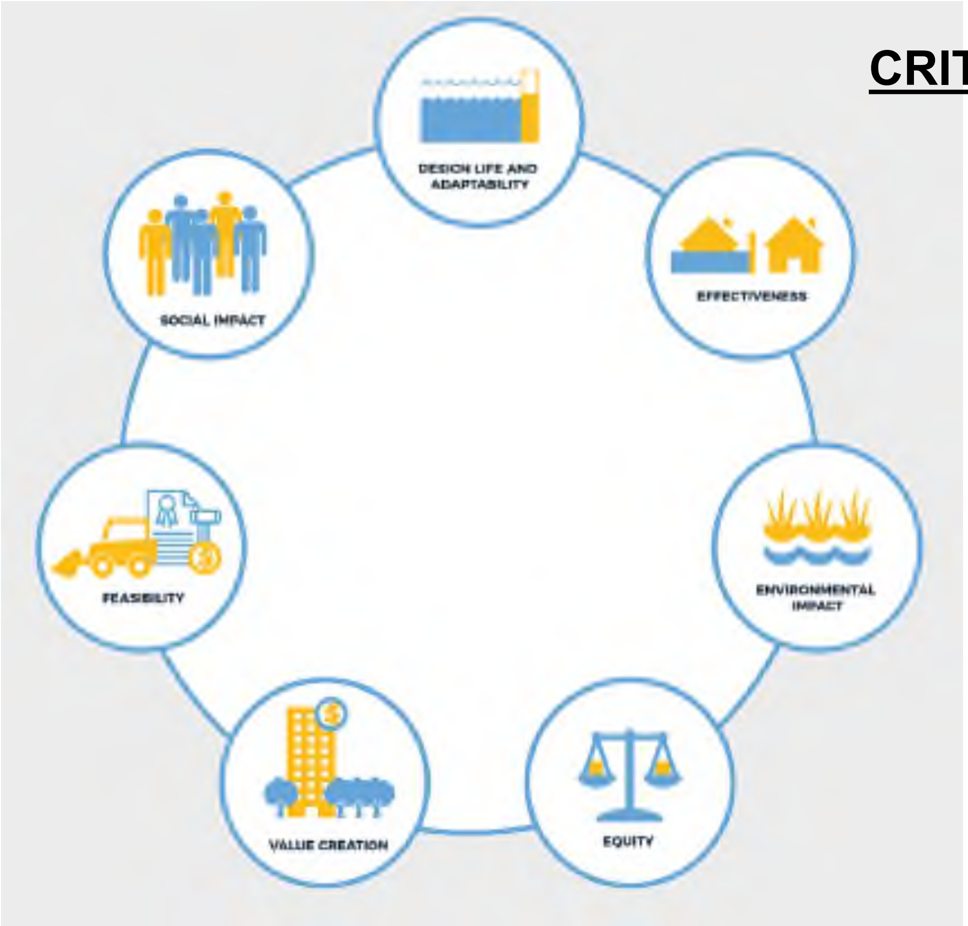
Adaptation Planning



- **PREPARE** FOR CHRONIC AND ACUTE CLIMATE IMPACTS
- **RESIST** CLIMATE EVENT (HEATWAVE, STORM)
- **RECOVER** FROM CLIMATE EVENT (FLOODING, DAMAGES)

Adaptation/Resiliency Strategies: Grouped by Type of Action

Policy	Retreat	Protect	Accommodate
Programmatic	Remove CC sensitivity	Prevent CC impact	Allow CC impact, reduce damage
Deferred Maintenance Request	Relocate on site	Flood Barriers	Increase drainage capacity
O&M	Relocate off-site	Backflow preventers/flood gates	Green infrastructure
Master Plan	Elevate above PFE	Reinforce Windows/Wall	Wet floodproofing



CRITERIA FROM CLIMATE READY BOSTON

- **Effectiveness** (risk reduction)
- **Feasibility** (cost/constructability)
- **Design Life & Adaptability** (flexibility/time to implement)
- **Social Impact** (recreational/aesthetic)
- **Equity** (benefits for vulnerable populations)
- **Value Creation** (new value)
- **Environmental Impact** (mitigation/health)

Source: Climate Ready Boston Report (2017)

EXAMPLES

Example Adaptation Strategy for Transformer – Elevate Transformer

VULNERABLE FACILITY ELEMENT	LOCATION	CLIMATE STRESS	PRIORITY
Transformer	Underground Vault	Extreme Precip./Coastal Flooding	High

- **Planning Horizon:** Before
- **Strategy:** Retreat
- **Cost** – $$$
- **Effectiveness** –Max
- **Feasibility** – Yes.
- **Adaptability** – No.
- **Timing** – Long-term.
- **Co-benefits** – Yes, ease of maintenance and access.

Example Adaptation Strategy for Floor Drains and Under-Slab Drain – Flood Guard

VULNERABLE FACILITY ELEMENT	LOCATION	CLIMATE STRESS	PRIORITY
Mechanical & Electrical Room	Basement	Coastal/Extreme Precip Flooding	High

- **Planning Horizon:** Before & During
- **Strategy:** Accommodate
- **Cost** – $, Low, retrofit
- **Effectiveness** – Moderate, reduces hydrostatic pressure
- **Feasibility** – Yes: easy to install
- **Adaptability** – Flexible, taller pipes could be used
- **Timing** - Short term
- **Co-benefits** - No.

Example Adaptation Strategy for Equipment/Mechanical Room – Flood Barriers

mage courtesy of PS Flood Barriers

VULNERABLE FACILITY ELEMENT	LOCATION	CLIMATE STRESS	PRIORITY
Basement doorways to Outdoor Equipment Room, Mechanical Room, etc.	North side of site	Extreme Precipitation & Flooding	High

- **Planning Horizon:** Before & During
- **Strategy:** Protect
- **Cost** – $ - $$. Customized to openings
- **Effectiveness** – Max: depends on structural strength of building walls and connections
- **Feasibility** – Yes: easy to install, use, store and transport
- **Adaptability** – Flexible: Adjust to water height
- **Timing** - Short term: <1 hour installation
- **Co-benefits** - No.

Example Adaptation Strategy for Temperature Control – Solar control window film

http://www.efficientwindows.org/existing_films.php

VULNERABLE FACILITY ELEMENT	LOCATION	CLIMATE STRESS	PRIORITY
Windows	All	Heat	Maybe

- **Planning Horizon:** Before & During
- **Strategy:** Protect
- **Cost** – $
- **Effectiveness**: Moderate (priority southern exposure)
- **Feasibility**: Yes, assuming that installation does not trigger security/ safety issues
- **Adaptability**: No
- **Timing** – short-term and long-term
- **Co-benefits** – Reduce the energy demand for the building and contribute to achieve GHG reduction.

GUIDELINES BY BUILDING SYSTEM

Exterior Site Features and Grounds Example

SITE DRAINAGE

Climate Stress:

- EXTREME PRECIPITATION
- FLOODING

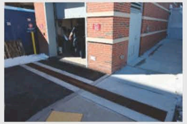
Adaptation: Install permeable pavement in the parking lot and walkways to aid with infiltration on site and reduce stormwater runoff

Photo courtesy of Oregon State University

Planning Horizon: During/After
Strategy: Accommodate
Cost: $$
Effectiveness: Moderate
Feasibility: Maybe
Adaptability: Not Flexible
Timing: Mid-term
Co-benefits: No

Discussion: This adaptation will reduce stormwater runoff during extreme precipitation events and help reduce recovery times after flooding. Porous pavement should be maintained in accordance with the designers' recommendations. Facility Managers should develop a schedule for maintaining the pavement in order to maximize effectiveness. Porous pavement may not be feasible at all sites.

Adaptation: Increase drainage capacity for site drainage systems.



Planning Horizon: Before
Strategy: Accommodate
Cost: $$
Effectiveness: Moderate
Feasibility: Yes
Adaptability: Not Flexible
Timing: Mid-term
Co-benefits: No

Discussion: This adaptation should be considered at low lying areas of the site. The designer should consider the initial rainfall volumes used for drainage sizing and compare to predicted rainfall volumes. Increasing the capacity of the system is effective as long as the surrounding drainage system is not over capacity, which could result in backflow on the site. A drainage study should be performed.

Adaptation: Deploy temporary barriers to alter the flow of stormwater runoff away from the site.

Photo courtesy of NOAQ BOXWALL FLOOD BARRIER

Planning Horizon: During
Strategy: Protect
Cost: $
Effectiveness: Moderate
Feasibility: Yes
Adaptability: Flexible
Timing: Short-term
Co-benefits: No

Discussion: This adaptation should be during climate impacts when stormwater is flowing from another site onto this site. This solution provides temporary relief from water damage. This solution requires personnel on site immediately before, during, and after an event to implement. It will require purchase of the barriers, so timing of implementation is short-term. Barriers can range from sandbags, quick dams, to NOAQ flood defenses (pictured).

GUIDELINES BY BUILDING SYSTEM

Architectural Building Example

DOORWAYS

Climate Stress:

- FLOODING

Adaptation: Install a temporary flood barrier in doorways.

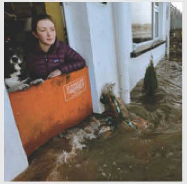


Photo courtesy of Global Industrial

Planning Horizon: During
Strategy: Protect (temporary barrier)
Cost: $ ($900/dam)
Effectiveness: Maximum
Feasibility: Yes
Adaptability: Flexible
Timing: Short-term
Co-benefits: No

Discussion: This adaptation should be implemented immediately before and during a flood event to prevent water from entering the building. The effectiveness depends on the structural strength of the building walls. This strategy is feasible to implement if personnel are on site immediately before, during, and after an event. It easy to install (2 minutes), store, and transport. The solution is flexible to fit different doorway widths. Timing of implementation is short-term.

Adaptation: Install flood plank barrier system around entrances.

Photo courtesy of Flood Planks PS Doors

Planning Horizon: Before/During
Strategy: Protect (temporary barrier)
Cost: $ -$$
Effectiveness: Maximum
Feasibility: Yes
Adaptability: Flexible
Timing: Short to Mid-term
Co-benefits: No

Discussion: This adaptation should be constructed before and implemented immediately during a flood event to prevent water from entering the building. The effectiveness depends on the structural strength of the building walls and connections. This strategy is feasible to implement if personnel are on site immediately before, during, and after an event. It is easy to install (1 hour), store, and transport. The solution is customized and additional planks can be added. Timing of implementation is short to mid-term.

Adaptation: Pedestrian Flood Doors

Partial image courtesy of PS Flood Barriers

Planning Horizon: Before/During
Strategy: Protect
Cost: $-$$
Effectiveness: Moderate
Feasibility: Yes
Adaptability: Not Flexible
Timing: Short to Mid-term
Co-benefits: No

Discussion: This adaptation should be implemented before climate impacts. This strategy would replace pedestrian doors with flood doors. Effectiveness depends on the structural strength of the building walls and frame connections. These doors are designed for hydrostatic pressures, and can be installed by a subcontractor. Timing of implementation is short to mid-term, and this measure does not require action to deploy before a storm event.

Next steps: translating recommendations into design

Existing Products

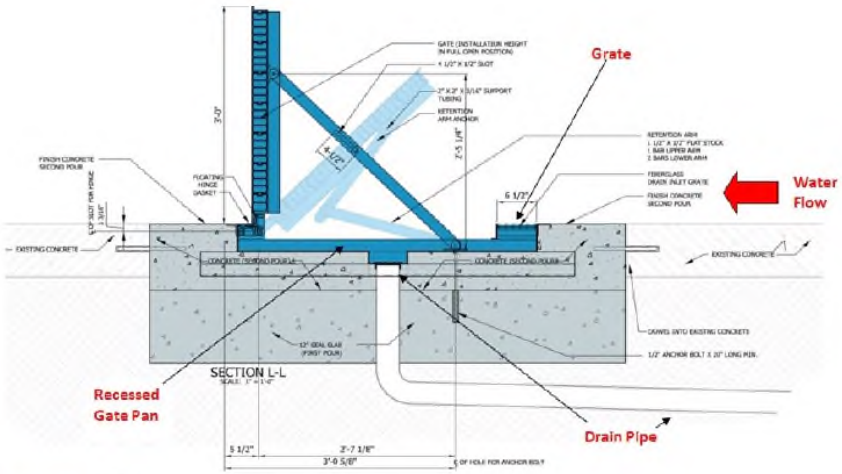
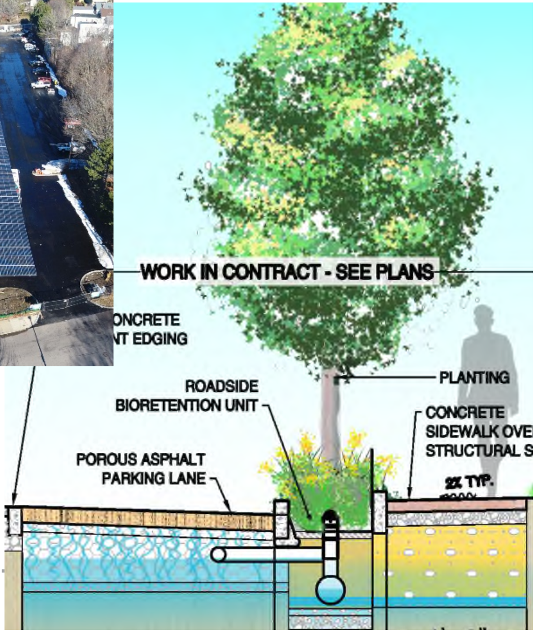


FIGURE 1 | A FloodBreak barrier gate diagram

Courtesy of A Better City

Leverage Opportunities

RCC Solar Canopy – Heat Adaptation Strategy with co-benefits



Chelsea Pump Station Example: Resilience tied into existing project

Weston & Sampson provided design, permitting, and bidding services. The scope of work included:

- Approx. 1,400 feet of new stormwater force main and abandonment of existing force main
- A new discharge structure at a culvert
- **Flood resiliency improvements at the Carter Street Pump Station**
  - **A wall around the perimeter of the pump station and a surface drain system to remove water captured within the enclosed perimeter**

Design Considerations

- Base-flood Elevation
- Hydrostatic Pressure and Uplift
- Geotechnical
- Structural
- Interior drainage
- Systems upgrades
- Emergency Power
- Access

Weston & Sampson[SM]

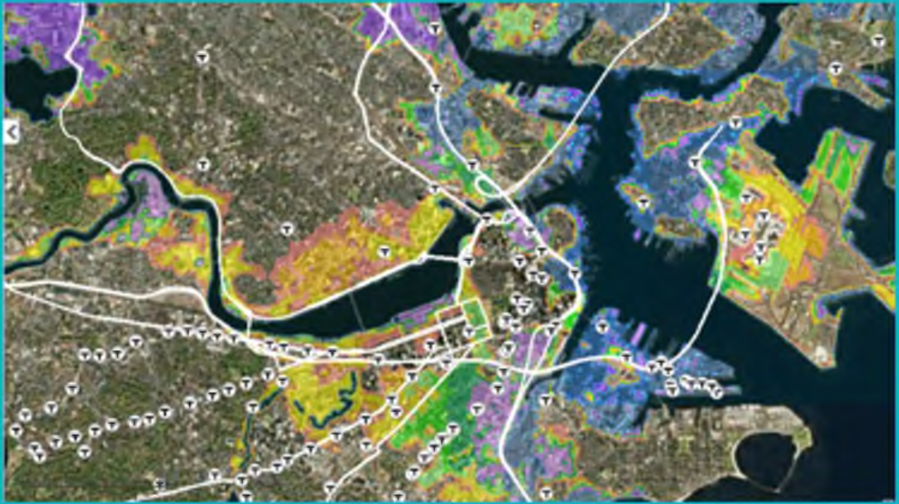
transform your environment

thank you

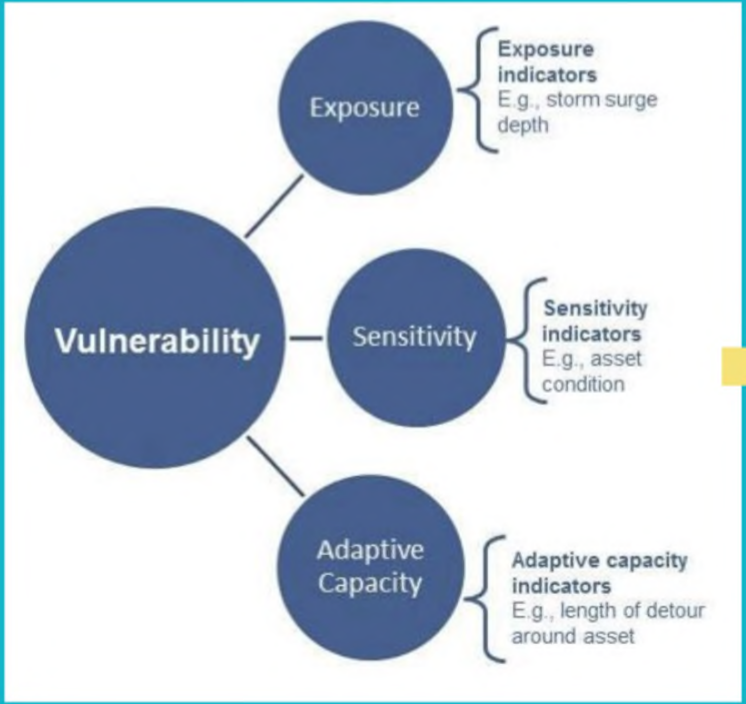
westonandsampson.com

Focus on Implementation

- Leverage Existing Information and Models
- Access to Public and Unpublished Data
- Model coastal and inland flooding, as well as extreme precipitation, heat, snow, and wind.
- Look at regional and site specific implications



VAST TOOL



iDataCollect[SM]
a Weston & Sampson solution

BUILDING SYSTEMS

SITE FEATURE	OBSERVATIONS	YES	NO	COMMENTS	CLIMATE PARAMETERS	[illegible]	VULNERABILITY RATING	CONSEQUENCE RATING**	RISK RATING
PRE-EXISTING	Existing problems and/or concerns?		x						
ELECTRICAL	Substation below PFE?		x		FLOOD				
	Transformer below PFE?	x		Transformer at ~El 12 located along bridge street (1)	FLOOD	4	High	4	High
	Temperature control around transformer?		x		HEAT	3	High	4	High
	Switchgear below PFE?	x	x	~1 ft below	FLOOD	4	High	4	High
	Distribution panel below PFE?	x	x	~1 ft below	FLOOD	4	High	4	High
	Temperature control around distribution panel?	x		HVAC temperature controlled	HEAT	2	Low	4	High
	Emergency generator below PFE?	x		See generator	FLOOD				
	Communications below PFE? List	x		Server room for trial courts	FLOOD	4	High	4	High
	Temperature control around communications?	x		All conduits insulated, temperature controlled (1)	HEAT	2	Low	4	High
	On-site renewable energy? List		x	No	WIND/WINTER STORM	1	Low	3	Low
MECHANICAL See HVAC systems	Fuel tank below PFE?	x			FLOOD				
	Water heating equipment below PFE?	x			FLOOD	4	High	4	High
	Air handling equipment below PFE?	x	x	Chillers, See HVAC section	FLOOD/WIND				
	Sanitary system below PFE? (Sewer or Septic)	x		Sewer	FLOOD	4	High	4	High
	Temperature control for sprinkler system?		x	Not insulated	HEAT/WINTER STORM	2	Low	3	Low
	Water supply on-site? (well/storage tank)	x		Non-potable water, no potable water stored on site	FLOOD/DROUGHT/FIRE	2	Low	1	Low
	Redundancy between fire suppressant system?		x	Localized fire suppressant areas, no redundancy	FIRE				

NOTE: PFE - PREDICTED FLOOD ELEVATION

ADDITIONAL COMMENTS: (1) Pad height unknown- obscured by snow.

* EXISTING CONDITION - ABILITY TO WITHSTAND CLIMATE EVENT

1. EXCELLENT – Very unlikely to result in damage given the related climate parameter
2. GOOD – Unlikely to result in damage given the related climate parameter
3. SATISFACTORY – May result in damage given the related climate parameter
4. FAIR – Likely to result in damage given the related climate parameter
5. POOR – Very likely to result in damage given the related climate parameter

** CONSEQUENCE TO PUBLIC HEALTH AND SAFETY, INTERDEPENDENCIES, AND/OR COST OF DAMAGE

1. Damage would result in low consequences (minor injuries and/or <$5,000)
2. Damage would result in moderate consequences (moderate injuries and/or <$250,000)
3. Damage would result in high consequences (severe injuries and/or <$1,000,000)
4. Damage would result in very high consequences (possible loss of life and/or <$10,000,000)
5. Damage would result in a local or regional emergency to interdependent systems

Facility Checklist Developed for Site Specific Risk and Vulnerability Assessment (W&S)

PHASE 1 – CLIMATE SCENARIO SELECTION

- **Synthesis of available relevant technical analyses and reports**
  - **Coastal Geomorphology**
  - **Watershed Characteristics**
  - **Municipal Asset Locations and Information**
- **Compilation of data into a Geographic Information System (GIS)**
- **Development of Study Scenarios**

- *Preliminary review of relevant regulations*

Evaluation Criteria Used for Resiliency Strategies

Cost

$$$

Effectiveness

(Risk Reduction)

Feasibility

(Technical/Practical)

Timing

(Short Term vs. Long Term)

Adaptability

(Flexibility)

Co-benefits

(Mitigation)

PRIMARY:

- Cost
- Effectiveness
- Feasibility

SECONDARY

- Adaptability
- Timing of Implementation
- Co-benefits