MBTA Red Line Climate Change Vulnerability Assessment

Summary Presentation

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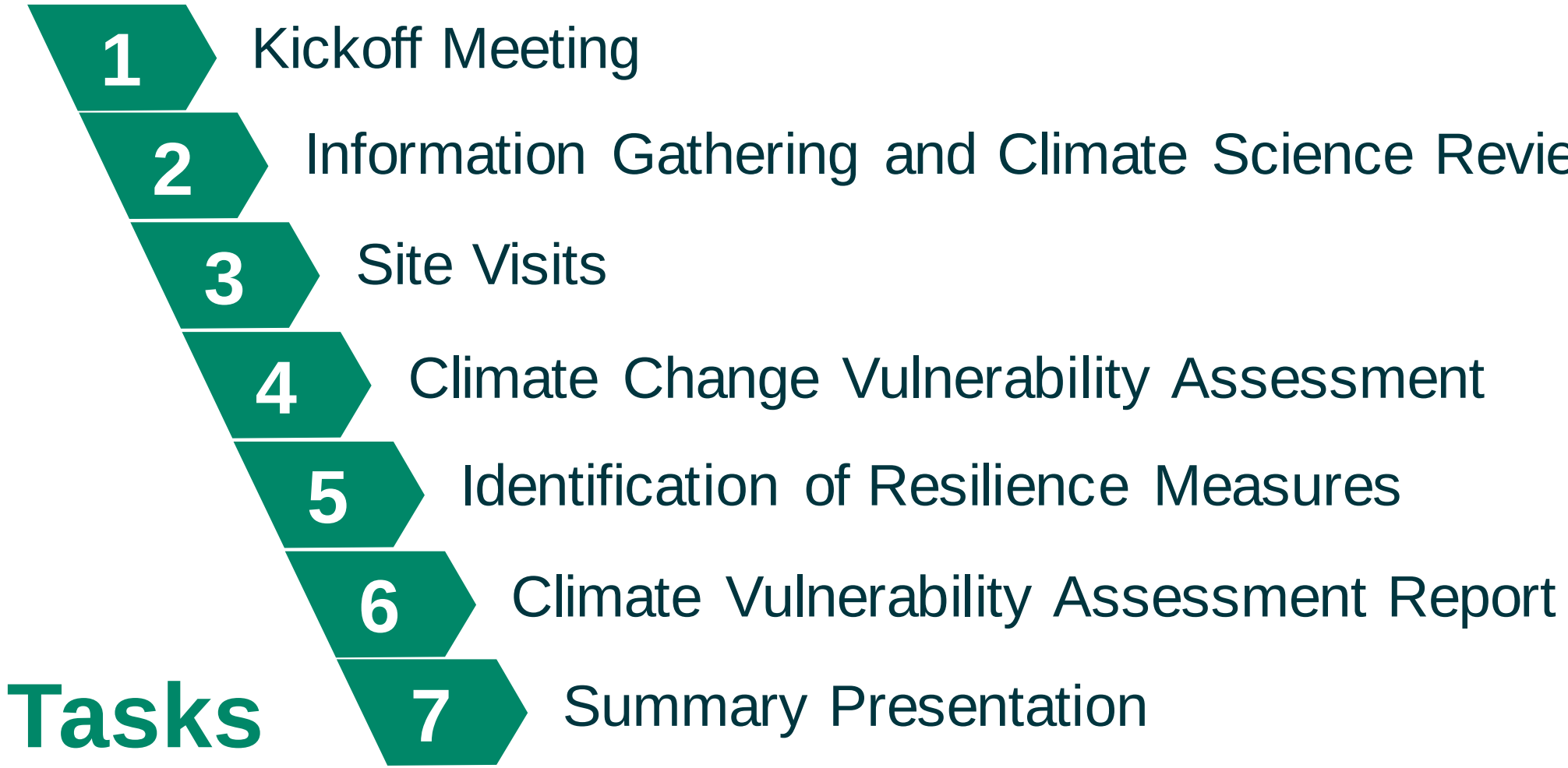
Presentation Outline

- Project Objectives
- Project Approach
- Climate Change Vulnerability Assessment Methodology
- Climate Change Vulnerability Assessment Results
- Adaptation Measures
- Next Steps

Project Objectives

- Support MBTA's systemwide climate change vulnerability assessment.
- Assess historical, current, and future vulnerabilities to extreme weather and climate change for the Red Line, including the Mattapan High-Speed Line.
- Develop a replicable process.
- Identify the most vulnerable assets.
- Inform MBTA's capital planning process.

Project Approach



Project Approach

– Three main data collection tasks informed the vulnerability assessment.

Information Gathering and Climate Science Review

- Red Line Asset Inventory
- Historical Challenges
- Climate Science Review

Stakeholder Meetings

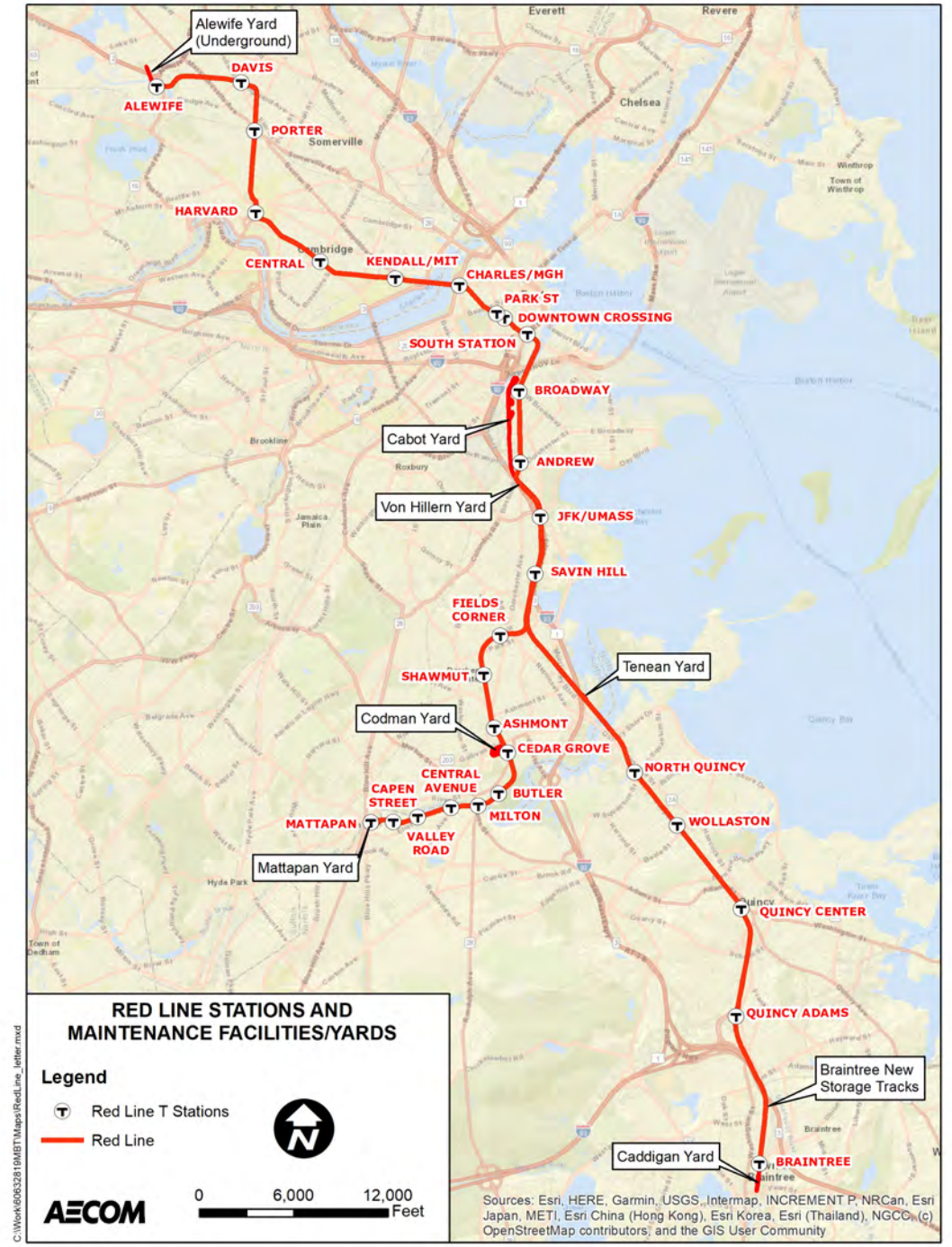
- Boston
- Braintree
- Cambridge
- Quincy
- Somerville

Site Visits

- Alewife Station
- Alewife Yard
- Andrew Station
- Cabot Yard
- Codman Yard
- Columbia Junction
- JFK/UMass Station
- Mattapan Line
- Mattapan Yard
- North Quincy Station
- Shawmut Station
- Tenean Yard

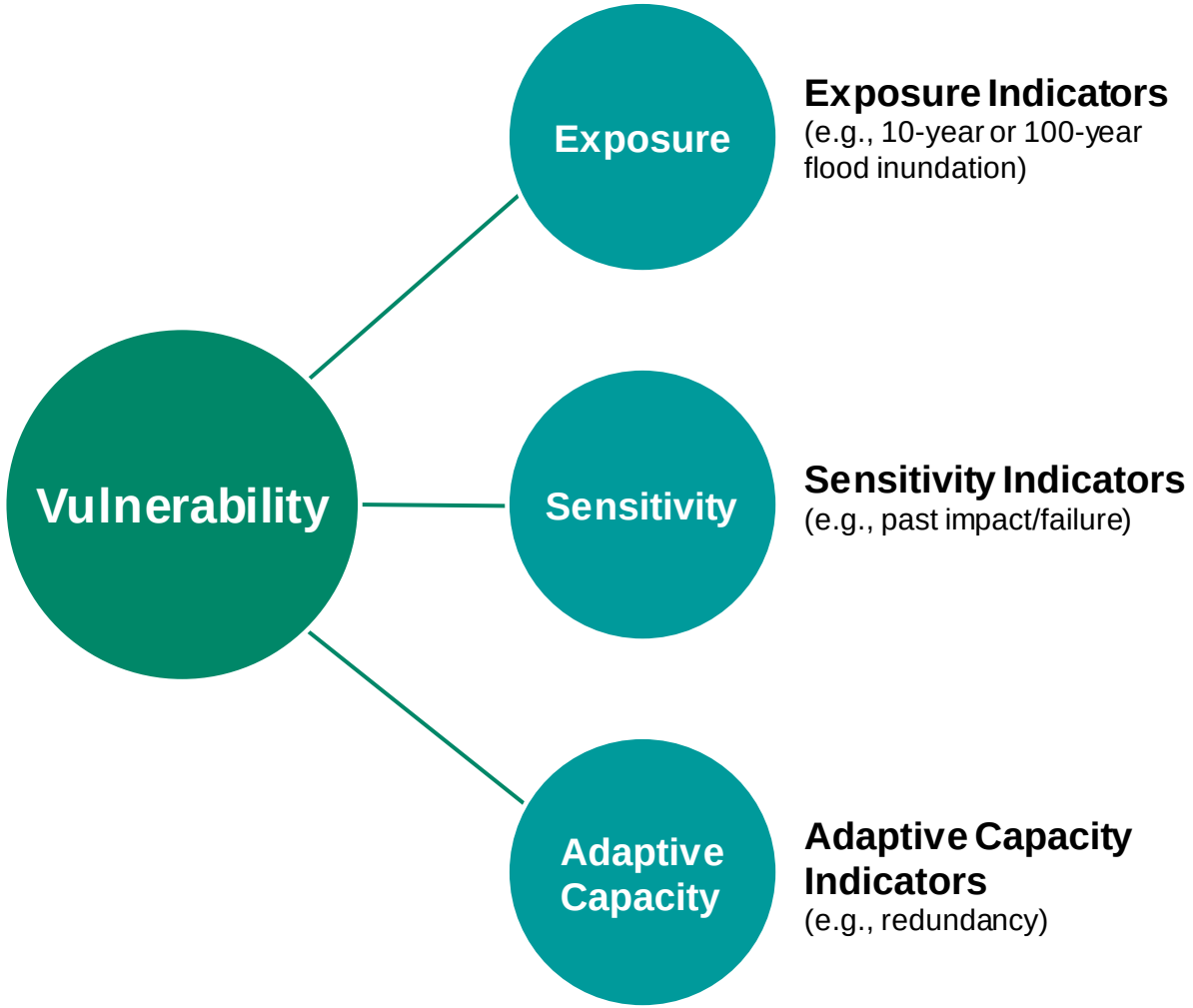
Climate Change Vulnerability Assessment Methodology

- Five climate stressors
  - Extreme Heat
  - Precipitation
  - Sea Level Rise / Storm Surge
  - Wind
  - Winter Weather
- Assets included in quantitative assessment
  - Stations (29)
  - Maintenance Facilities/Yards (8)
  - Guideway Segments (68)
- Several assets addressed qualitatively



Climate Change Vulnerability Assessment Methodology

- Used the approach of Federal Highway Administration's (FHWA's) Vulnerability Assessment Scoring Tool (VAST).
- Developed an Excel tool like VAST tailored to MBTA assets and needs.
- Indicators and scoring for Exposure, Sensitivity, and Adaptive Capacity developed and selected through collaboration with:
  - MBTA
  - AECOM subject mater experts
  - Orange Line CCVA consulting team
- See Methodology Appendix slides for more details on indicators and scoring.

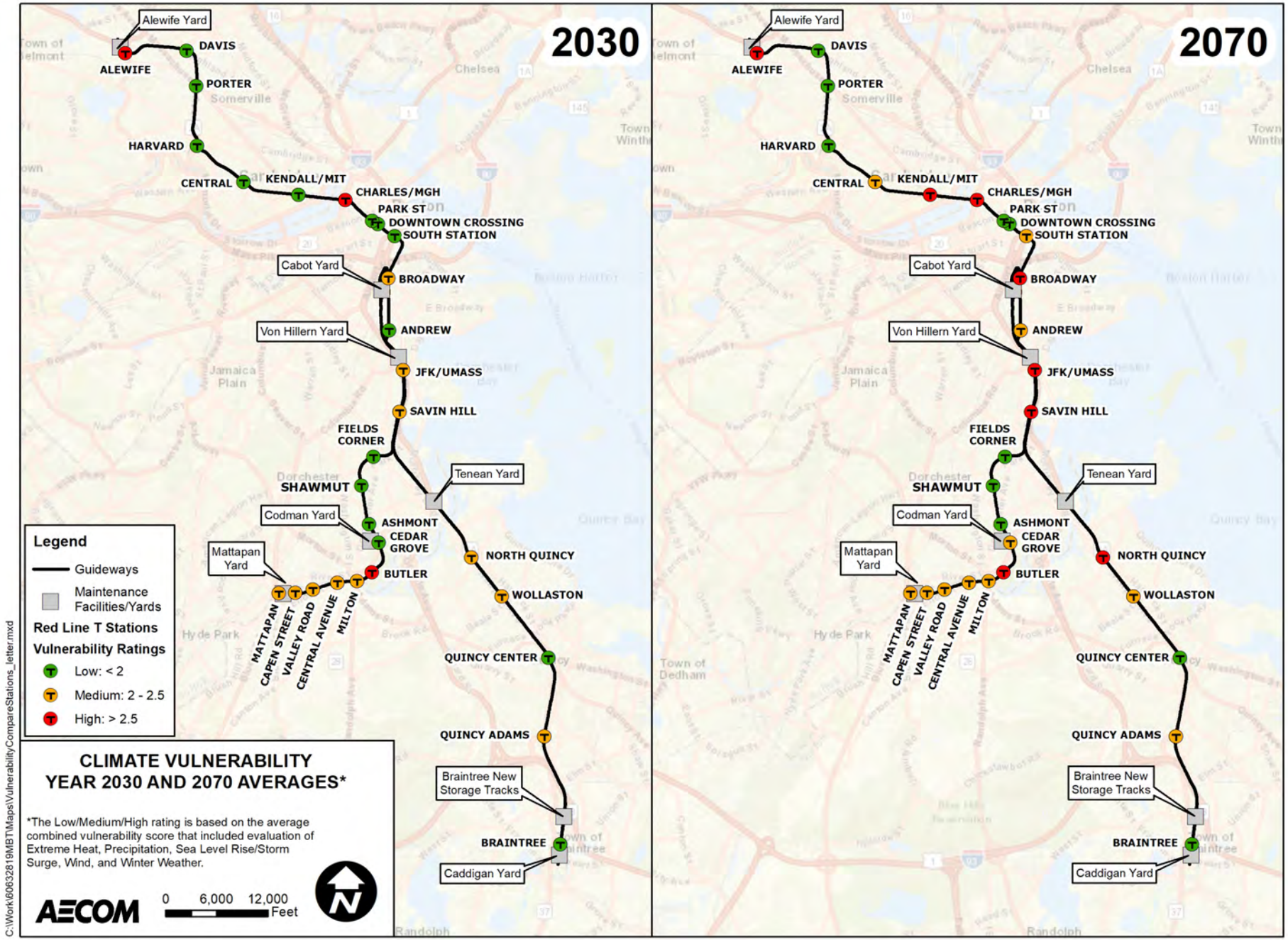


Primary Concerns for Stations

Climate Stressor	Station Vulnerabilities
Extreme Heat 	• Human health and safety concerns for passengers and MBTA employees • Increased operating stress on mechanical and electrical components and HVAC • Possibility for deformation of tracks within stations (heat kinks) • Power outages
Precipitation 	• Health and safety hazards • Loss of access to areas and possible interruption of service • Damage to electrical components • Chronic exposure to floodwaters can degrade infrastructure and cause structural failures • Power outages
SLR/Storm Surge 	• Health and safety hazards • Salt water that can corrode and cause electrical components as well as other infrastructure to fail • Loss of access to areas and possible interruption of service • Impact from surge waters that can damage infrastructure and carry debris into the station • Power outages
Wind 	• Exterior elements that can be damaged or destroyed • Debris that can impact sensitive areas of the station • Extreme winds that could result in train derailment or other hazardous situations, such as debris on tracks that could interrupt service • Power outages
Winter Weather 	• Health and safety hazards • Loss of access to areas and possible interruption of service • Snow and ice accumulation along the guideway within stations • Sudden temperature changes that could result in pipe bursts and other equipment damage or failure • Power outages

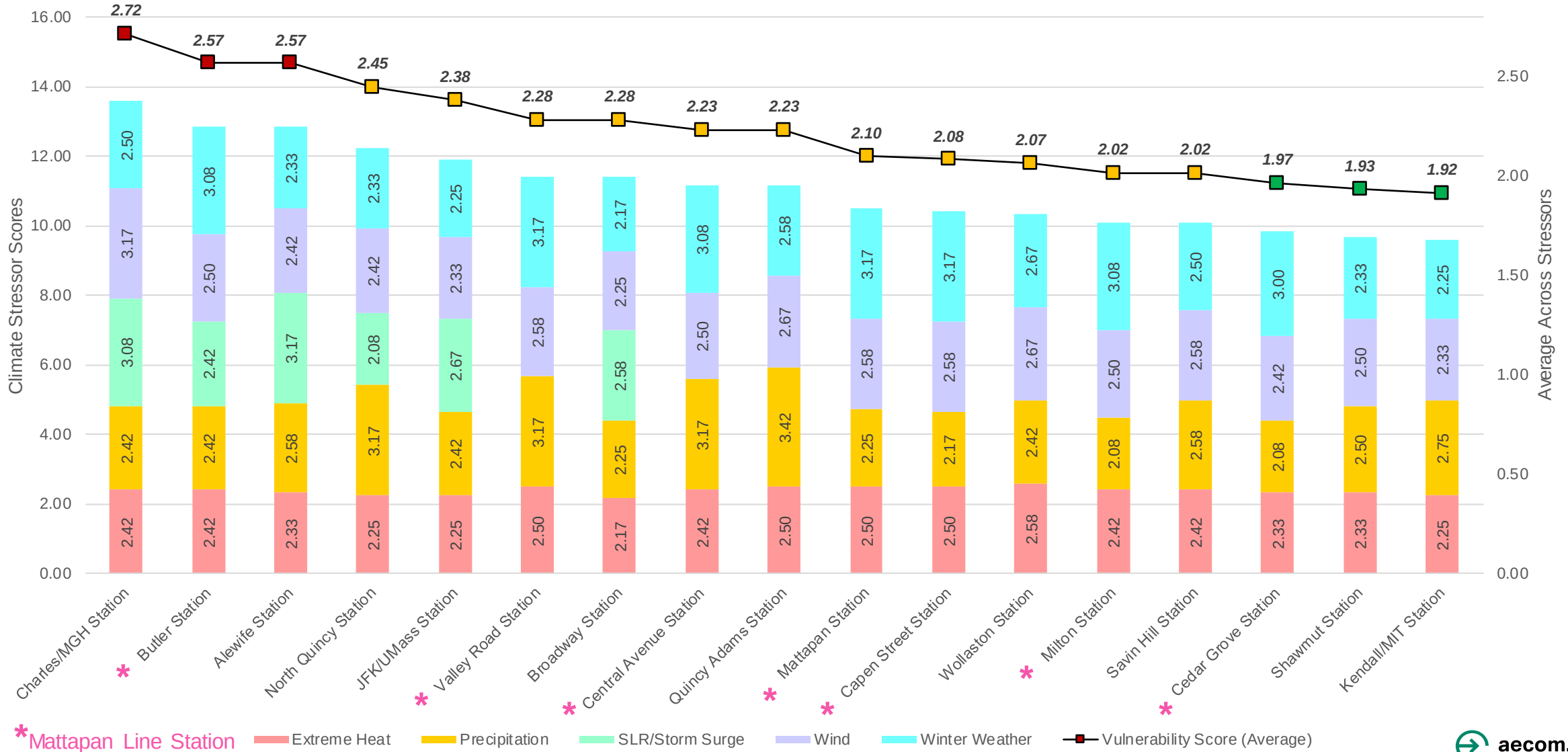
Station Vulnerability 2030 & 2070

- Assets are binned by overall vulnerability score.
- Score is calculated by the average across each climate stressor score.
- Scores range from 1 to 4, with 4 being higher vulnerability.



Climate Change Vulnerability Assessment Results

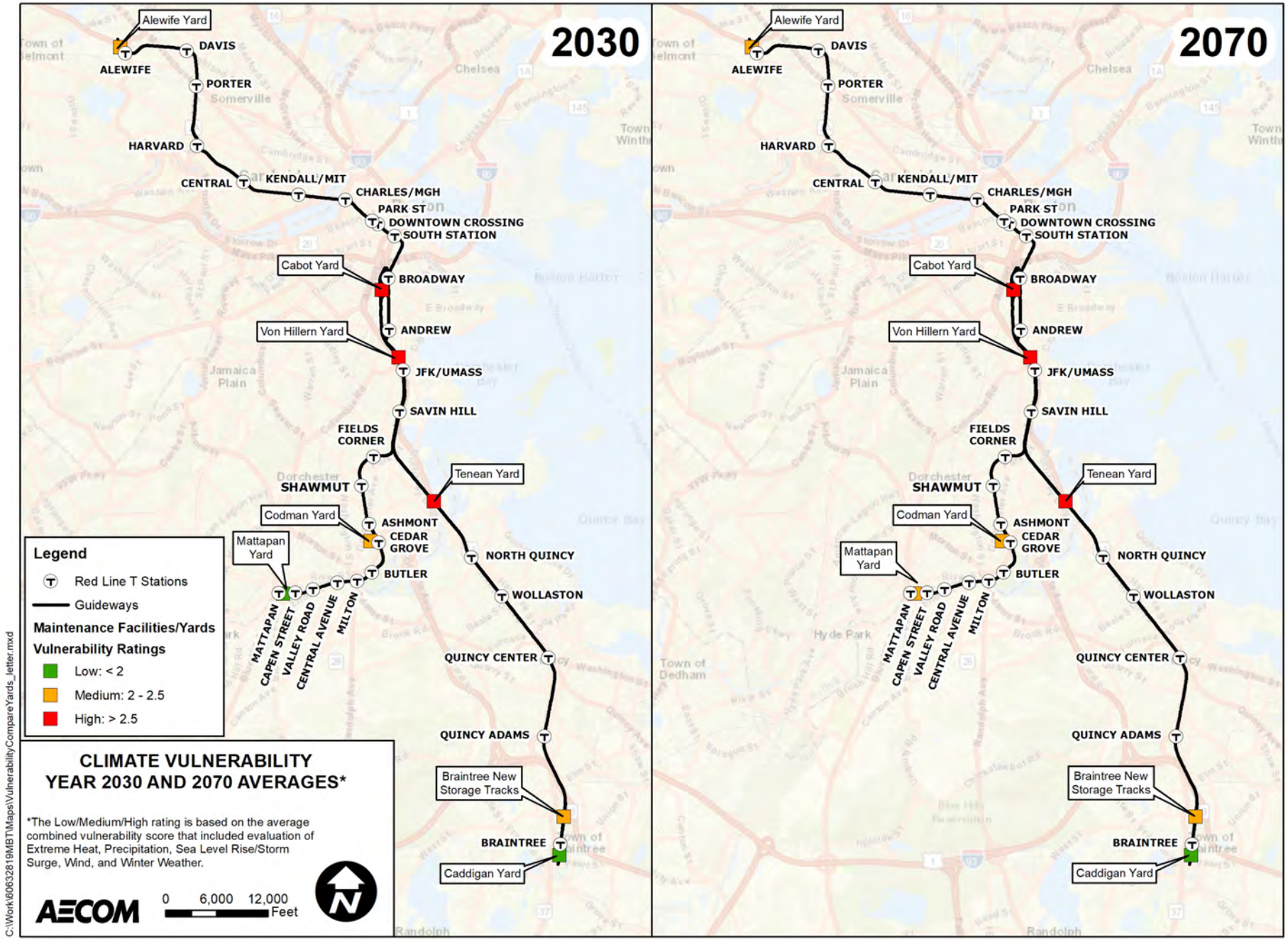
Top Station Vulnerability - 2030



Primary Concerns for Maintenance Facilities/Yards

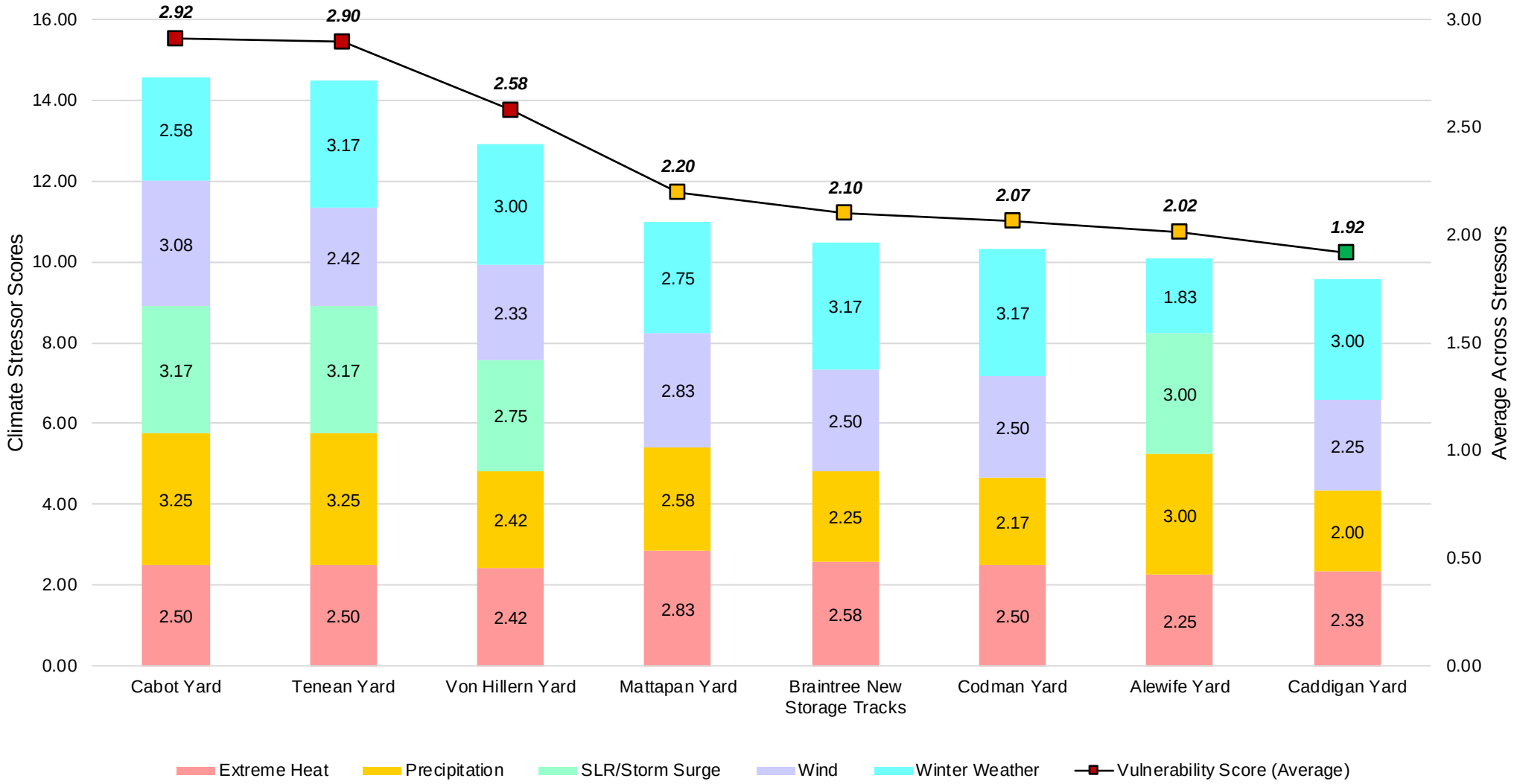
Climate Stressor	Maintenance Facilities/Yards Vulnerabilities
Extreme Heat 	• Human health and safety concerns for MBTA employees • Increased operating stress on mechanical and electrical components and HVAC • Possibility for deformation of tracks in maintenance yards and storage areas (heat kinks) • Power outages
Precipitation 	• Health and safety hazards • Loss of access to work areas • Damage to electrical components • Chronic issues that can degrade infrastructure and cause structural failures • Power outages
SLR/Storm Surge 	• Health and safety hazards • Salt water that can corrode and cause electrical components as well as other infrastructure to fail • Loss of access to work areas • Surge waters that can damage assets and carry debris into buildings and work areas • Power outages
Wind 	• Health and safety hazards • Exterior structural elements that can be damaged or destroyed • Debris that can impact sensitive equipment or work areas • Extreme winds that could result in train derailment or other hazardous situations, such as debris on track • Power outages
Winter Weather 	• Health and safety hazards • Loss of access to work areas • Snow and ice accumulation on building roofs and along maintenance and storage tracks • Sudden temperature changes that could result in pipe bursts and other equipment damage or failure • Power outages

Maintenance Facility/Yard Vulnerability 2030 & 2070



Climate Change Vulnerability Assessment Results

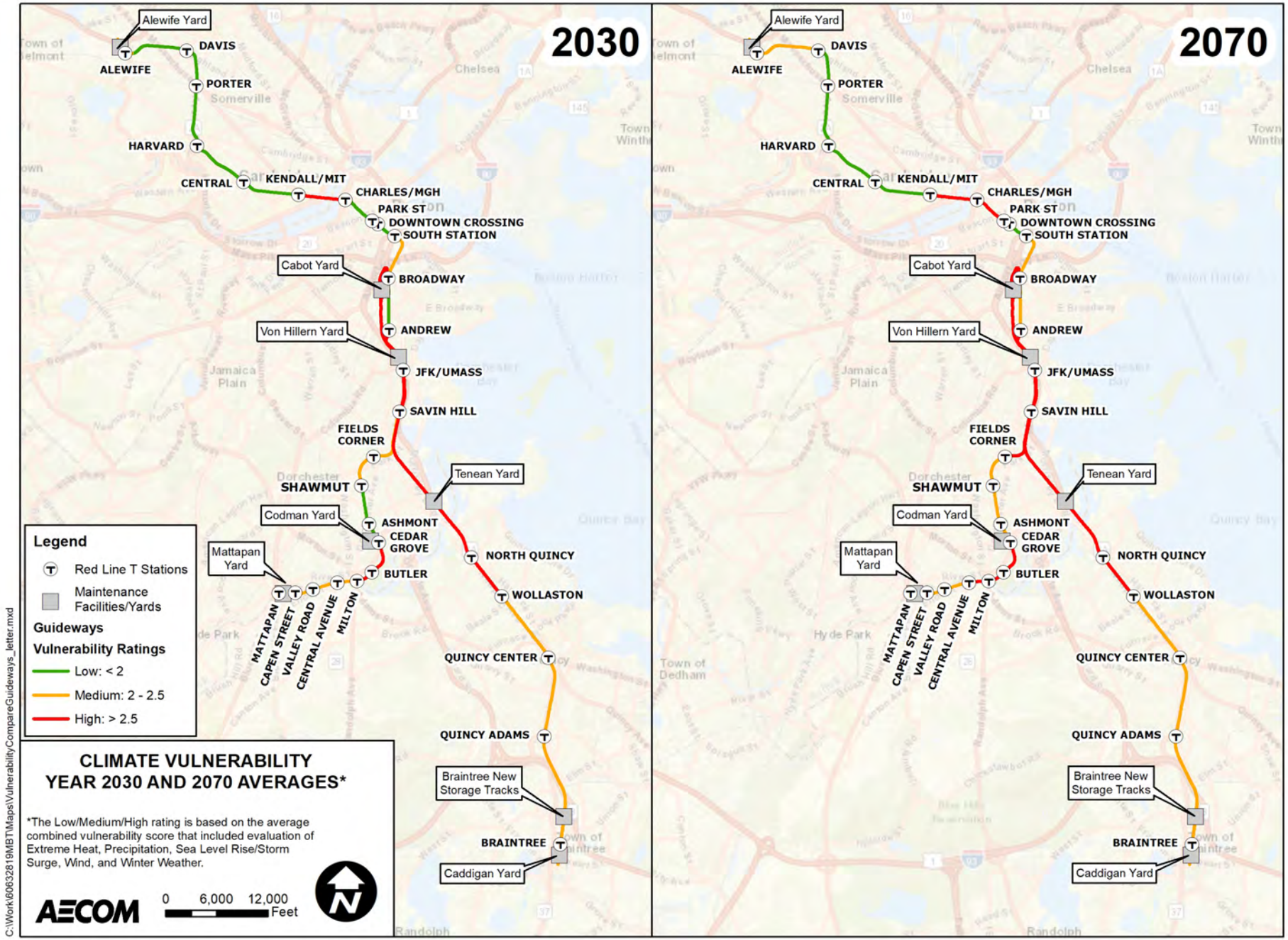
Maintenance Facility/Yard Vulnerability - 2030



Primary Concerns for the Guideway

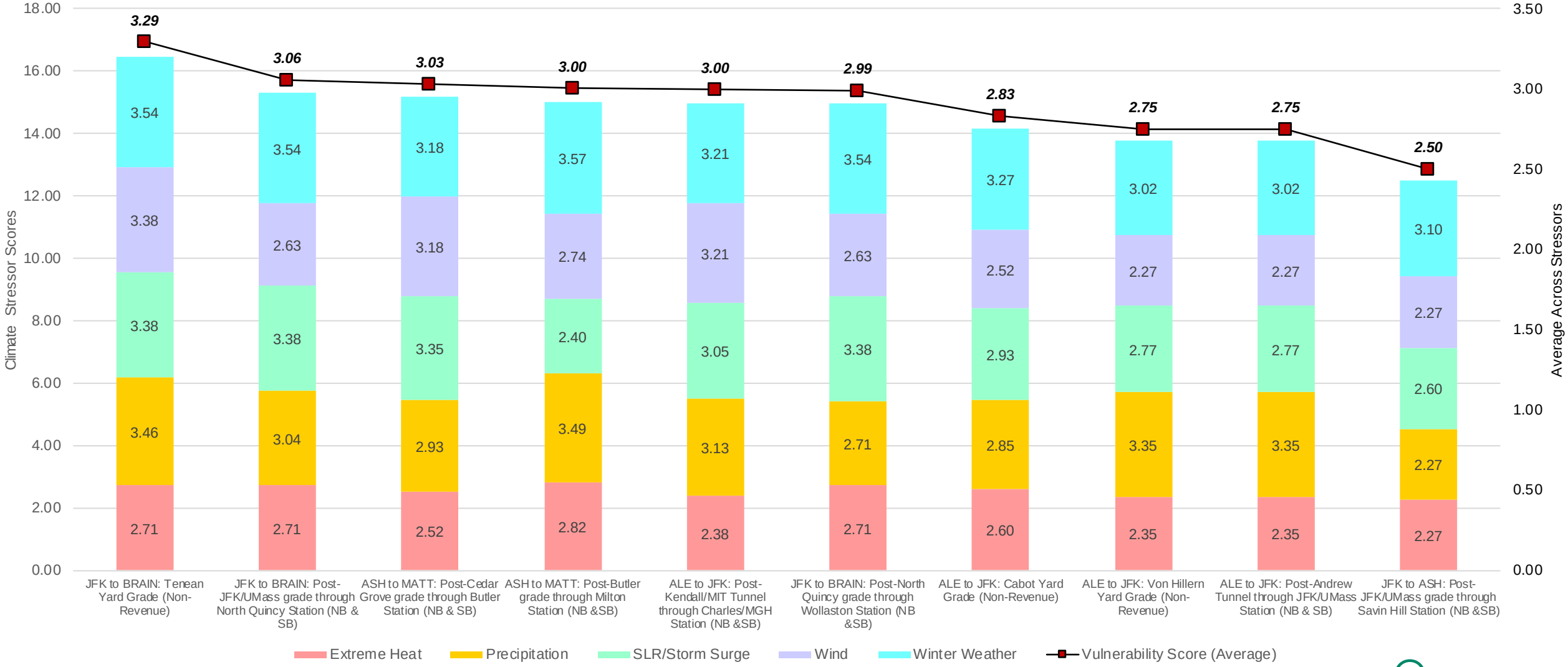
Climate Stressor	Guideway Vulnerabilities
Extreme Heat 	• Human health and safety concerns for MBTA employees • Increased operating stress on mechanical and electrical components • Possibility for deformation of tracks (heat kinks) • Power outages
Precipitation 	• Health and safety hazards • Loss of access to work areas; interruption of service • Damage to electrical components • Chronic issues that can degrade infrastructure and cause structural failures • Power outages
SLR/Storm Surge 	• Health and safety hazards • Salt water, which can corrode and cause electrical components as well as other infrastructure to fail • Loss of access to work areas; interruption of service • Impact from surge waters that can damage infrastructure and carry debris across tracks • Power outages
Wind 	• Health and safety hazards • Debris that can impact sensitive equipment or block access to work areas • Extreme winds that could result in train derailment or other hazardous situations, such as debris on track • Power outages
Winter Weather 	• Health and safety hazards • Loss of access to work areas • Snow and ice accumulation on tracks • Possibility for deformation of tracks (rail pull aparts) • Power outages

Guideway Vulnerability 2030 & 2070



Climate Change Vulnerability Assessment Results

Top Guideway Segment Vulnerability - 2030



Overall Red Line CCVA Key Findings

Stations

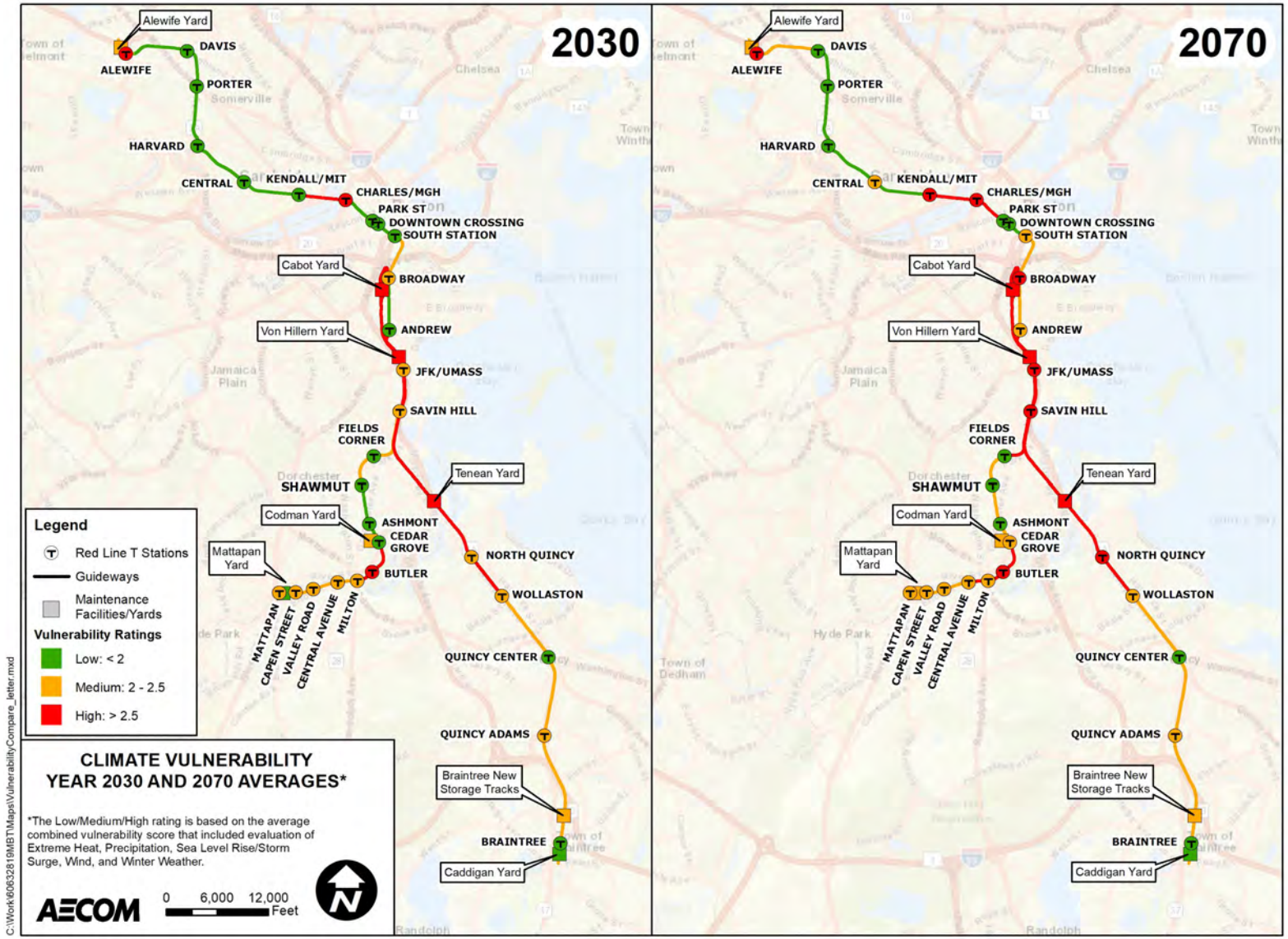
- Precipitation has greatest current and future impact to stations.
- SLR/storm surge is only a concern for coastal stations; most stations are inland or on higher ground.
- Wind is only a concern for stations near water or with past impacts.

Maintenance Facilities/Yards

- Flooding (precipitation and SLR/storm surge) could have highest impact due to equipment and access issues.
- Winter weather has highest past impacts on facilities/yards.

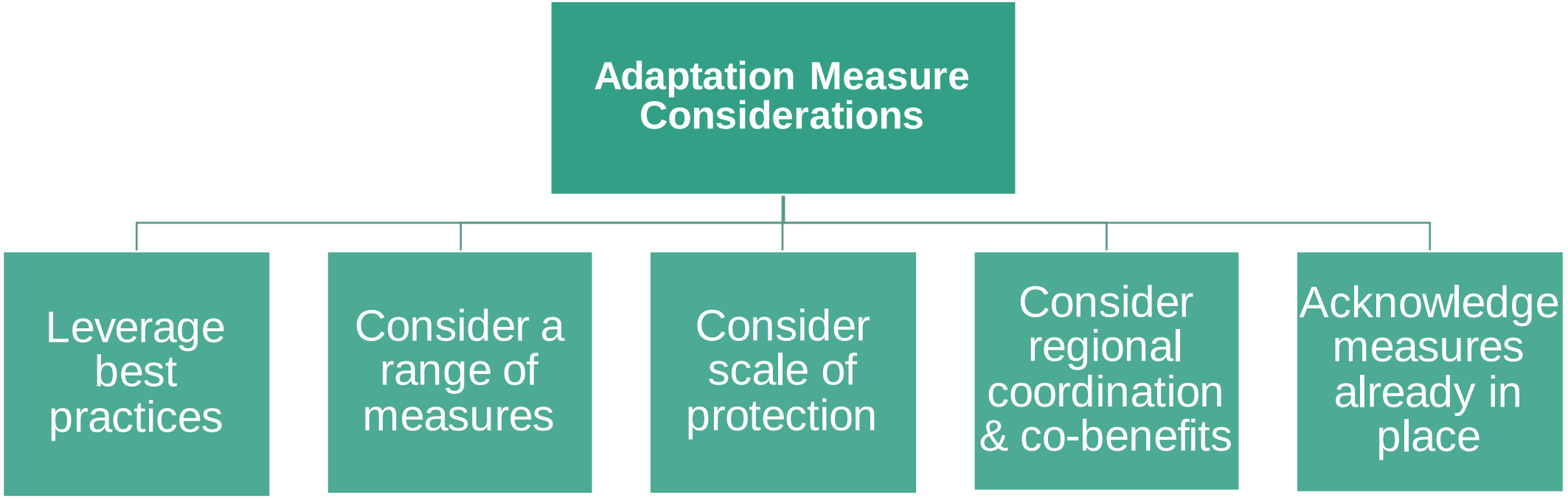
Guideways

- Columbia Junction and segments from Cedar Grove Station to Milton Station are at high risk of precipitation and SLR/storm surge flooding.
- Clayton Curve is noted as having extreme heat risk.



Adaptation Measures

– Several guiding principles informed the development of adaptation measures



Adaptation Measures

Categories

- Infrastructure
- Policy
- Operations & Management

Subcategories

Menu of Options

42 adaptation measures are applicable for MBTA assets

Adaptation Measures

Adaptation Measure Menu

- Excel-based spreadsheet
- Includes:
  - Adaptation subcategory
  - Stressor
  - Measure
  - Description
  - Asset type protected
  - Implementation effort
  - Cost

Massachusetts Bay Transportation Authority

CLIMATE CHANGE
ADAPTATION MEASURES - RED LINE

Category	Subcategory	Hazard	Measure	Description	Asset Type Protected			Implementation Effort	Cost
					Station	Maintenance Yard	Guideway		
Infrastructure	Elevated Barrier	Flooding - Coastal and Precipitation	Raising Curbs	Raising curbs at ventilation grates and subway entrances to reduce floodwater influx	X		X	Moderate	$$$
Infrastructure	Wet Floodproofing	Flooding - Coastal and Precipitation	Apply Impermeable Membrane to Tunnel Walls	Sealing tunnel walls, floors, and ceilings to reduce seepage from groundwater and seasonal infiltration issues	X		X	Moderate	$$
Policy	Stormwater Management	Flooding - Precipitation	Coordinate with Red Line Municipalities	Coordinate with municipalities on proper reporting, recording, addressing poor drainage under guideways and increasing stormwater capacity in areas of guideways prone to flooding.	X	X	X	Low	$
Infrastructure	Wet Floodproofing	Flooding - Coastal and Precipitation	Flood Barrier at Tunnel Entrances	Install temporary flood wall at tunnel entrances prior to large storm event to reduce risk of large-scale damage	X		X	Moderate	$$
Infrastructure	Elevated Structures	Flooding - Coastal and Precipitation	Elevate Rail and Platforms	Elevate rail lines and associated infrastructure to maintain rail operations regardless of flood conditions	X		X	High	$$$
Infrastructure	Elevated Structures	Flooding - Coastal and Precipitation	Elevate Electrical	Elevate critical electrical components (e.g., switches, signals, panel boxes) to prevent flood damage	X	X	X	Low	$$$
Infrastructure	Water Removal	Flooding - Coastal and Precipitation	Install New/Additional Pumps*	Install pumps to remove water from flood-prone areas during/following storm events	X	X	X	Moderate	$$$
Infrastructure	Wet Floodproofing	Flooding - Precipitation	Temporary Barriers of Ventilation Grates	Place temporary covers (e.g., plywood) on at-grade ventilation areas in anticipation of large events to help prevent flooding of subway tunnels	X		X	Low	$$

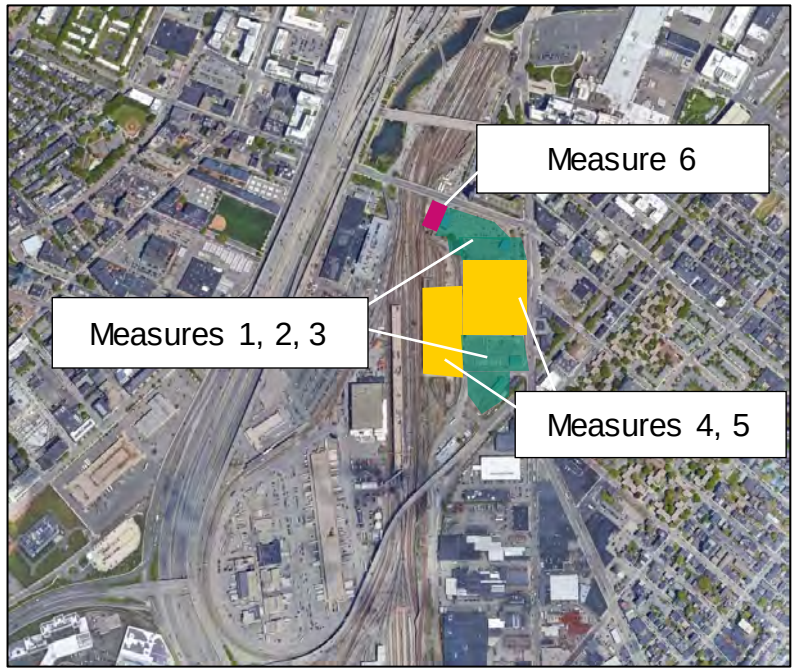
Adaptation Measures

Sample Application at Cabot Yard for Precipitation Flooding

1) Increase stormwater drainage capacity in flood-prone areas (carhouse, Gate 9).
2) Install permeable pavement in parking areas.
3) Add green infrastructure around parking areas.

4) Install backflow prevention (e.g., flap gates at stormwater drainage points connected to the carhouse and bus operations facility).
5) Install pump station to increase stormwater drainage against high tides.

6) Floodproof the Signal Tower, using a flood field at entryways or a waterproof membrane.



Implementation Timing: 2030

Assets Protected: Carhouse, bus operations facility, guideways, parking lots, buildings, substations, electrical/mechanical equipment

Co-Benefits: Increased yard aesthetics from green infrastructure

Potential Partners: Boston Water and Sewer Commission

Next Steps

– Mainstream Climate Resilience

- Integrate asset vulnerability scores into MBTA's asset management system
- Further integrate climate change considerations into capital planning

– Build on Red Line CCVA Results

- Revisit limitations identified
- Conduct a detailed assessment of Cabot Yard
- Examine drainage systems and major stormwater interceptors
- Coordinate with the Boston Water and Sewer Commission regarding stormwater management

– Implement Adaptation Strategies

- Define criticality to aid in prioritization of climate adaptation efforts
- Use of the menu of adaptation measures by MBTA staff

Thank you.

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List of Appendices

Appendix A: Detailed Methodology Slides and Cabot Yard Scoring Example
Appendix B: Adaptation Measures Cabot Yard Example
Appendix C: 2070 Result Charts
Appendix D: Guideway Segments

Appendix A:
Detailed Methodology Slides and Cabot Yard Scoring Example

Scoring for Exposure Indicators

Climate Hazard		Scoring (1 = least exposed, 4 = most exposed)	
		2030	*2070*
Extreme Heat		2 2030	3 2070
Precipitation	*Areas within stormwater model domains*	1 Not in the 10-year or 100-year storm, or no data available 2 100-year storm (any flood inundation depth) 3 10-year storm (≤ 1-foot inundation) 4 10-year storm (> 1-foot inundation)	1 Not in the 10-year or 100-year storm, or no data available 2 100-year storm (any flood inundation depth) 3 10-year storm (< 1-foot inundation) 4 10-year storm (> 1-foot inundation)
	For all other locations	1 Not in a FEMA floodplain 4 In a FEMA floodplain	1 Not in a FEMA floodplain 4 In a FEMA floodplain
SLR/Storm Surge		0 <0.1% ACFEP or not in mapped extent 1 0.1%-0.19% ACFEP 2 0.2%-0.9% ACFEP 3 1%-9% ACFEP 4 10%+ ACFEP	0 <0.1% ACFEP or not in mapped extent 1 0.1%-0.19% ACFEP 2 0.2%-0.9% ACFEP 3 1%-9% ACFEP 4 10%+ ACFEP
Wind		1 Belowground/fully enclosed 2 Dense urban/suburban environment & heavily wooded areas (Exp. B) 3 Flat, unobstructed areas or open terrain with scattered buildings no taller than 30' within 1500' of asset (Exp. C) 4 Within 600' of open waterway that is 1 mile across (Exp. D)	1 Belowground/fully enclosed 2 Dense urban/suburban environment & heavily wooded areas (Exp. B) 3 Flat, unobstructed areas or open terrain with scattered buildings no taller than 30' within 1500' of asset (Exp. C) 4 Within 600' of open waterway that is 1 mile across (Exp. D)
Winter Weather		1 Not exposed to snow and ice (fully enclosed or underground) 2 Partially exposed to outdoors 4 Fully outdoors	1 Not exposed to snow and ice (fully enclosed or underground) 2 Partially exposed to outdoors 4 Fully outdoors

‘ = feet
< = less than
ACFEP = annual coastal flood exceedance probability
Exp. = exposure
FEMA = Federal Emergency Management Agency

Climate Change Vulnerability Assessment Methodology

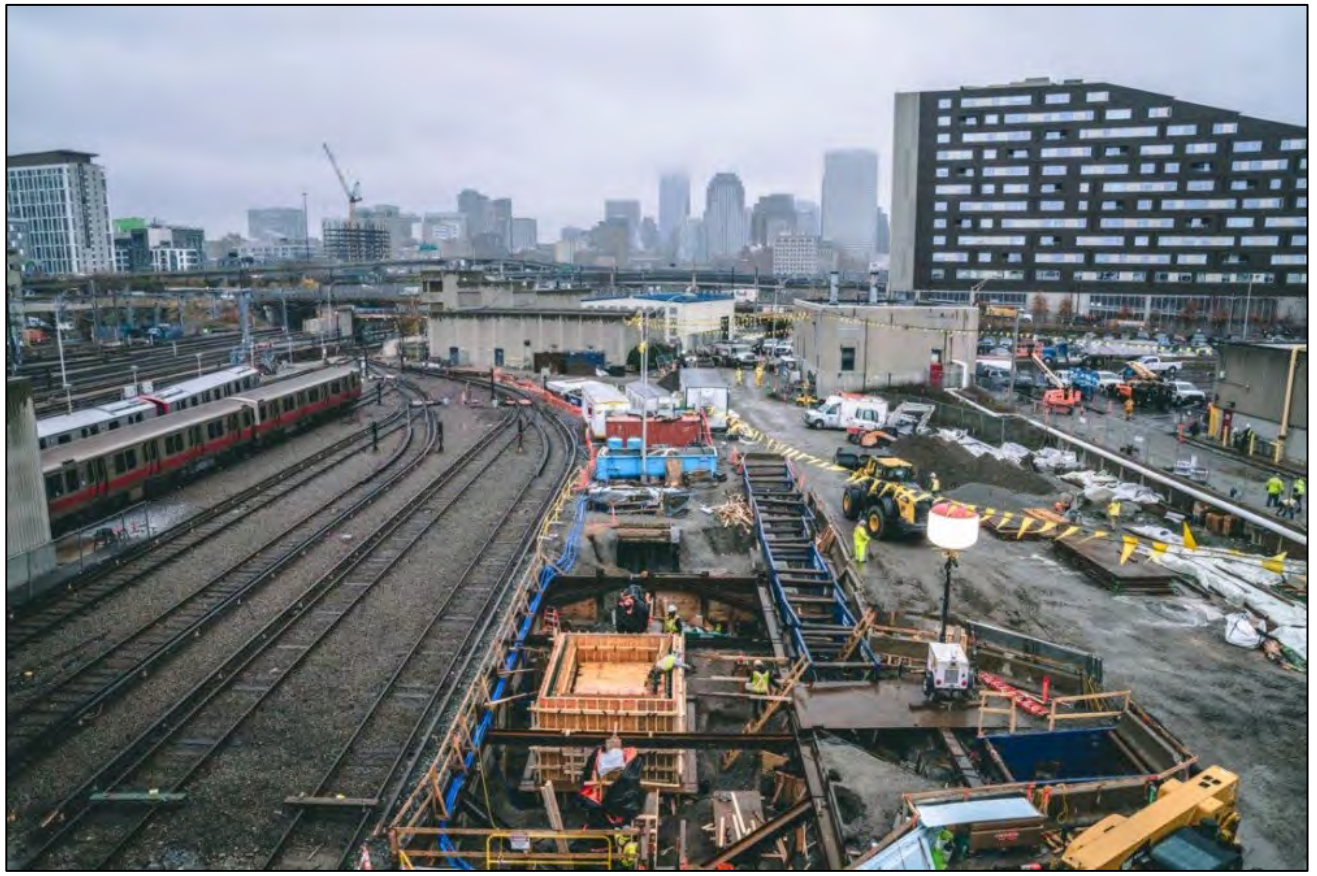
Example Application – Cabot Yard

Exposure → **Sensitivity** → **Adaptive Capacity**

Extreme Heat
- 2030 (2)

Wind
- Within 600 feet of open waterway that is 1 mile across (Exp. D); close to Fort Point Channel/open connection to Boston inner harbor (4)

Winter Weather
- Partially exposed to outdoors (2)



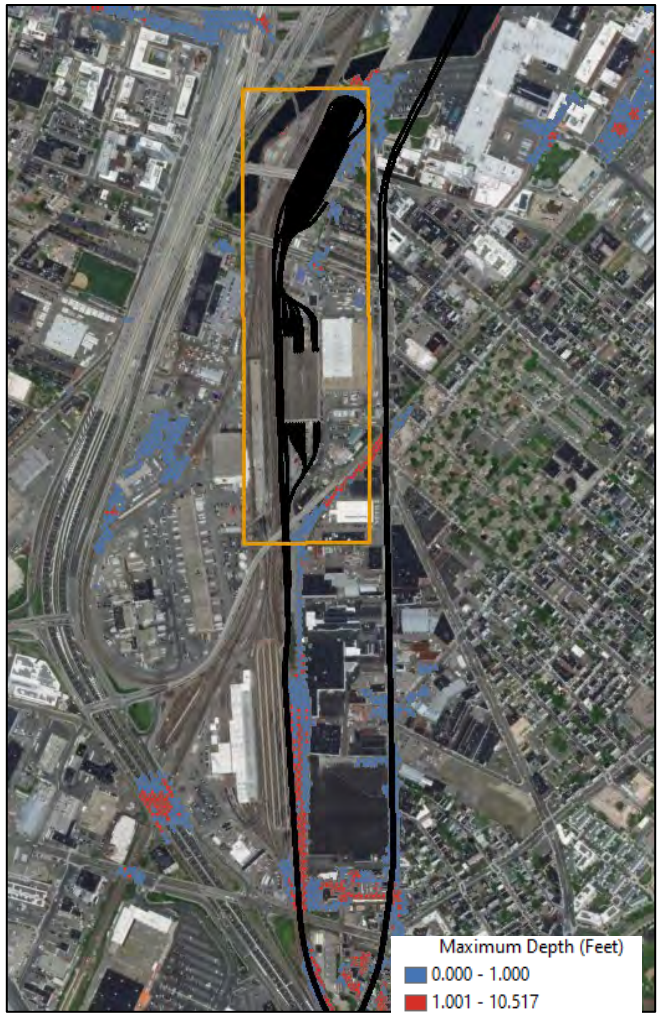
Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Exposure → Sensitivity → Adaptive Capacity

Precipitation

- *10-year (>1-foot inundation) - Score of 4*



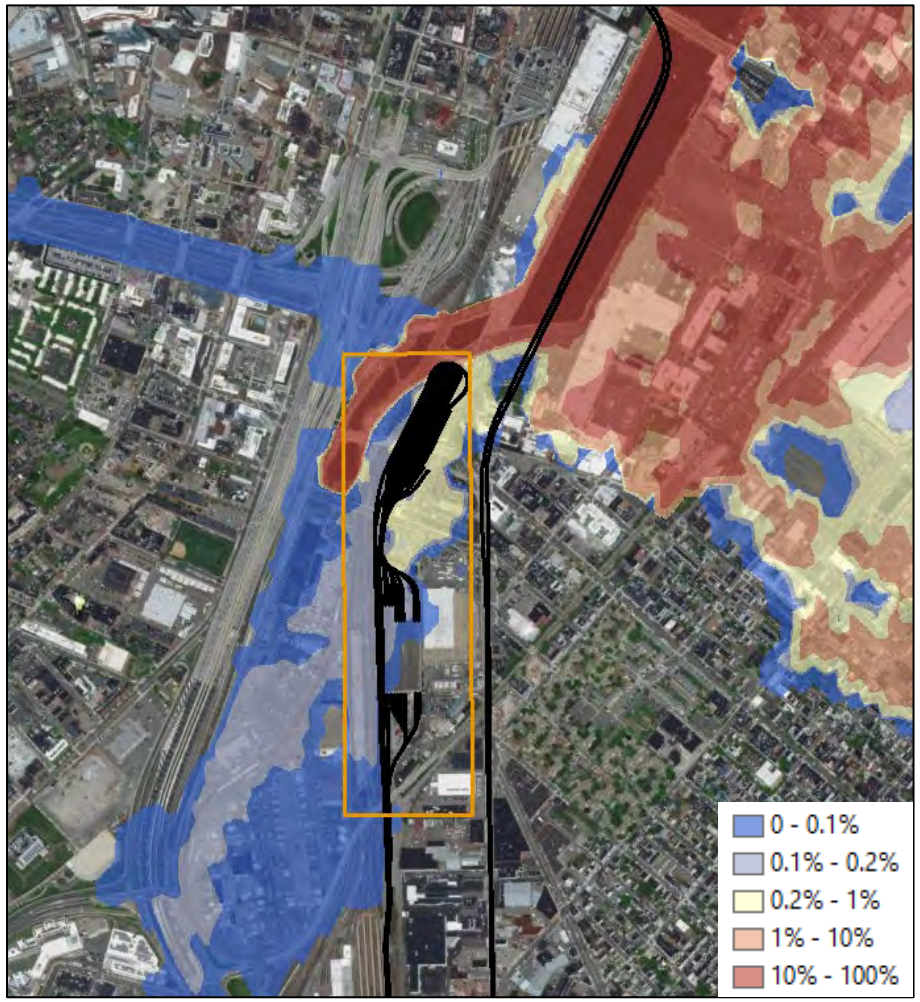
Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Exposure → **Sensitivity** → **Adaptive Capacity**

SLR/Storm Surge

- *10% + Annual Coastal Flood Exceedance Probability (ACFEP) – Score of 4*



Scoring for Sensitivity Indicators

Indicators	Scores *(1 = least sensitive, 4 = most sensitive)*			
	4	**3**	**2**	**1**
Asset complexity (% of possible critical systems present at asset)	76–100%	51–75%	26–50%	0–25%
Critical systems sensitivity (% of possible sensitivity score for critical systems present)	76–100%	51–75%	26–50%	0–25%
Past impact/failure	Yes – Major		Yes – Minor	No
Asset Location (SLR/Storm Surge and Precipitation Score Only)	Belowground	At-grade (open/partially enclosed)	At-grade (fully enclosed)	Aboveground
Asset Location (Wind, Heat, and Winter Weather Score Only)	Not enclosed	Partially enclosed	Fully enclosed	Belowground

Sensitivity Score Per Climate Stressor *= (Asset Complexity Score * 25%) + (Critical Systems Sensitivity Score * 25%) + (Past Impact/Failure Score * 25%) + (Asset Location * 25%)*

Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Exposure → Sensitivity → Adaptive Capacity

Does System exist within Cabot?		Heat	Precip	SLR/SS	Wind	Winter Weather
Carhouse	Y	2	4	4	3	2
Signal Tower	Y	2	4	4	2	1
Tracks & Roadbed	Y	2	4	4	2	2
Switches &Switch Heaters	Y	4	4	4	2	2

Sensitivity Indicators	Heat		Precip		SLR/SS		Wind		Winter Weather	
Asset complexity (% of possible critical systems present at asset)	100%	4	100%	4	100%	4	100%	4	100%	4
Critical systems sensitivity (% of possible sensitivity score for critical systems present)	63%	3	100%	4	100%	4	56%	3	44%	2
Past impact/failure	Yes-Minor	2	Yes-Minor	2	No	1	No	1	Yes-Major	4
Asset Location (SLR & Precipitation)	N/A for this hazard		At-grade (open/ partially enclosed)	3	At-grade (open/ partially enclosed)	3	N/A for this hazard		N/A for this hazard	
Asset Location (Wind, Heat & Winter Weather)	Partially enclosed	3	N/A for this hazard		N/A for this hazard		Partially enclosed	3	Partially enclosed	3
VAST Score	**3**		**3.25**		**3**		**2.75**		**3.25**	

Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Exposure → **Sensitivity** → Adaptive Capacity

Climate Stressor	Past Impact Failure Details *(Source)*
Extreme Heat	• Small fires can happen on the rail ties in the yard when sparked during hot/dry periods *(Site Visit).*
Precipitation	• Mothers Day Flood 2006: Service for Lead Track 2 at Cabot Yard was lost, and some track circuits were dropped *(MBTA Records).* • Flooding at the Cabot Southbound lead track underpass to the Braintree line. • Flooding in parking lot located southeast of carhouse, and water can pond at the southern edge of the carhouse; same situation at Gate 9. Poor drainage *(Site Visit).*
Winter Weather	• Blizzard 2013: A partial out and back at Cabot Yard *(MBTA Records).* • Winter 2015: Impacted *(Survey).* • Snow storage can be difficult because of limited space in the parking lot; derailment occurred recently due to a frozen switch *(Site Visit).*

Scoring for Adaptive Capacity Indicators

Indicators	Scores (1 = high adaptive capacity, 4 = low adaptive capacity)			
	4	3	2	1
Distance from Central Point of MBTA System	>5 miles from principal maintenance facility (Cabot Yard)	3-5 miles from principal maintenance facility (Cabot Yard)	1-3 miles from principal maintenance facility (Cabot Yard)	<1 mile from principal maintenance facility (Cabot Yard)
Redundancy (Service Option, Interchange Utility) *Guideway not scored for this indicator*	No ability to transfer (bus service line, commuter rail, other yard, other lines)			Ability to transfer (bus service line, commuter rail, other yard, other lines)
Presence of Backup Generator(s) for Critical Infrastructure	Does not have a backup generator on-site	Has ability to connect to mobile generator		Has a backup generator on-site
Flood Protection Systems	No flood protection / limited to standard operating procedures (sandbags only)	Deployable system (designed to appropriate design storm)		Passive system (designed to appropriate design storm)

Station and Maintenance Adaptive Capacity Score across All Climate Stressors *= (Distance from Central Point of MBTA System* 25%) + (Redundancy Score * 25%) + (Backup Generator Score * 25%) + (Flood Protection Score * 25%)*

Guideway Adaptive Capacity Score across All Climate Stressors *= (Distance from Central Point of MBTA System* 33%) + (Backup Generator Score * 33%) + (Flood Protection Score * 33%)*

Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Exposure → Sensitivity → Adaptive Capacity

- Distance from Central Point of MBTA System
  - *<1 mile from Cabot Yard (1)*
- Redundancy
  - *No ability to transfer (1)*
- Backup Generator(s) for Critical Infrastructure
  - *Backup generator on-site (1)*
- Flood Protection Systems
  - *No flood protection (4)*

Overall Vulnerability Score

- Vulnerability scores per climate stressor were calculated for both 2030 and 2070, using the outputs for exposure, sensitivity, and adaptive capacity.
- Each score was multiplied by equal weighting (33%) and then added together.

Vulnerability Score Per Climate Stressor *= (Exposure Score * 33%) + (Sensitivity Score * 33%) + (Adaptive Capacity Score * 33%)*

- SLR/Storm Surge and Wind vulnerability scores are zeroed out if not exposed.
- An overall vulnerability score for 2030 and 2070 was developed by averaging the scores across the five climate stressors.

Climate Change Vulnerability Assessment Methodology

Example Application – Cabot Yard

Overall Vulnerability Assessment Score Calculations (2030 Example)

	Exposure	*Sensitivity*	*Adaptive Capacity*	
– ***Extreme Heat:***	*(2*33%)*	*+ (3*33%)*	*+ (2.5*33%)*	*= **2.50***
– ***Precipitation:***	*(4*33%)*	*+ (3.25*33%)*	*+ (2.5*33%)*	*= **3.25***
– ***SLR/Storm Surge:***	*(4*33%)*	*+ (3*33%)*	*+ (2.5*33%)*	*= **3.17***
– ***Wind:***	*(4*33%)*	*+ (2.75*33%)*	*+ (2.5*33%)*	*= **3.08***
– ***Winter Weather:***	*(2*33%)*	*+ (3.25*33%)*	*+ (2.5*33%)*	*= **2.58***

*Average across stressors = **2.92***

Appendix B: Adaptation Measures Cabot Yard Example

Adaptation Measures

Applying Adaptation Measures: Cabot Yard

Highly vulnerable to:

- Extreme Heat
- Precipitation
- Winter Weather
- SLR/Storm Surge
- Wind

Adaptation Measures

Extreme Heat

1) Install rail expansion joints in areas of Cabot Yard that are prone to buckling during extreme heat conditions.

2) Add cool or green roofs to on-site utility buildings to lower temperatures for housed electronics

Implementation Timing: 2030

Assets Protected: Maintenance facility/yard guideways, contents of utility buildings

Co-Benefits: Increased stormwater capture/treatment from green roofs

Potential Partners: Not applicable

Adaptation Measures

Precipitation Flooding

1) Increase stormwater drainage capacity in flood-prone areas (carhouse, Gate 9).
2) Install permeable pavement in parking areas.
3) Add green infrastructure around parking areas.
4) Install backflow prevention (e.g., flap gates at stormwater drainage points connected to the carhouse and bus operations facility).
5) Install pump station to increase stormwater drainage against high tides.
6) Floodproof the Signal Tower, using a flood field at entryways or a waterproof membrane.

Implementation Timing: 2030

Assets Protected: Carhouse, bus operations facility, guideways, parking lots, buildings, substations, electrical/mechanical equipment

Co-Benefits: Increased yard aesthetics from green infrastructure

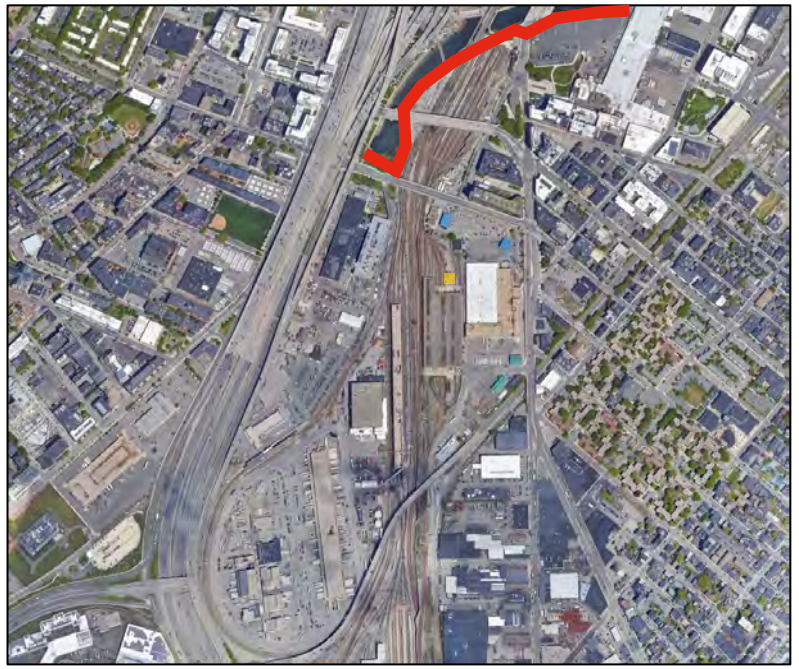
Potential Partners: Not applicable

Adaptation Measures

SLR/Storm Surge Flooding

1) Coordinate with the City of Boston to address low-lying shoreline elevations along Bass River and the Fort Point Waterfront.

2) Elevate the substation currently under construction.



Implementation Timing: 2030

Assets Protected: Substation, carhouse, guideways, parking lots, buildings, electrical/mechanical equipment, stored train cars

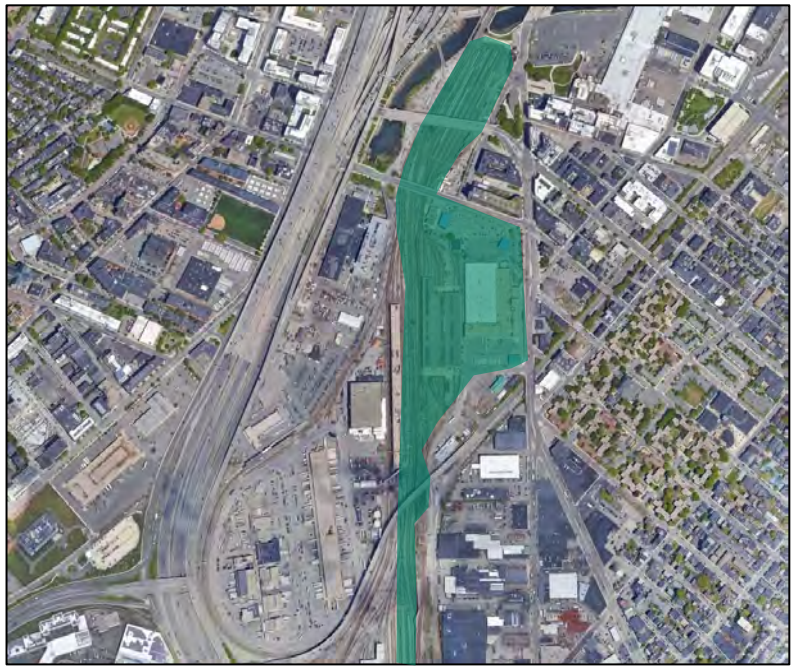
Co-Benefits: Regional flood protection for adjacent properties (Fort Point, South Boston, D Street/West Broadway)

Potential Partners: City of Boston

Adaptation Measures

Wind

1) Develop protocols to secure loose objects in the yard prior to coming high-wind events.



Implementation Timing: 2030

Assets Protected: Carhouse, buildings, electrical/mechanical equipment, stored train cars

Co-Benefits: Not applicable

Potential Partners: Not applicable

Adaptation Measures

Winter Weather

1) Continue operational snow and ice removal procedures (using snow throwers, installing scraper shoes, “rocking” trains in the yard).
2) Coordinate with the City of Boston to prioritize snow removal to the Cabot Yard site.
3) Store trains inside the carhouse overnight prior to winter storms.

Implementation Timing: 2030

Assets Protected: Stored train cars, parking lots

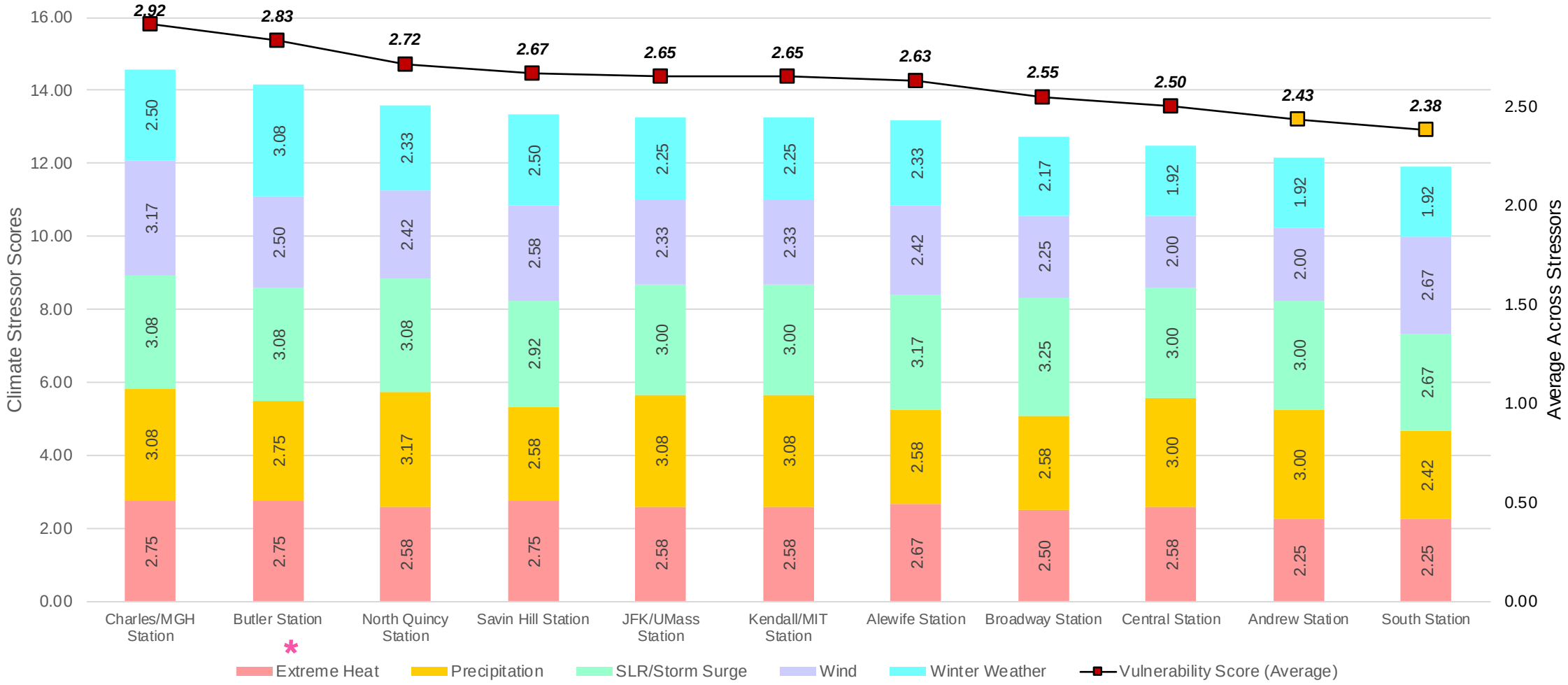
Co-Benefits: Not applicable

Potential Partners: City of Boston

Appendix C: 2070 Result Charts

Climate Change Vulnerability Assessment Results

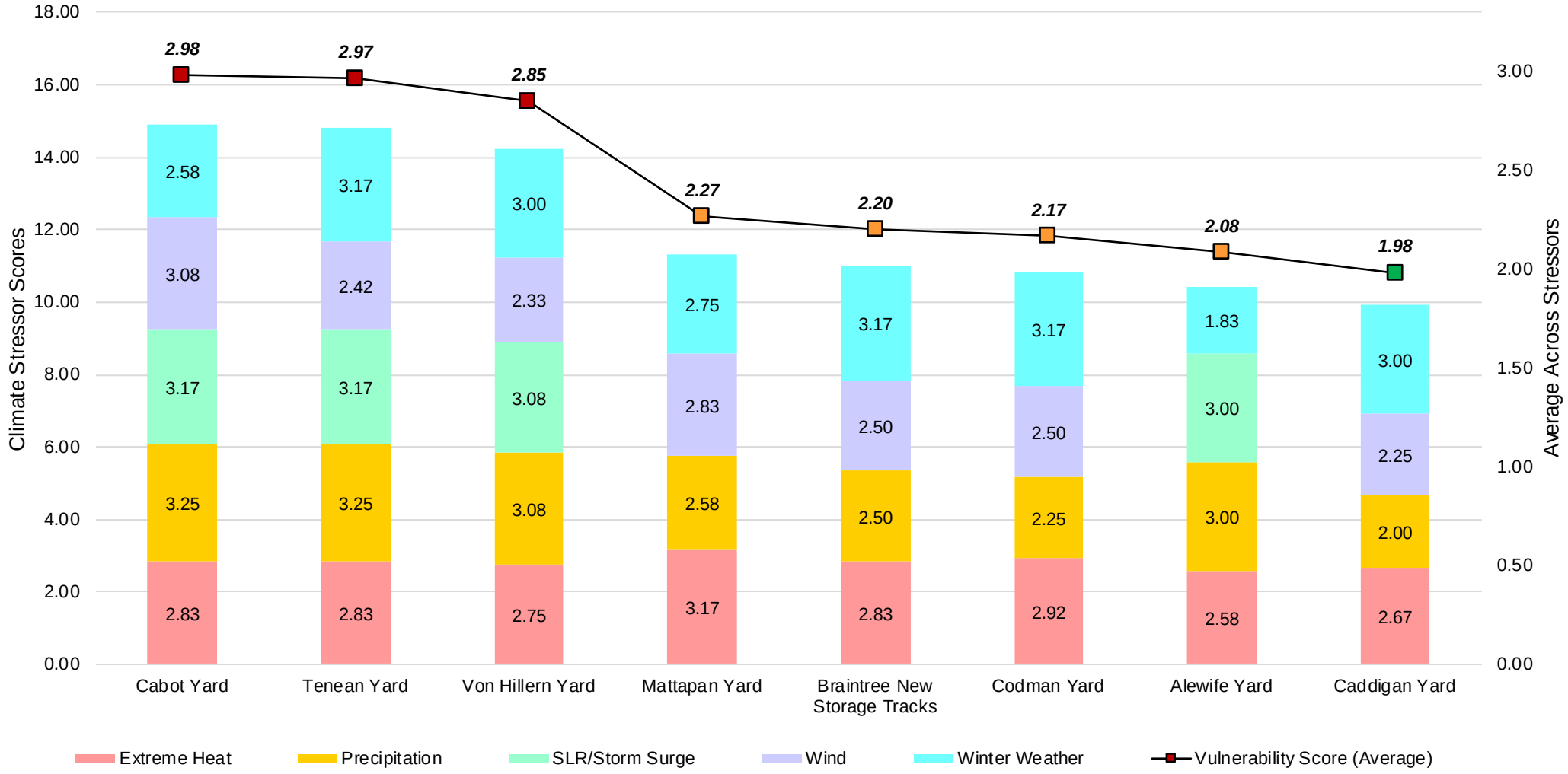
Top Station Vulnerability - 2070



*Mattapan Line Station

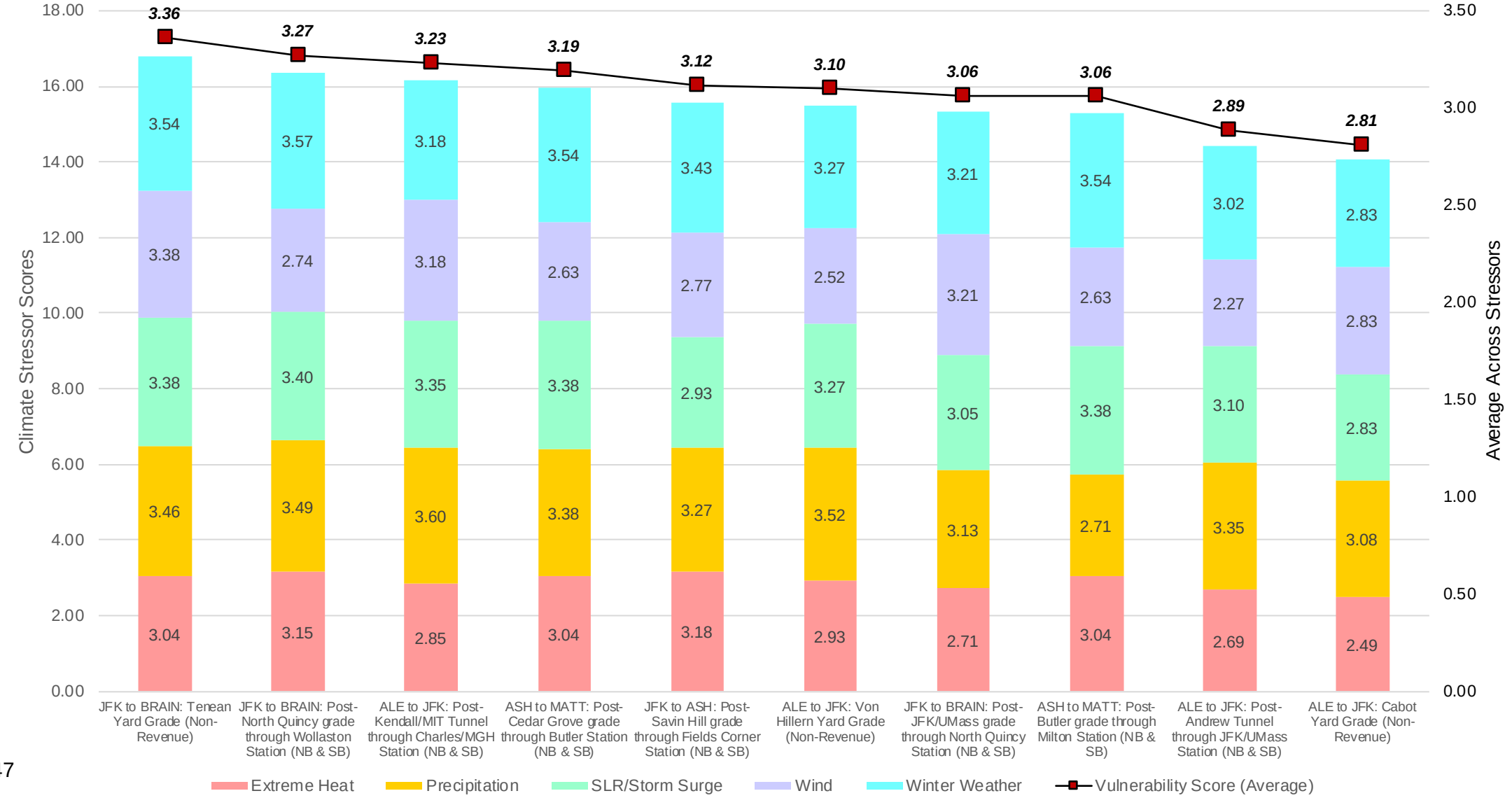
Climate Change Vulnerability Assessment Results

Top Maintenance Facility/Yard Vulnerability - 2070



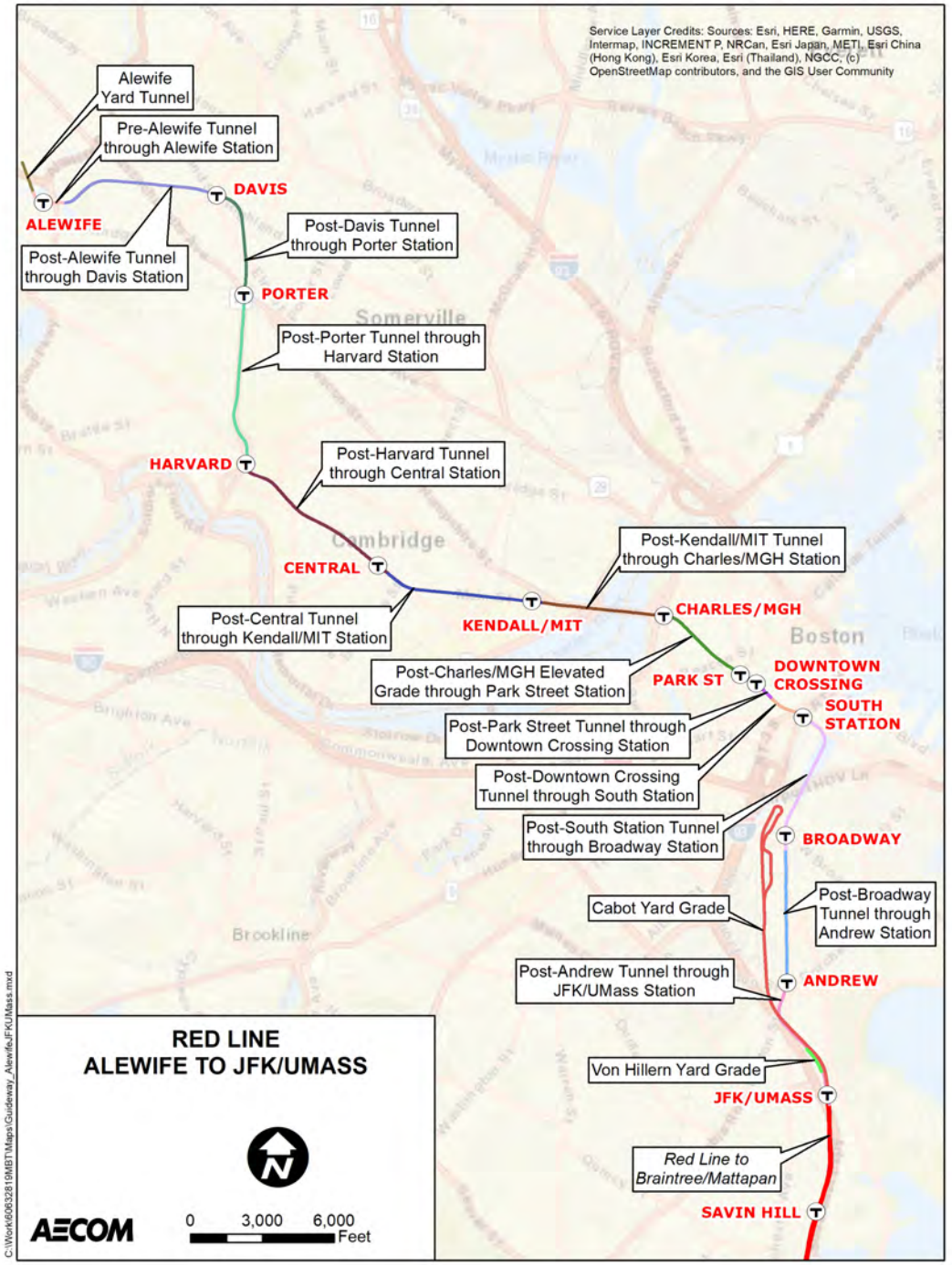
Climate Change Vulnerability Assessment Results

Top Guideway Vulnerability - 2070

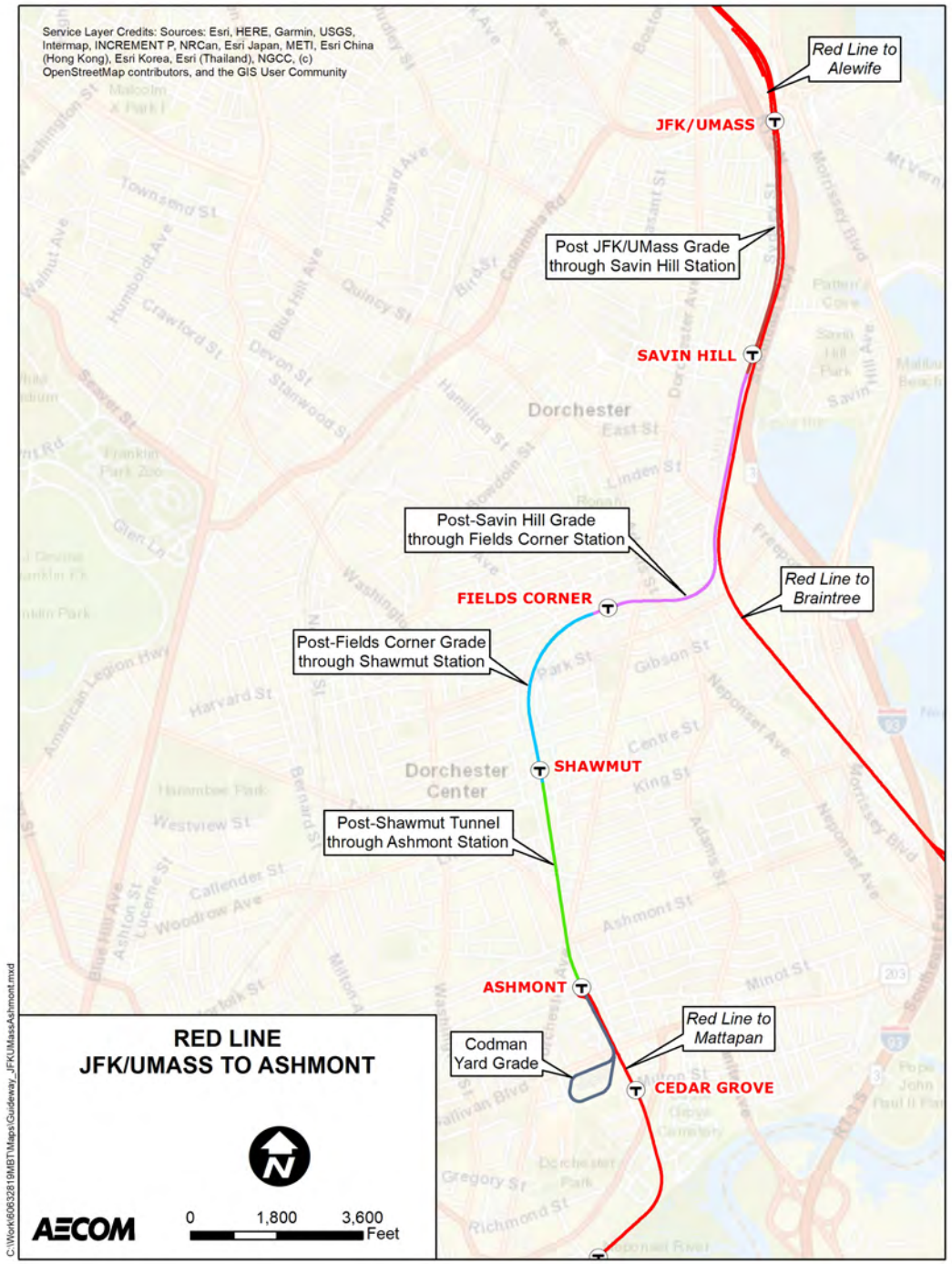


Appendix D: Guideway Segments

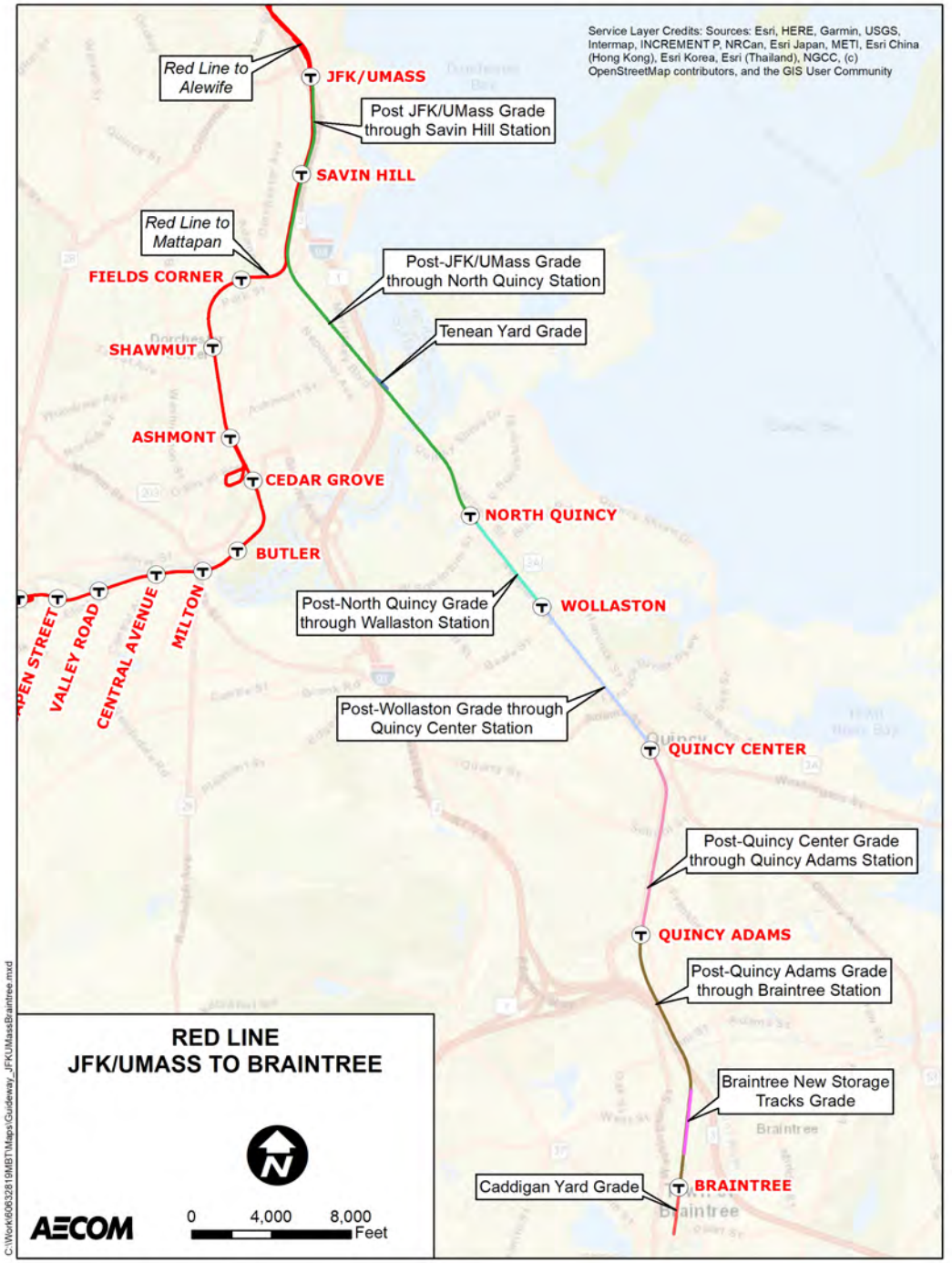
Labeled Guideway Segments for Alewife to JFK/UMass



Labeled Guideway Segments for JFK/UMass to Ashmont



Labeled Guideway Segments for JFK/UMass to Braintree



Labeled Guideway Segments for Ashmont to Mattapan