

ORANGE LINE

Climate Change Vulnerability
Assessment

Final Presentation to MBTA



Weston & SampsonSM

ARUP

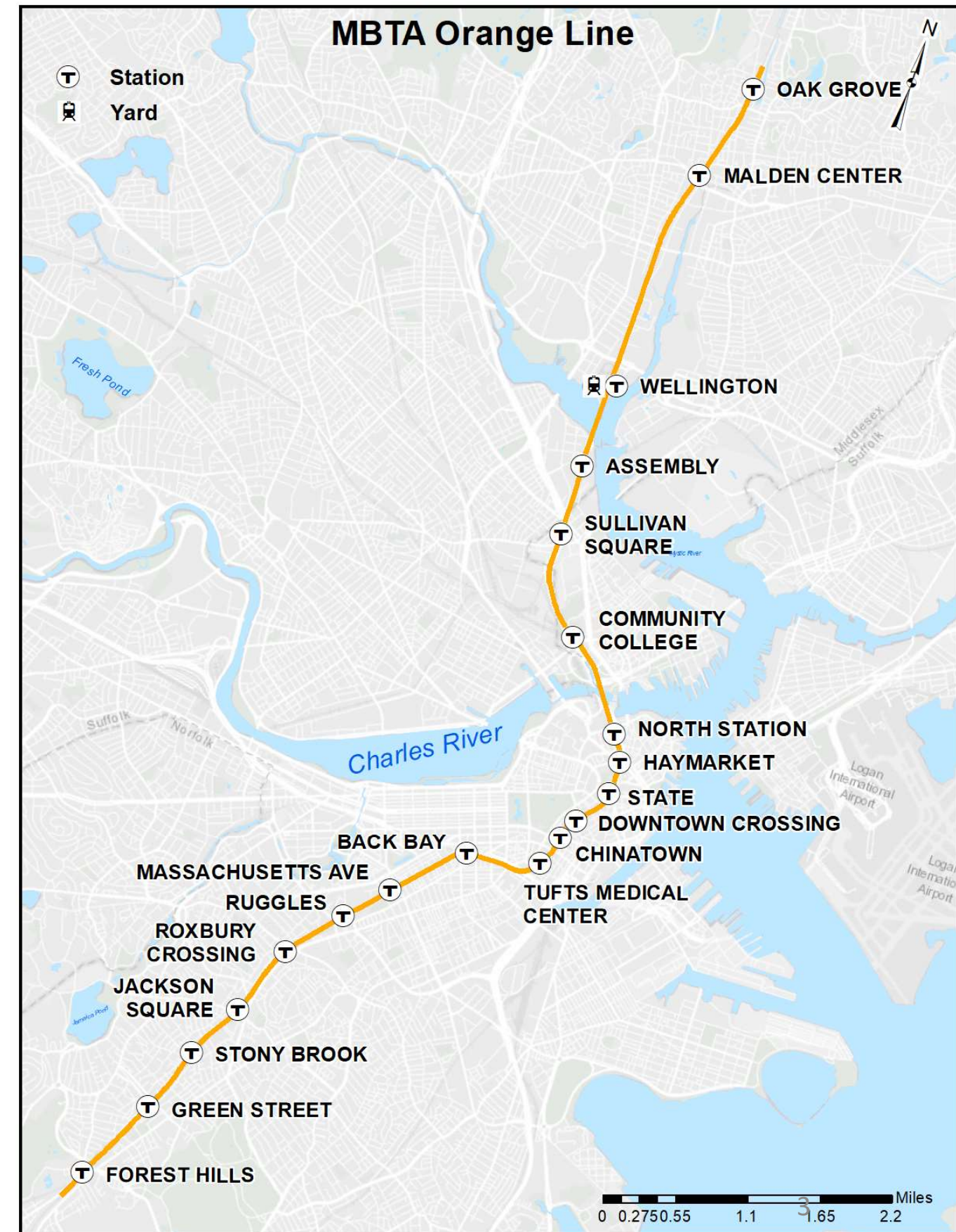
January 2022

Presentation Outline

- Recap goals & objectives
- Brief overview of methodology
- Data gathering
- Exposure
- Vulnerability Assessment Results – 2030 and 2070
- Key Findings
- Adaptation Strategies
- Recommendation & Next Steps
- Q&A

Goals and Objectives

- Advance and document the MBTA's understanding of its **climate vulnerabilities**.
- Evaluate the anticipated **near- and long-term vulnerability of the Orange Line system** to the climate hazards of coastal flooding and sea level rise, extreme precipitation, extreme heat, wind, and winter weather.
- Develop a **standard climate change vulnerability assessment methodology**, which will allow the MBTA to conduct comparable assessments for all of its assets and infrastructure
- **Integrate resilience considerations** into the asset management and capital planning decisions
- Provide representative **climate adaptation strategies** and additional detailed studies for **prioritized most vulnerable** Orange Line system assets.



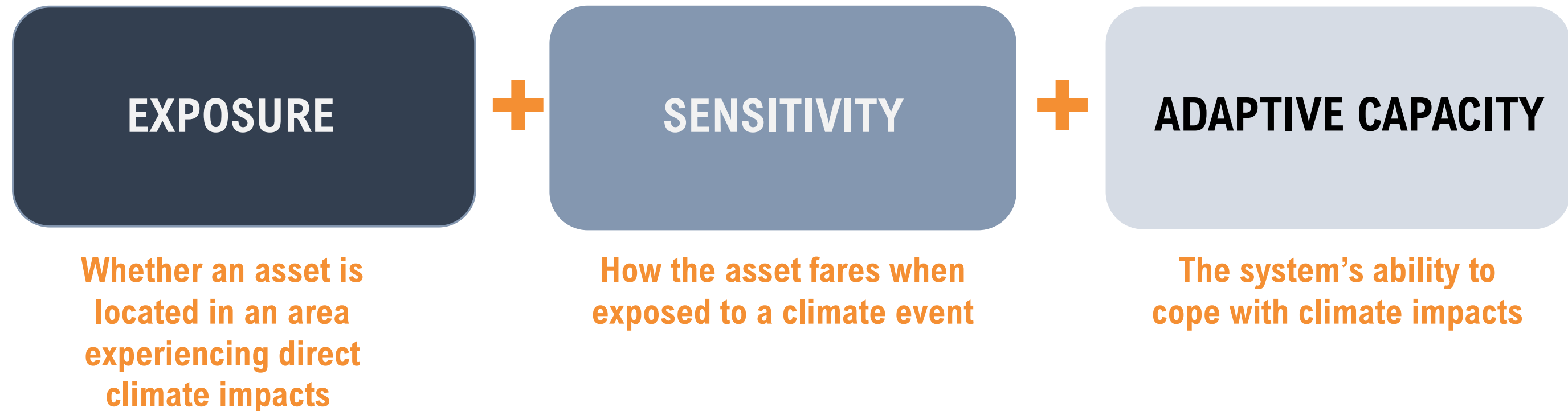
Key Deliverables

- **Vulnerability Assessment Tool**, which can:
 - identify major climate vulnerabilities
 - produce Vulnerability Scores for project planning & asset management and maintenance
 - assess resilience benefits of potential projects
 - be customized by adjusting weightings of individual climate stressors or vulnerability scores
 - be updated as projects are completed
- **Vulnerability Assessment Report**, including Summary Recommendations of Priority Projects and Adaptation Strategies
- **GIS file of Linear References Assets**, for identification of vulnerable assets
- **Flood Screening Memorandum + 2D Flood Modeling at 3 locations**, to identify areas of potential additional precipitation flood hazards
- **Vulnerability Assessment Presentation**, for communicating findings

Process Overview

The Federal Highway Administration's (FHWA) Vulnerability Assessment Scoring Tool (VAST) was used and **adapted** to align with the MBTA's goals and operations.

VULNERABILITY =



Data Gathering

Data Collection

- MBTA Plans, drawings, and background documents
- Site walks and interviews
- MBTA Asset Management Inventory, Severe Weather Plan, Snow and Ice Operations Plan, Rail Transit Manual, and Ventilation Report

Data Analysis

- Assets linear-referenced in GIS
- Sorted by category and type
- Evaluated based on criticality
- Elevations and critical details documented

42 Assets Selected for Assessment

Stations	Maintenance Yards	Guideway Sections
Forest Hills	Storage Track to Forest Hills**	Forest Hills - Green St
Green Street	Wellington Yard	Green St - Stony Brook
Stony Brook	Oak Grove to Northbound Storage Track***	Stony Brook - Jackson Sq
Jackson Square		Jackson Sq - Roxbury Crossing
Roxbury Crossing		Roxbury Crossing - Ruggles
Ruggles		Ruggles - Mass Ave
Massachusetts Avenue		Mass Ave - Back Bay
Back Bay		Back Bay - Tufts Medical Center
Tufts Medical Center		Tufts - Chinatown
Chinatown		Chinatown - DTX
Downtown Crossing		DTX - State
State		State - Haymarket
Haymarket		Haymarket - North Station
North Station		North Station - Community College + Test Track*
Community College		Community College - Sullivan Sq + Test Track*
Sullivan Square		Sullivan Sq - Assembly + Test Track*
Assembly		Assembly - Wellington + Test Track*
Wellington		Wellington - Malden Center + Test Track*
Malden Center		Malden Center - Oak Grove
Oak Grove		

*Scores are based on revenue track. Test track was not included as part of the scoring, but there are guideway segments where test tracks run parallel that were included and, thus, would likely have similar scores.

**Forest Hills storage can accommodate 48 cars and consists of 4 tracks below ground, where each track can hold two 6-car trains for daily pull-out/operations.

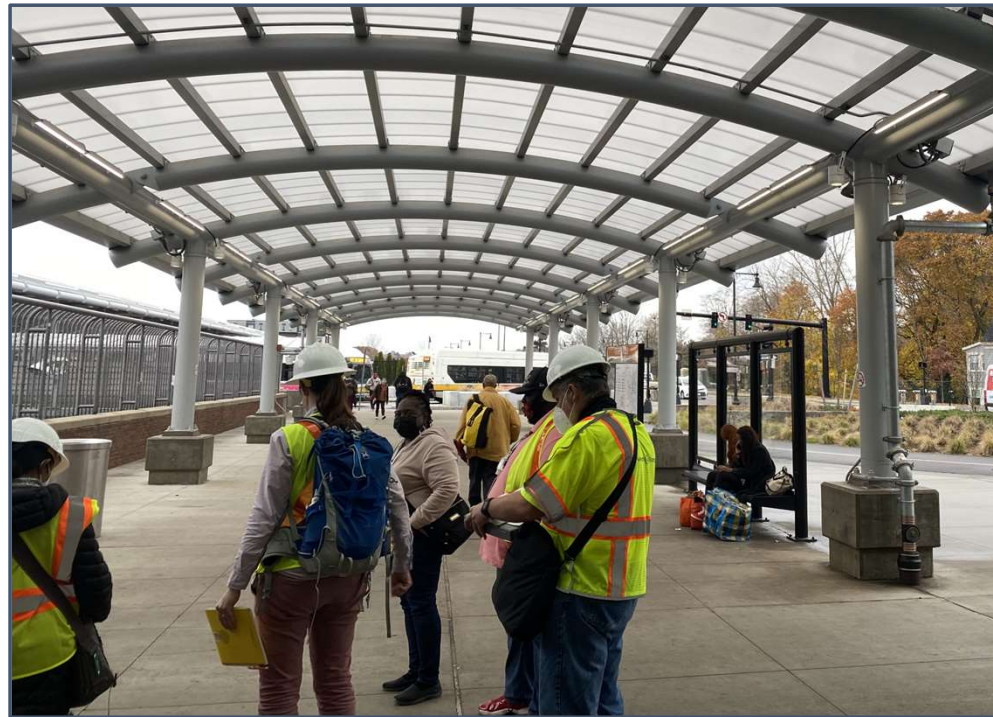
*** Wellington Yard can store 72 cars and consists of 10 tracks, where each track can hold 8-car trains, but 6-car trains are preferable.

Data Gathering

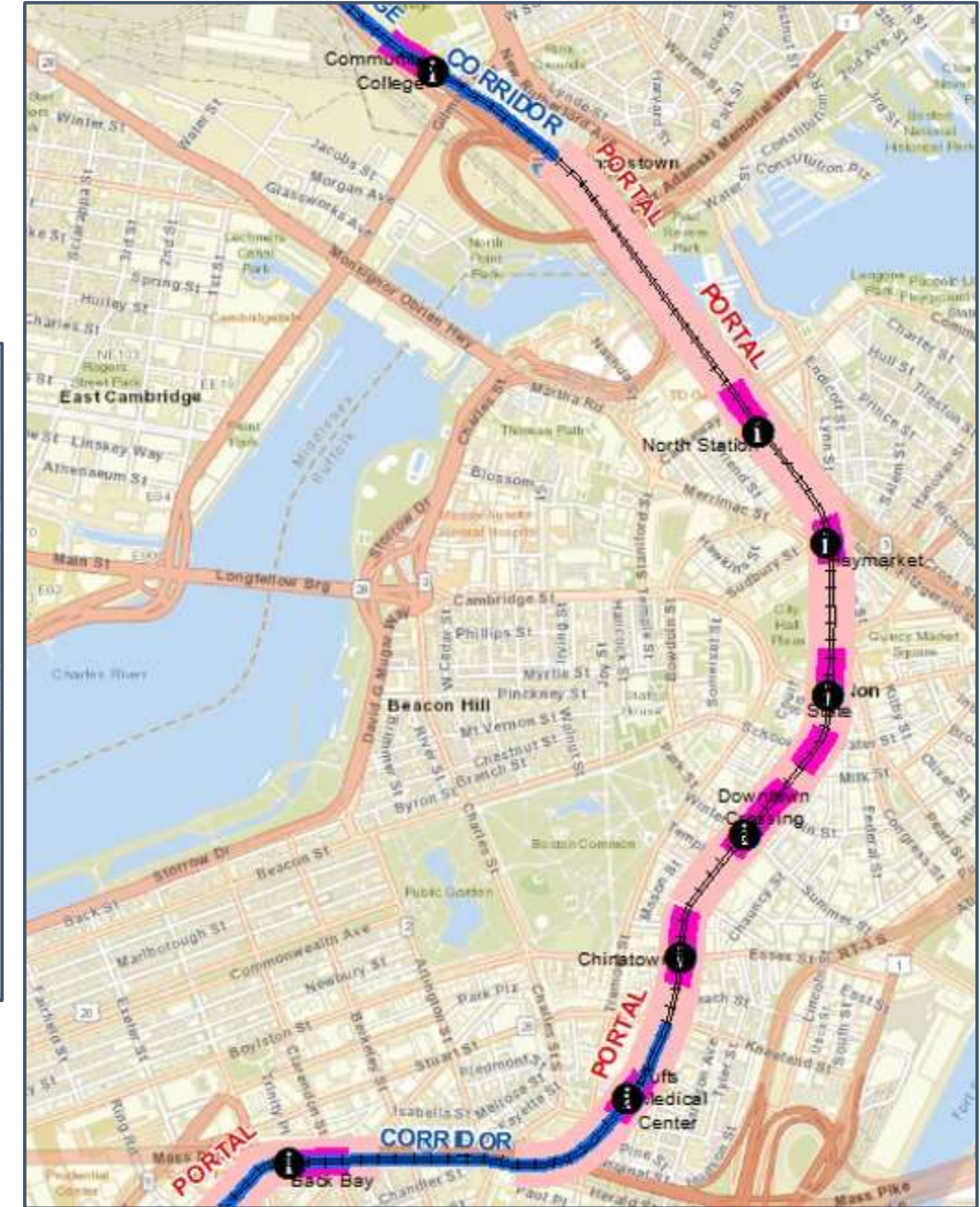
Station Site Visits



Interviews with MBTA Staff



Assets Linear Referenced in GIS








Data Gathering – Critical Systems Data by Asset Typology

Stations		Maintenance Yards		Guideway	
System Type	Components Included in Assessment	System Type	Components Included in Assessment	System Type	Components Included in Assessment
HVAC	Chillers, cooling towers, AHUs, boilers	Car House	Building structure & equipment	Bridge/Viaduct	Substructure, Superstructure
Electrical (Site)	Transformer	Signal Tower	Building structure & equipment	Tunnel Structure	
Conveyance	Escalator/ elevator electrical equipment and controls	Switches & switch heaters		Tunnel Mechanical - Pump Rooms	Pump rooms
Passenger Areas	Platforms & station entrance/lobby	Tracks & Roadbed		Tunnel Mechanical - Ventilation	Vent shafts, Ventilation fans
Fire Protection (Building)	Sprinkler system, fire suppression unit			Switches & switch heaters	
				Catenary	
				Track & Roadbed	

Historic Vulnerabilities

Table 4. Historic Climate Vulnerabilities and Impacts Reported by MBTA Staff

Asset Location					
Open-Air Stations					
Forest Hills Station					
Ruggles Station					
Ruggles Underpass					
Back Bay Station					
Tufts Medical Center Station					
Chinatown Station					
Downtown Crossing Station					
North Station					
Community College Station					
Sullivan Square Station					
Assembly Station					
Wellington Yard Signal Tower					
Wellington Yard Carhouse Basement					
Oak Grove Station					

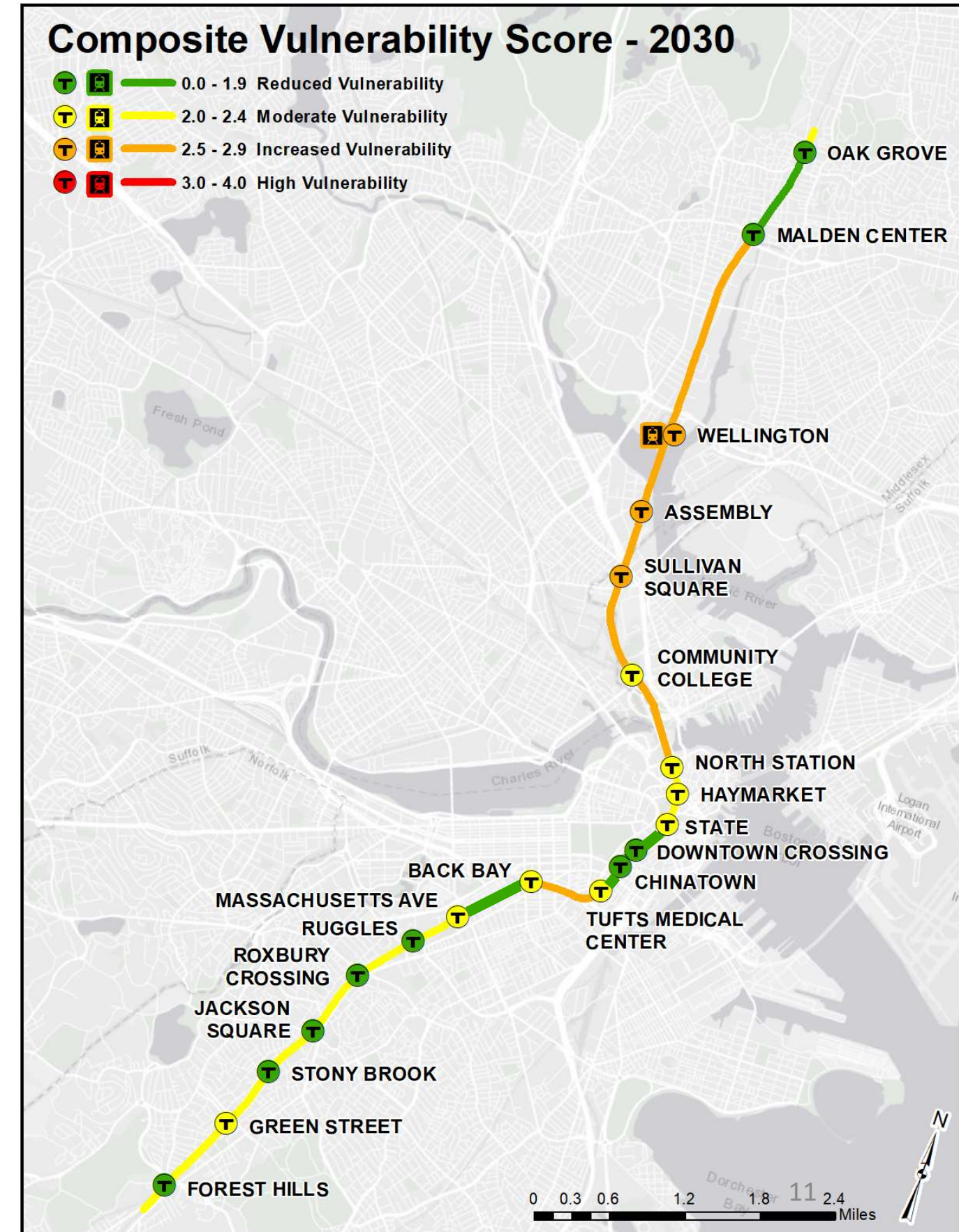
Assessment Results – 2030

Summary 2030 results map and table of Highly Vulnerable Assets

Highly Vulnerable Assets: 2030 Vulnerability Scores ≥ 2.5

- Vulnerability = Exposure + Sensitivity + Adaptive Capacity

Asset Description			2030 Vulnerability Scores					
No.	Name	Type	Composite					
1	Wellington Yard	Yard	2.9	2.5	3.0	2.3	3.2	3.2
2	Assembly - Wellington	Guideway	2.8	2.5	2.1	3.1	3.0	3.1
3	Assembly Station	Station	2.7	2.3	2.1	2.8	3.1	3.1
4	Wellington – Malden	Guideway	2.6	2.2	3.0	2.7	2.2	3.0
5	Community College – Sullivan Sq.	Guideway	2.6	2.2	2.9	2.9	2.2	2.9
6	Sullivan Sq. – Assembly	Guideway	2.6	2.6	2.2	2.6	2.5	3.2
7	North Station – Community College	Guideway	2.5	2.2	3.1	3.1	1.9	2.3
8	Back Bay – Tufts Medical Center	Guideway	2.5	2.4	3.2	2.2	2.4	2.4
9	Wellington Station	Station	2.5	2.1	2.6	2.0	2.8	2.9
10	Sullivan Square Station	Station	2.5	2.3	2.1	3.1	2.3	2.4



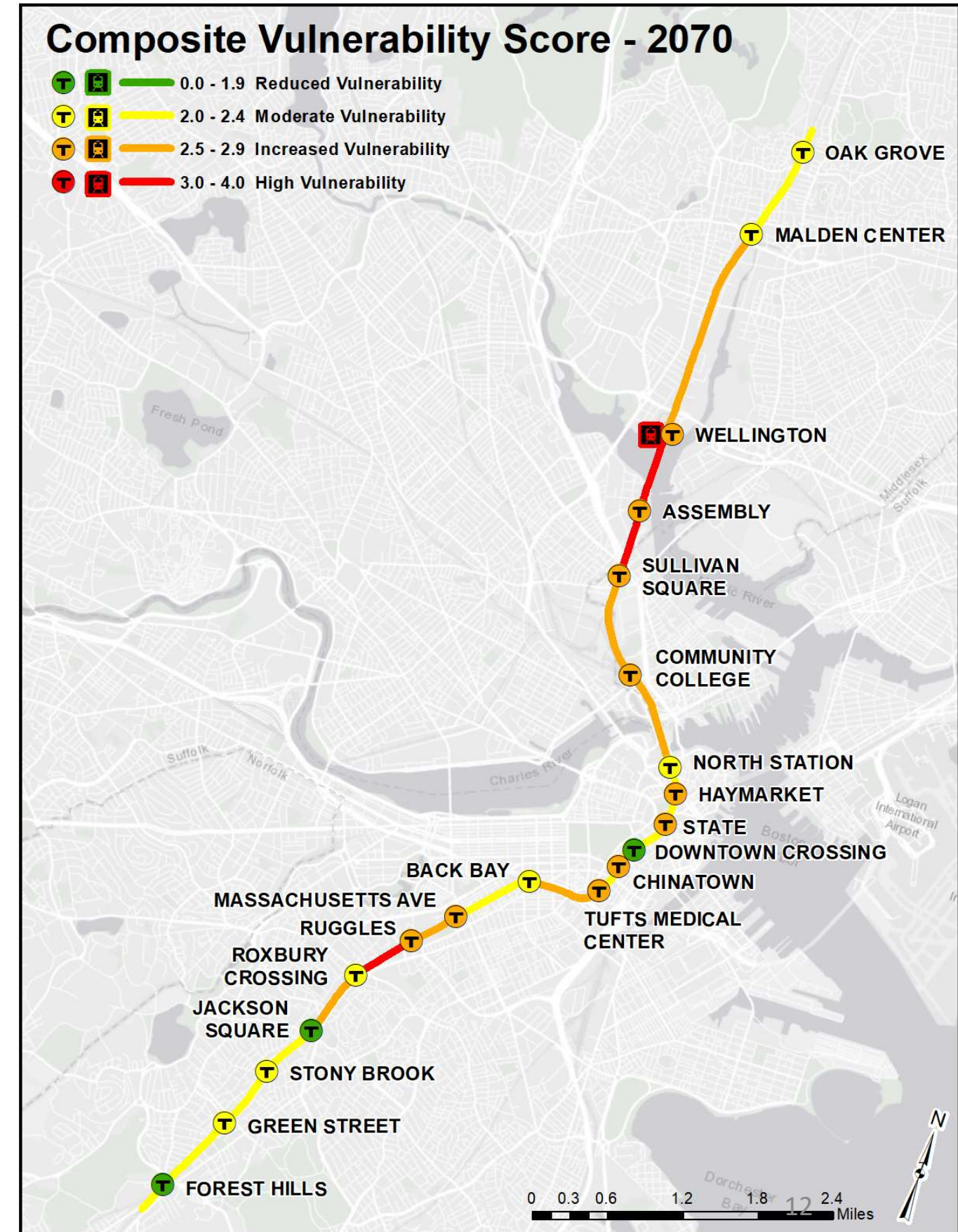
Assessment Results – 2070

Summary 2070 results map and table of Highly Vulnerable Assets

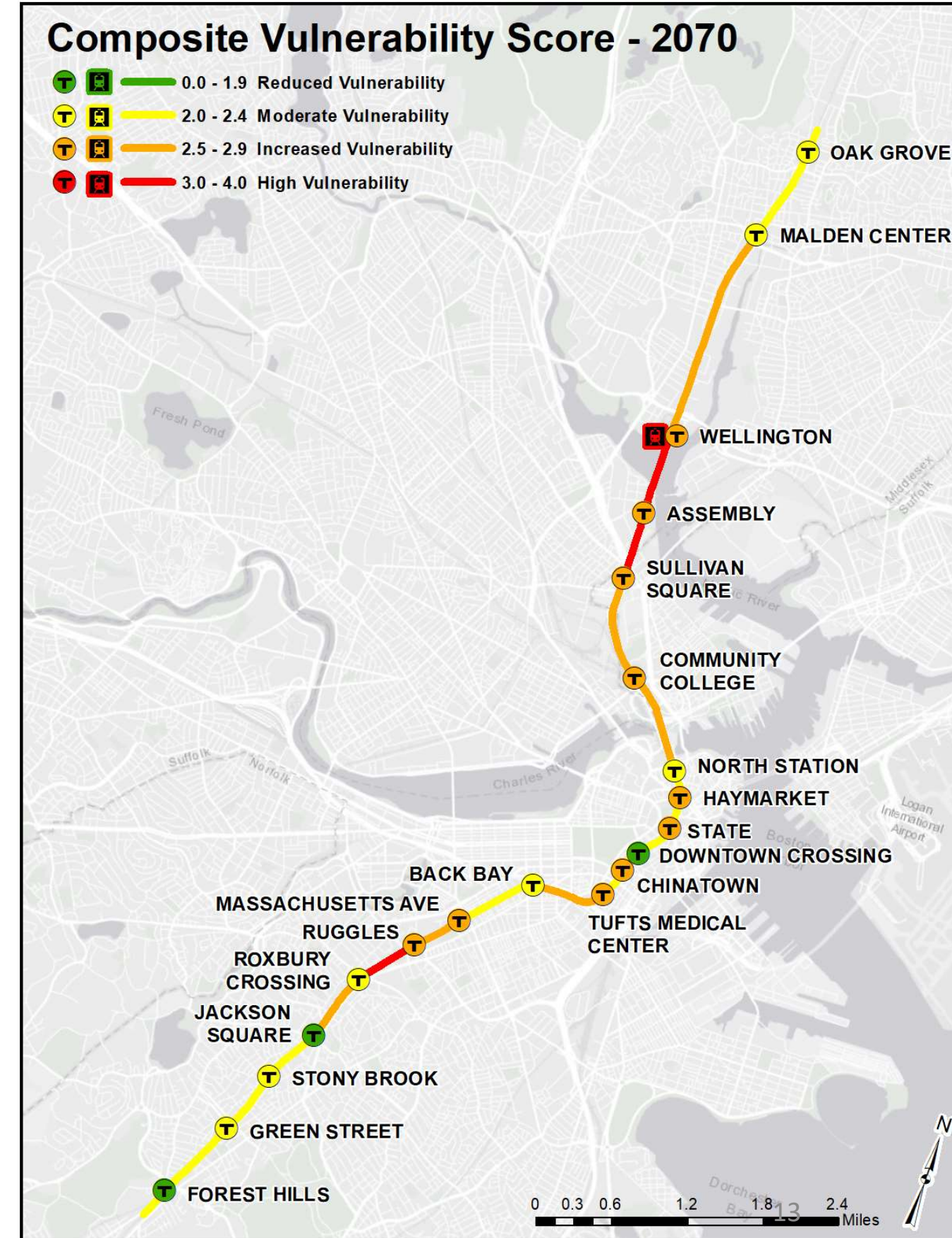
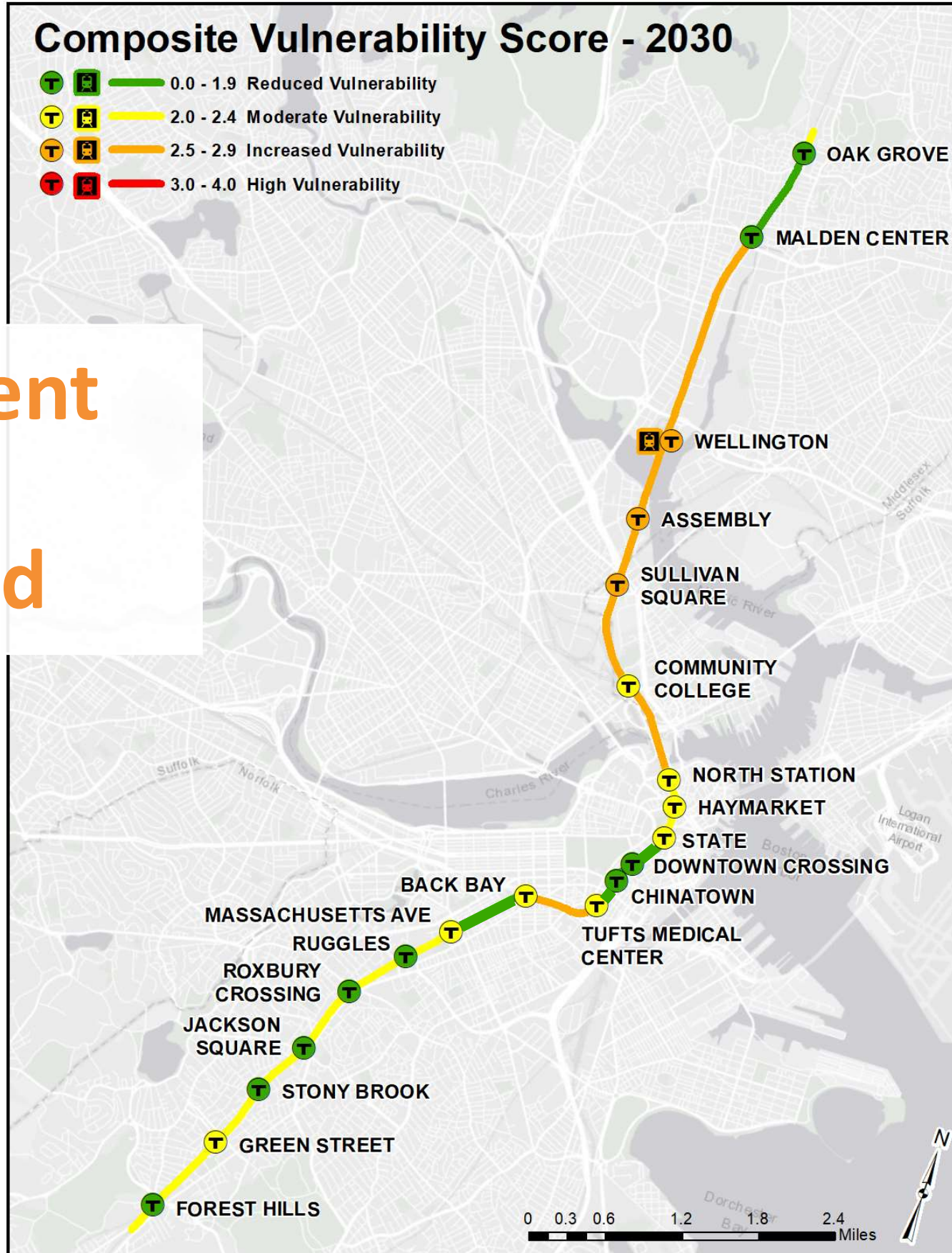
Highly Vulnerable Assets: 2070 Vulnerability Scores ≥ 2.5

- Vulnerability = Exposure + Sensitivity + Adaptive Capacity






Asset Description			2070 Vulnerability Scores						
No.	Name	Type	Composite						
1	Wellington Yard	Yard	3.2	2.9	3.4	3.3	3.2	3.2	
2	Assembly - Wellington	Guideway	3.0	2.8	3.1	3.1	3.0	3.1	
3	Sullivan Sq. – Assembly	Guideway	3.0	2.9	3.2	3.2	2.5	3.2	
4	Roxbury Crossing – Ruggles	Guideway	3.0	3.2	3.0	3.0	2.9	3.0	
5	Ruggles – Mass Ave	Guideway	2.9	2.9	3.3	2.9	2.5	3.2	
6	Wellington Station	Station	2.8	2.5	3.0	3.0	2.8	2.9	
7	Assembly Station	Station	2.8	2.6	2.1	3.1	3.1	3.1	
8	Wellington – Malden Center	Station	2.8	2.6	3.0	3.0	2.2	3.0	
9	Sullivan Square Station	Station	2.7	2.6	3.1	3.1	2.3	2.4	
10	Back Bay – Tufts Medical Center	Guideway	2.7	2.7	3.2	2.9	2.4	2.4	
11	Community College – Sullivan Sq.	Guideway	2.7	2.6	2.9	2.9	2.2	2.9	
12	Massachusetts Ave Station	Station	2.7	2.6	3.1	2.8	2.4	2.4	
13	Haymarket Station	Station	2.6	2.6	3.3	3.3	2.0	2.0	
14	State Street Station	Station	2.6	2.6	3.3	3.3	2.0	2.0	
15	North Station – Community College	Guideway	2.6	2.6	3.1	3.1	1.9	2.3	
16	Ruggles Station	Station	2.6	2.7	2.6	2.8	2.4	2.4	
17	Chinatown Station	Station	2.6	2.6	3.0	3.3	1.9	2.0	
18	Jackson Sq. – Roxbury Crossing	Guideway	2.5	3.1	3.3	0.0	2.8	3.5	
19	Community College Station	Station	2.5	2.6	2.0	3.0	2.3	2.4	
20	Tufts Medical Center Station	Station	2.5	2.6	2.6	3.3	1.9	2.0	



Assessment Results – Compared








Key Findings – Most Vulnerable Assets by 2030

Asset Description		2030 Vulnerability Scores					
Name	Type	Composite					
Wellington Yard	Yard	2.9 ¹	2.5	3.0	2.3	3.2 ²	3.2
Assembly – Wellington + Test Track	Guideway	2.8 ¹	2.5	2.1	3.1	3.0	3.1
Assembly Station	Station	2.7 ¹	2.3	2.1	2.8	3.1	3.1
Mass Ave – Back Bay	Guideway	1.7	2.6	3.6 ²	0.0	0.0	2.3
Green St – Stony Brook	Guideway	2.3	2.8	2.6	0.0	2.8	3.5 ²
Jackson Sq – Roxbury Crossing	Guideway	2.3	2.8	2.6	0.0	2.8	3.5 ²
Sullivan Square Station	Station	2.5	2.3	2.1	3.1 ²	2.3	2.4
Roxbury Crossing - Ruggles	Guideway	2.3	2.9 ²	3.0	0.0	2.9	3.0
North Station	Station	2.3	2.0	3.1 ³	2.8	1.7	1.7

Notes:

1. Asset has one of the top 3 highest composite Vulnerability scores
2. Asset has the highest Vulnerability score for a single hazard
3. Asset has the highest Exposure + Sensitivity (Impact) score out of the hazards studied

Key Findings – Most Vulnerable Assets by 2070

Asset Description		2030 Vulnerability Scores					
Name	Type	Composite					
Wellington Yard	Yard	3.2 ¹	2.9	3.4	3.3	3.2 ²	3.2
Assembly – Wellington + Test Track	Guideway	3.0 ¹	2.8	3.1	3.1	3.0	3.1
Sullivan – Assembly + Test Track	Guideway	3.0 ¹	2.9	3.2	3.2	2.5	3.2
Mass Ave – Back Bay	Guideway	2.4	3.0	3.6 ²	3.3	0.0	2.3
Green St – Stony Brook	Guideway	2.4	3.1	2.6	0.0	2.8	3.5 ²
Jackson Sq – Roxbury Crossing	Guideway	2.5	3.1	3.3	0.0	2.8	3.5 ²
State - Haymarket	Guideway	2.3	2.8	3.4	3.4 ²	0.0	2.1
Roxbury Crossing - Ruggles	Guideway	3.0	3.2 ²	3.0	3.0	2.9	3.0
North Station	Station	2.4	2.3	3.1 ³	3.1	1.7	1.7

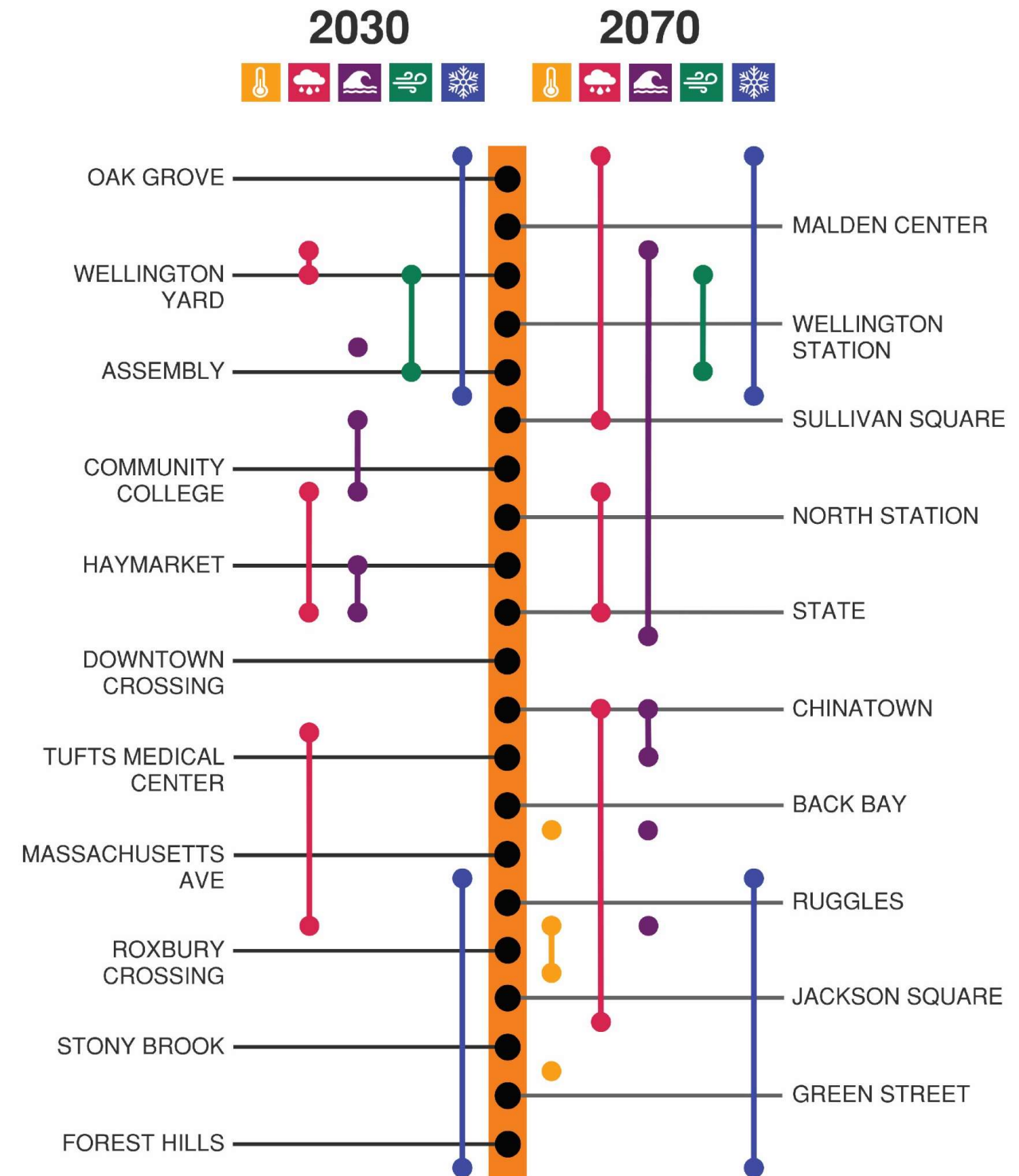
Notes:

1. Asset has one of the top 3 highest composite Vulnerability scores
2. Asset has the highest Vulnerability score for a single hazard
3. Asset has the highest Exposure + Sensitivity (Impact) score out of the hazards studied






Key Findings – Trends

- Sea Level Rise / Storm Surge and Precipitation flooding are responsible for the greatest increases in vulnerability scores from 2030 to 2070
- Assets with greatest change in Vulnerability from 2030 to 2070 are:
 - Roxbury Crossing – Ruggles guideway to Mass Ave – Back Bay guideway,
 - from Tufts – Chinatown guideway to Chinatown Station,
 - the DTX – State Street guideway,
 - and Wellington Yard to Malden Center guideway.
 - These changes are generally due to new areas and/or the expansion of existing areas being exposed to Sea Level Rise / Storm Surge Flooding
- Vulnerability assessment scoring for heat is based on a uniform increase in heat Exposure from 2030 to 2070 for each asset to reflect overall more significant impacts associated with rising temperatures and more extreme heat days by 2070.






General Locations of Increased and High Vulnerabilities



Climate Impacts to OL assets –Guideways

Additional Climate Impacts to Guideways					
Extreme weather may cause power supply disruptions for emergency fans	■	■	■	■	■
Snow and ice may build on rails and switches , impacting operations					■
Flooding may damage emergency fans and signal bungalows or washout rail ballasts		■	■		
Flooding may enter the MBTA system through ventilation shafts		■	■		
Extreme precipitation may surcharge existing stormwater infrastructure and overflow to MBTA system		■			
Wind and associated debris from wind events may damage overhead utility lines and signal bungalows , overturn signal bungalows, or cause utility lines, trees, and debris to fall on guideway				■	
Extreme heat may cause stress on the running rails and lead to buckling	■				
Extreme heat may cause the HVAC system in signal bungalows to fail and may damage equipment	■				
Extreme Heat may harm trees not suited for increased heat stress, resulting in trees falling on MBTA tracks .	■				

Climate Impacts to OL assets – Maintenance Yards






Additional Climate Impacts to Maintenance Yards					
Extreme weather may cause power supply disruptions for utility rooms					
Flooding may damage utility room equipment, trailers, revenue cars or maintenance equipment on storage tracks, or washout rail ballast					
Flooding may prevent MBTA Staff access to or leaving site					
Extreme weather may limit MBTA Staff ability to access and work in utility rooms and trailers					
Wind and associated debris from wind events may damage trailers or revenue cars and maintenance equipment on storage tracks					
Extreme heat may cause stress on the running rails of the storage track and lead to buckling					
Extreme heat may cause the HVAC system in trailers to fail and may damage equipment					

MBTA Staff & Passenger Impacts

MBTA Staff and Passenger Impacts	🌡️	☁️	🌊	♿	❄️
Slippery surfaces.		■	■		■
Reduced visibility.		■			■
Hypothermia or cold temperature exposure.					■
Heat exhaustion or extreme heat temperature exposure.	■				
Reduced ridership.	■	■			■
Difficulty with access/walking.		■	■	■	■
Dangerous and potentially harmful conditions, particularly for elderly or vulnerable populations.	■	■	■	■	■







Staff & Passenger Recommendations






Climate Hazard	Recommendations	
	MBTA Staff	Passengers
General	<ul style="list-style-type: none"> Review historic impacts to MBTA staff and passengers to improve mitigation and response. Develop Extreme Weather Preparedness, Response, and Recovery Plan. 	
	<ul style="list-style-type: none"> Review and update health and safety policies for heat stress in field work. Assess the need for improved shading, ventilation, cooling systems, and hydration facilities. 	<ul style="list-style-type: none"> Assess the need for improved shading, ventilation, cooling systems, and hydration facilities
	<ul style="list-style-type: none"> Identify evacuation areas. Develop a flood forecasting and monitoring system. Assess adequacy of staff training for extreme weather events. 	<ul style="list-style-type: none"> Assess emergency communication systems, egress systems, and shelter-in-place locations.
		
	<ul style="list-style-type: none"> Assess emergency communication systems, egress systems, and shelter-in-place locations. Develop a program for verifying assets are secured ahead of storm events. Identify wind thresholds resulting in unsafe conditions for operating doors & develop safety plan 	
	<ul style="list-style-type: none"> Regularly update MBTA's Snow and Ice Operations Plan and maintenance schedules. 	

Near Term Recommended Adaptation Strategies






Stations

	
	<ul style="list-style-type: none"> • Increase drainage system capacity • Coordinate with Medford to divert runoff to Malden river • Develop flood warning and communications system
	<ul style="list-style-type: none"> • Assess feasibility of SLR/SS flood barrier system • Develop flood warning and communications system
	
	<ul style="list-style-type: none"> • Collect and monitor winter storm response data; update Snow and Ice Plan as needed

Guideways






	<ul style="list-style-type: none"> • Refer to operational and staff strategies,
	<ul style="list-style-type: none"> • Increase drainage capacity • Assess utility room flood vulnerability, backup power supply, and extreme weather event access restrictions • Identify flood adaptation strategies for protecting critical utility room equipment • Implement Flood Event Parking Plan for MBTA staff • Develop flood warning & communications system
	
	<ul style="list-style-type: none"> • Assess utility room backup power supply and extreme weather event access restrictions • Assess structural design of poles, foundations, & structures • Develop design guidelines for poles, foundations, & structures • Implement plan for securing site furniture and equipment • Develop guidelines for vegetation along Station
	<ul style="list-style-type: none"> • Refer to operational and staff strategies,

Yards






	
	<ul style="list-style-type: none"> • Increase drainage system capacity • Assess utility room flood vulnerability, backup power supply, and extreme weather event access restrictions • Identify flood adaptation strategies for protecting critical utility room equipment • Implement Flood Event Parking Plan for MBTA Staff • Elevate tracks & trailers to address flood hazards that cannot be diverted away from the MBTA corridor, or develop contingency plan for extreme flood events • Develop flood warning & communications system
	
	<ul style="list-style-type: none"> • Assess utility room backup power supply and extreme weather event access restrictions • Assess structural design of poles, foundations, & structures • Develop design guidelines for poles, foundations, & structures • Implement plan for securing site furniture and equipment • Develop guidelines for vegetation in coordination with Towns
	<ul style="list-style-type: none"> • Assess utility room backup power supply and extreme weather event access restrictions • Collect and monitor winter storm response data; update Snow and Ice Plan as needed

Longer Term Recommended Adaptation Strategies






Stations

	<ul style="list-style-type: none"> Refer to operational and staff strategies,
	<ul style="list-style-type: none"> Elevate station tracks & platform to address flood hazards that cannot be diverted away from the MBTA corridor, or develop contingency plan for extreme flood events
	<ul style="list-style-type: none"> Assess feasibility of SLR/SS flood barrier system Develop flood warning & communications system Elevate station tracks & platform to address flood hazards that cannot be diverted away from the MBTA corridor, or develop contingency plan for extreme flood events
	
	<ul style="list-style-type: none"> Refer to operational and staff strategies,

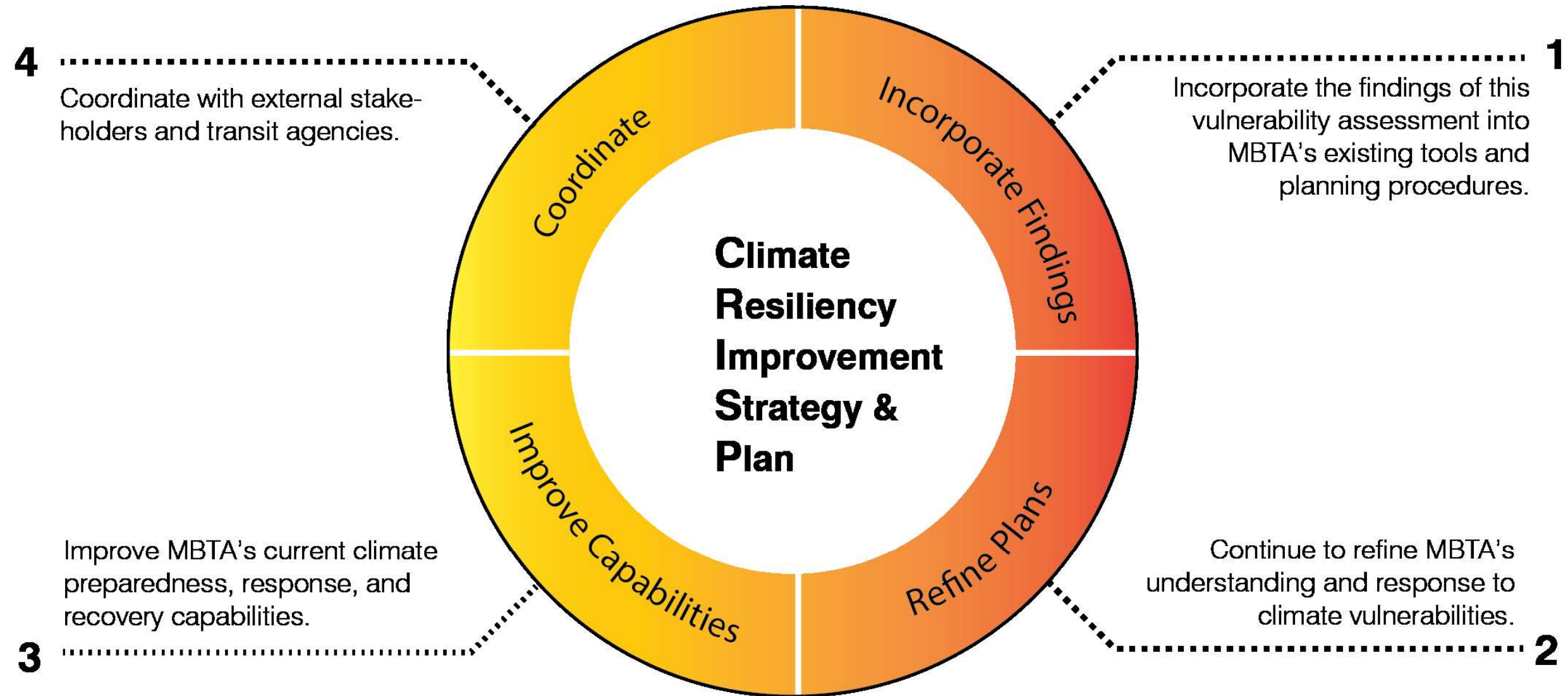
Guideways

	<ul style="list-style-type: none"> Refer to operational and staff strategies,
	<ul style="list-style-type: none"> Increase drainage capacity Assess utility room flood vulnerability, backup power supply, and extreme weather event access restrictions Identify flood adaptation strategies for protecting critical utility room equipment Implement Flood Event Parking Plan for MBTA staff Develop flood warning & communications system
	
	<ul style="list-style-type: none"> Assess utility room backup power supply and extreme weather event access restrictions Assess structural design of poles, foundations, & structures Develop design guidelines for poles, foundations, & structures Implement plan for securing site furniture and equipment Develop guidelines for vegetation along Station
	<ul style="list-style-type: none"> Refer to operational and staff strategies,

Yards

	
	
	<ul style="list-style-type: none"> Assess feasibility of SLR/SS flood barrier system Develop flood warning & communications system Elevate tracks & trailers to address flood hazards that cannot be diverted away from the MBTA corridor, or develop contingency plan for extreme flood events
	
	

Use the Assessment Findings for Longer Term Planning



Use the Assessment Findings for Longer Term Planning

Incorporate Findings

- A. Integrate 2030 Composite Vulnerability Scores into MBTA's Asset Management decision making tools, (e.g. Trapeze)
- B. Develop instructions for MBTA Staff to review and incorporate findings and recommendations of this assessment into MBTA's new potential projects, as well as to assess benefits associated with reduced extreme weather impacts on operating costs and revenues.
- C. Revisit vulnerability assessments as new climate change projections and climate modeling data becomes available.

Refine Plans

- A. Evaluate MBTA's Flood Resiliency Design Directive and Design Guidelines with the Climate Resilience Design Standards Tool and guidelines that have been developed by the State's Resilient Massachusetts Action Team (RMAT) project to compare how climate change projections can be integrated into design standards and practices.
- B. Revisit existing MBTA plans with a resiliency lens to understand how and when to best integrate resiliency.
- C. Expand on the ongoing vulnerability assessments by identifying potential cascading failure events
- D. Develop a change management process for tracking improvements to physical assets, and triggering updates to these vulnerability assessment results.
- E. Develop a checklist for use during State of Good Repair (SOGR) assessments to obtain asset-specific information for use in future updates to the vulnerability assessment scores.

Use the Assessment Findings for Longer Term Planning

Improve Capabilities

- A. Add to existing extreme weather planning by using techniques, such as:
 - Incorporate real time data gathering (e.g. storm monitoring, groundwater and flood sensors, wet well and moisture sensors, weather forecasting, etc.) into preparedness and response actions, including communications alert systems across the MBTA system, including Orange Line.
 - Collect and monitor feedback from MBTA staff following climate resilience preparedness training and following extreme weather event response activities.
- B. Address MBTA staff and passenger impacts by assessing the needs for improved shading, ventilation, cooling systems, and hydration facilities in areas used by staff and passengers.
- C. Review adequacy of MBTA's insurance policies against potential vulnerabilities in the future.

Coordinate

- A. Continue to coordinate with regional partners on climate resiliency strategies with neighboring stakeholders and communities.
 - Examples of partners include: Resilient Mystic Collaborative, Charles River Climate Compact, Metro Mayors Climate Preparedness Task Force
- B. Share and compare lessons learned with other transit agencies to identify and share successful climate resiliency strategies implemented and lessons learned.

THANK YOU

Questions?

Weston (&) SampsonSM

ARUP

26