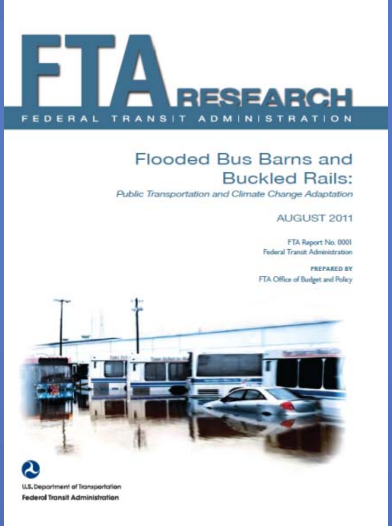
Flooded Bus Barns and Buckled Rails:

Public Transportation and Climate Change Adaptation



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Why Important to FTA?

Climate change directly impacts top FTA goals:

– State of Good Repair

– Safety

FTA is steward of $10 billion/yr federal investment in public transportation, which will be impacted by changes in climate.

New mandate from White House Council on Environmental Quality

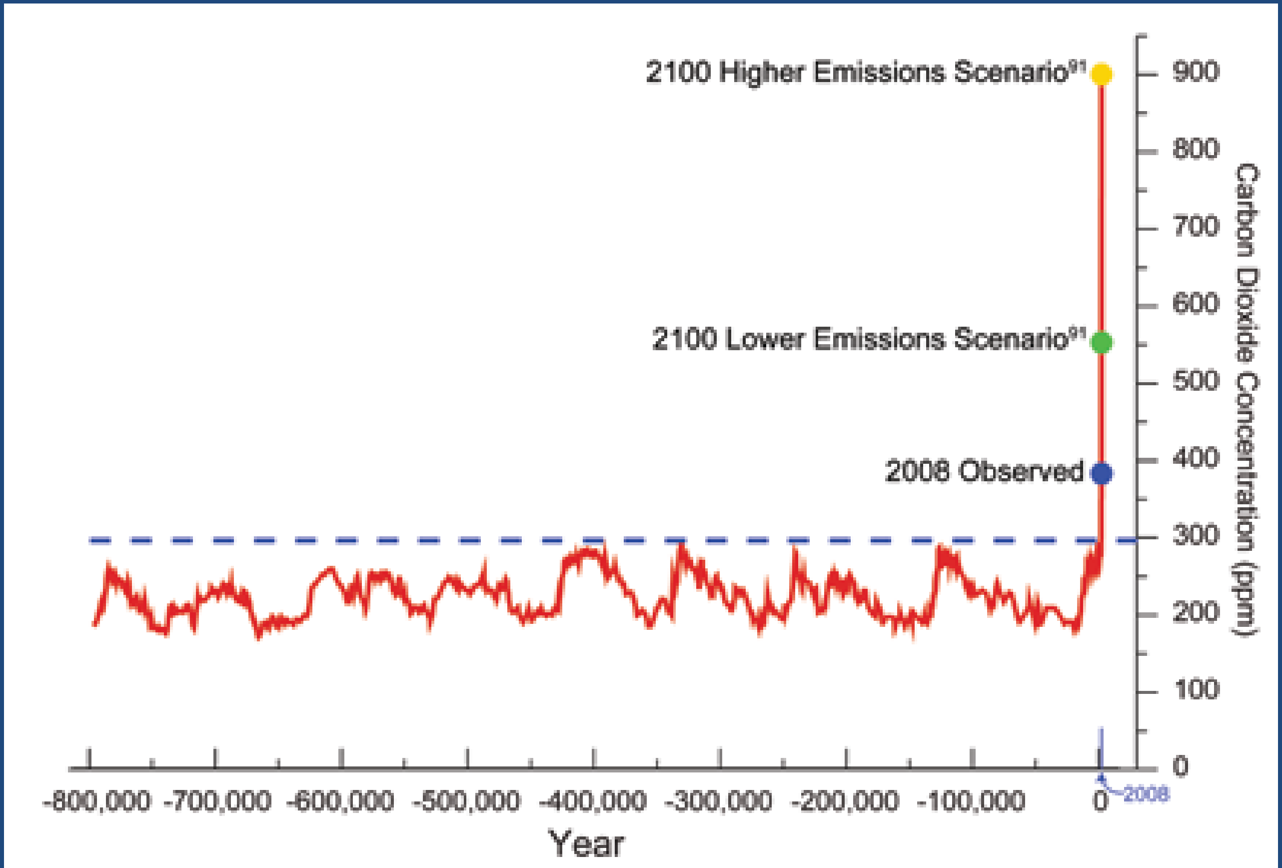
Climate adaptation is responsible risk management

FTA Adaptation Work

- Report examines climate impacts on U.S. transit, adaptation strategies, risk management tools, and incorporation into organizational structures and processes.
- Pilots of transit agency adaptation assessments – applications due August 25 (one to focus on asset management systems)
- Workshops and webinars – first workshop Aug 3. Webinar Aug 8.
- FTA Policy Statement – signed May 2011; explains impact of climate change on state of good repair and safety; commits FTA to taking action

Learn more: www.fta.dot.gov/sustainability click on "climate change"

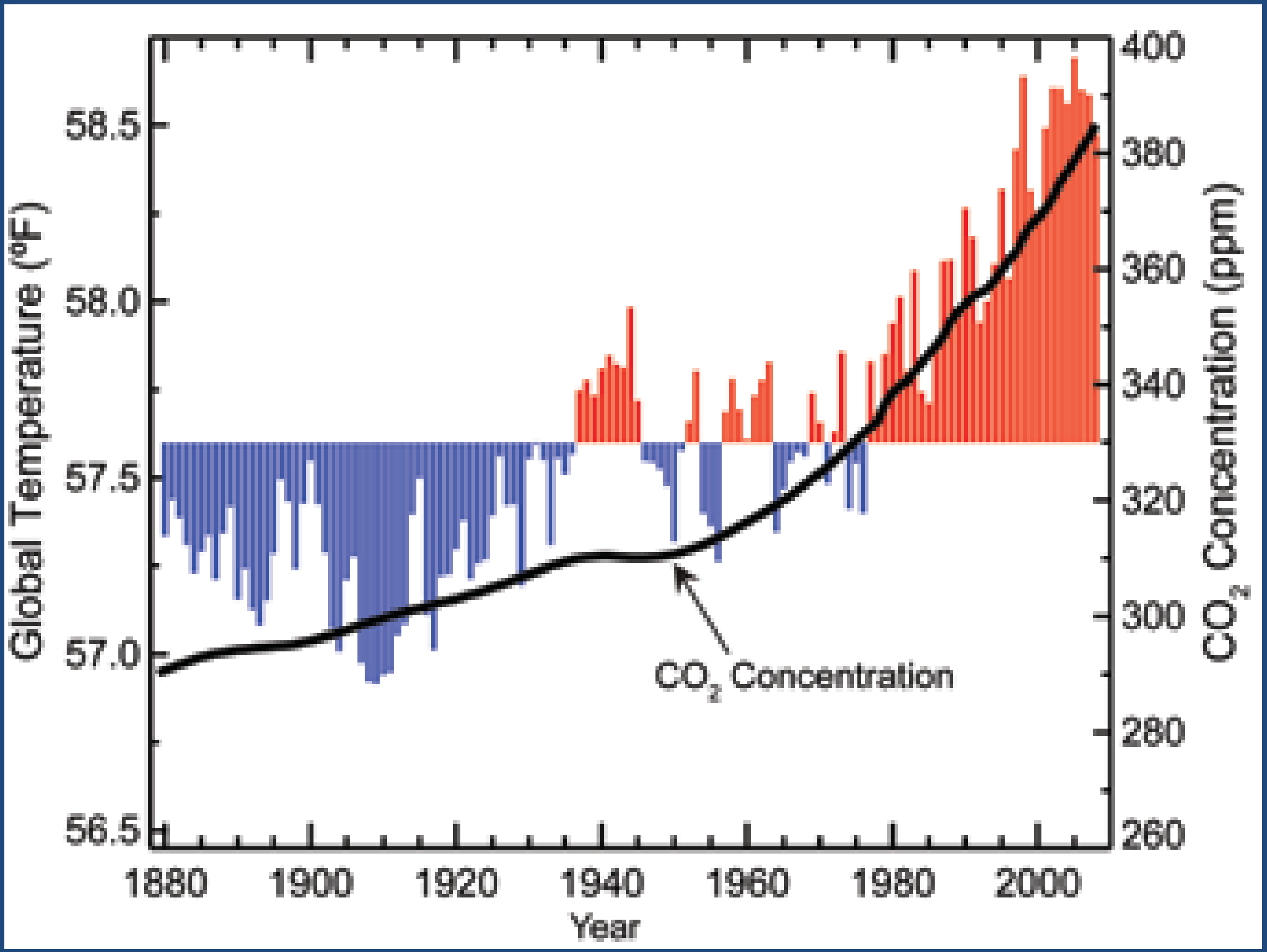
Background: Large Increase in Greenhouse Gas Emissions



Source: US Global Change Research Program, *Global Climate Change Impacts in the US*, 2009.

- CO_2 concentrations in atmosphere up 36% since industrial revolution.
- CO_2 concentration likely to be 2 to 3 times higher than highest level in 800,000 years in absence of strong control measures.

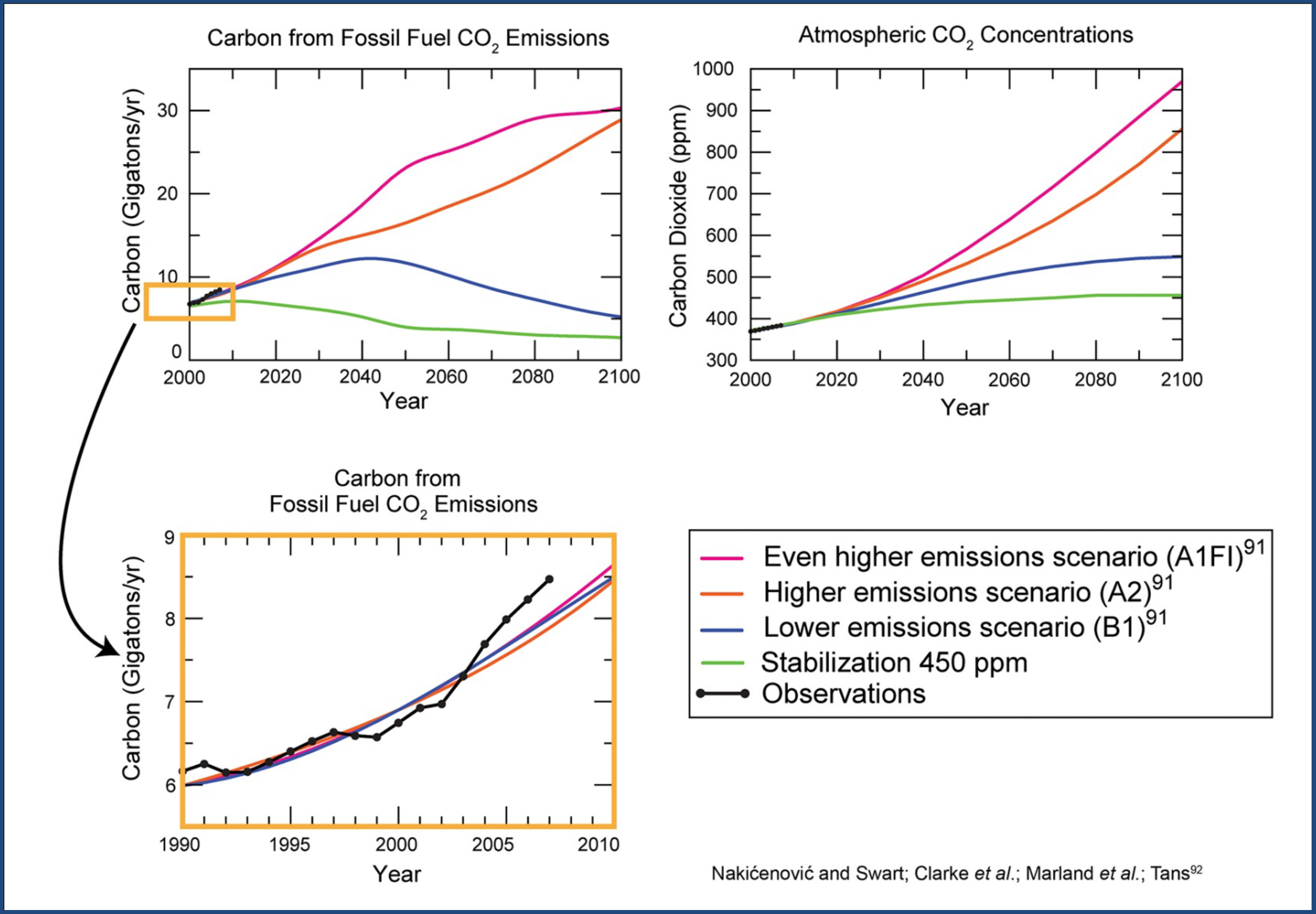
Global Temperature and Carbon Dioxide



Source: US Global Change Research Program, *Global Climate Change Impacts in the US*, 2009.

- Average temp up 1.5°F since 1900
- Projected to increase another 2-11.5°F by 2100

Impacts Vary by Emissions Scenario

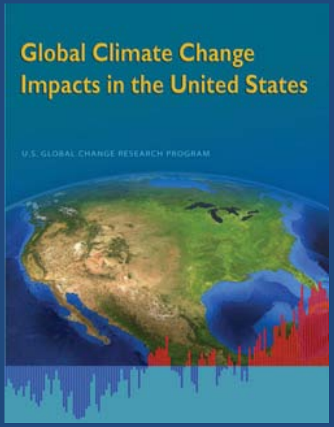


Current emissions are above the highest modeled scenario

USGCRP Key Findings

- Global warming is unequivocal and primarily human-induced.
- Climate changes and impacts are occurring now and are expected to increase.
- Thresholds will be crossed, leading to large changes in climate and ecosystems. (Species extinction, coral reefs, rainforests)
- Future climate change and its impacts depend on choices made today.

U.S. Global Change Research Program, *Global Climate Change Impacts in the United States*, 2009.



Need Both Mitigation and Adaptation

- Mitigation: "An intervention to reduce the causes of changes in climate," such as
  - reduce greenhouse gas (GHG) emissions to the atmosphere.
  - sequester carbon by reforestation and preventing deforestation
  - Need 80% reduction by 2050

- Adaptation: "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects."
  - Needed because climate impacts already occurring,
  - and additional impacts already built in to system given level of long-lived emissions already in atmosphere.

Definitions from National Academy of Sciences

4 Transit Impacts

↑ Intense Precipitation
(very likely, >90%)

- Flooding of track, bus ways, tunnels, lots, facilities
- Landslides

↑ Very Hot Days & Heat Waves
(very likely, >90%)

- Track buckling leads to slow order or derail
- Customer comfort issue
- Worker safety issue

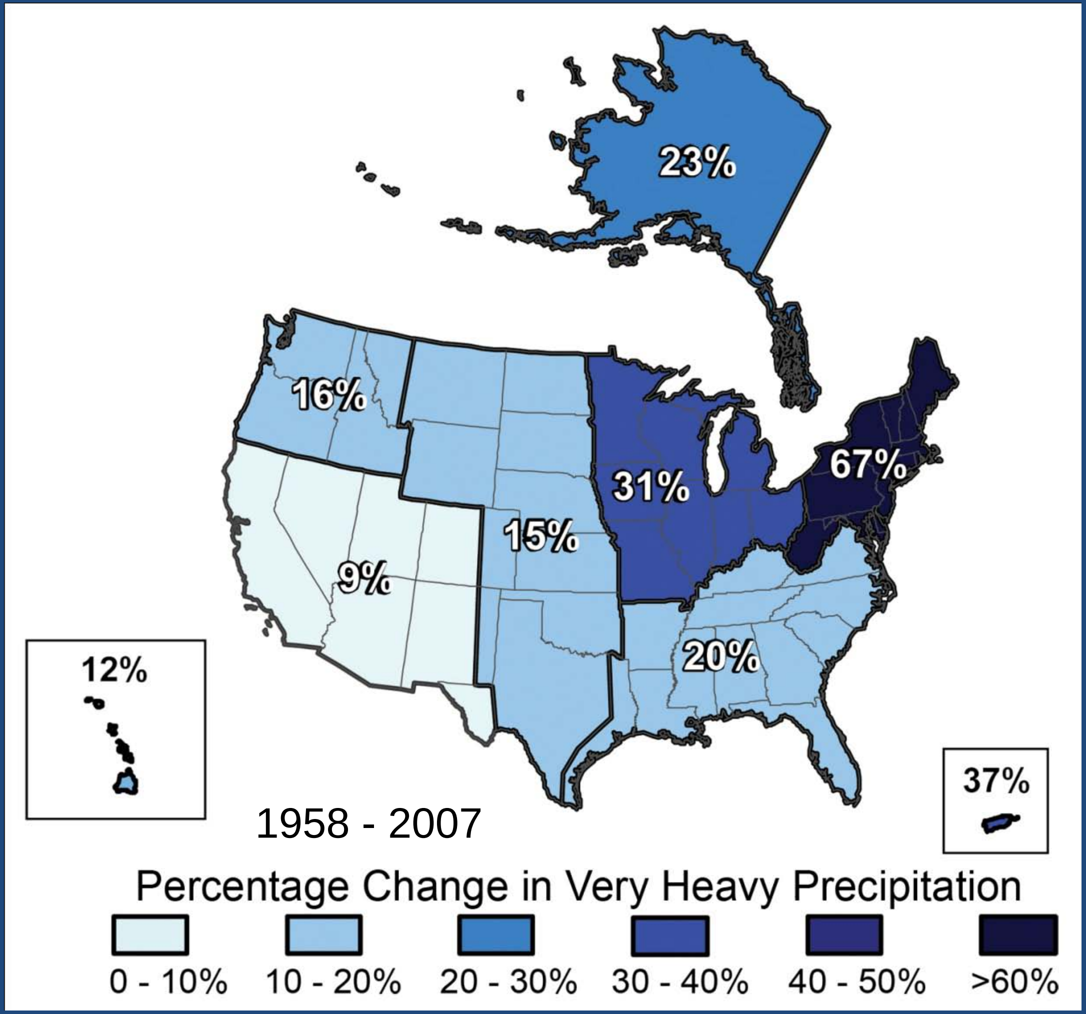
Rising Sea Levels
(virtually certain, >99%)

- Flooded track, bus ways, tunnels, lots, facilities
- Higher groundwater level floods tunnels

↑ Hurricane Intensity
(likely, >66%)

- Flooding from storm surge, rain
- High winds – debris, wind damage
- Transit provision of evacuation service

Climate Impacts Already Occurring



- "When it rains, it pours"
- Note that largest impact is in Northeast, home of some of largest and oldest rail transit systems.

*defined as the heaviest 1 percent of all daily events

Source: Groisman et al as cited in USGCRP 2009.

Nashville Flood, May 2010

Photos courtesy of Nashville MTA

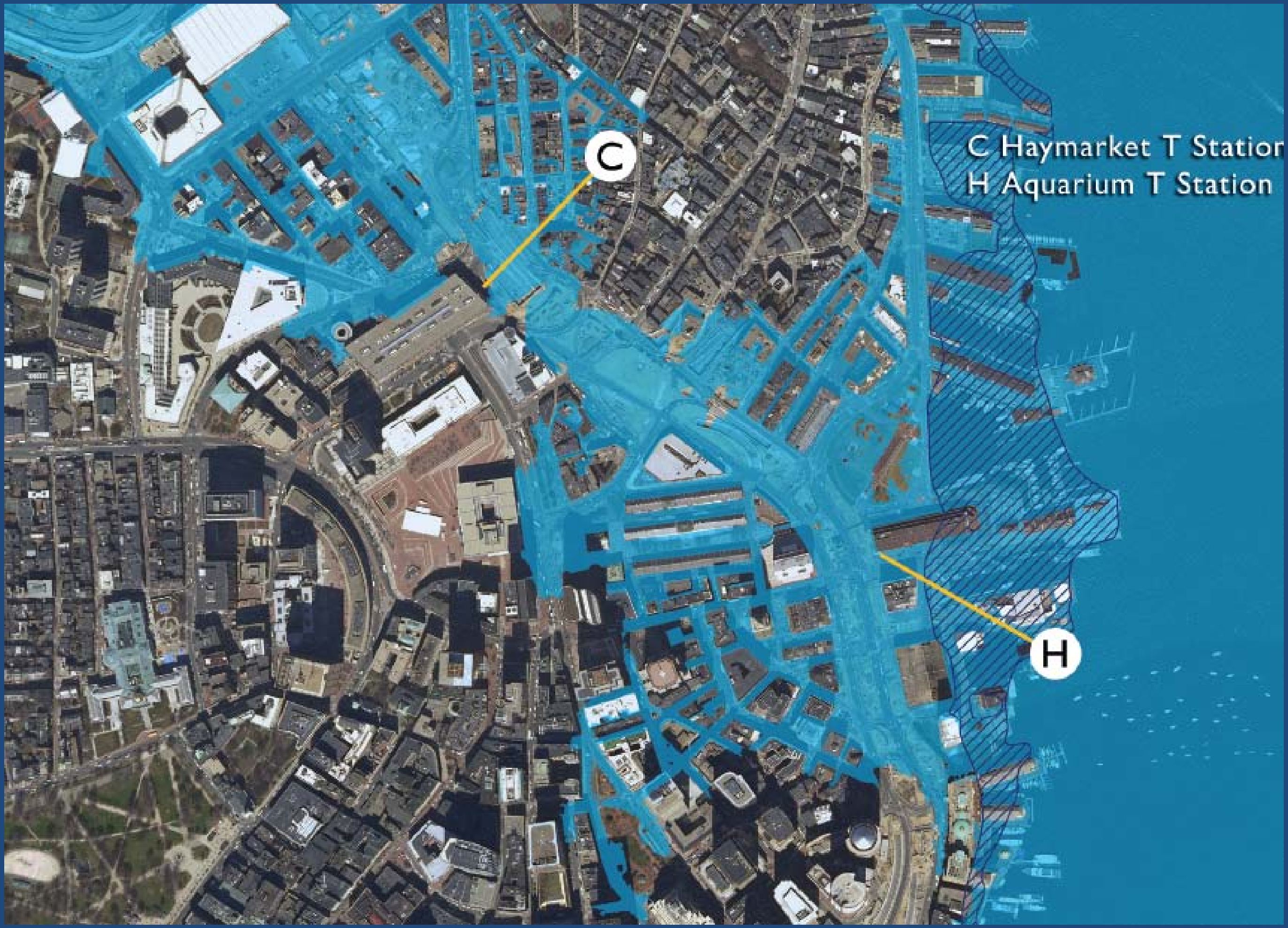
Cumberland River floods MTA property on Nestor Street

Sea Level Rise – San Francisco Bay Area

- Blue: Areas that could be inundated by 16 inch sea level rise
- Purple: Areas that could be inundated by 55 inches sea level rise

Source: San Francisco Bay Conservation and Development Commission, *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline*, April 7, 2009.

Sea-level Rise + Bigger Storms = More Flooding



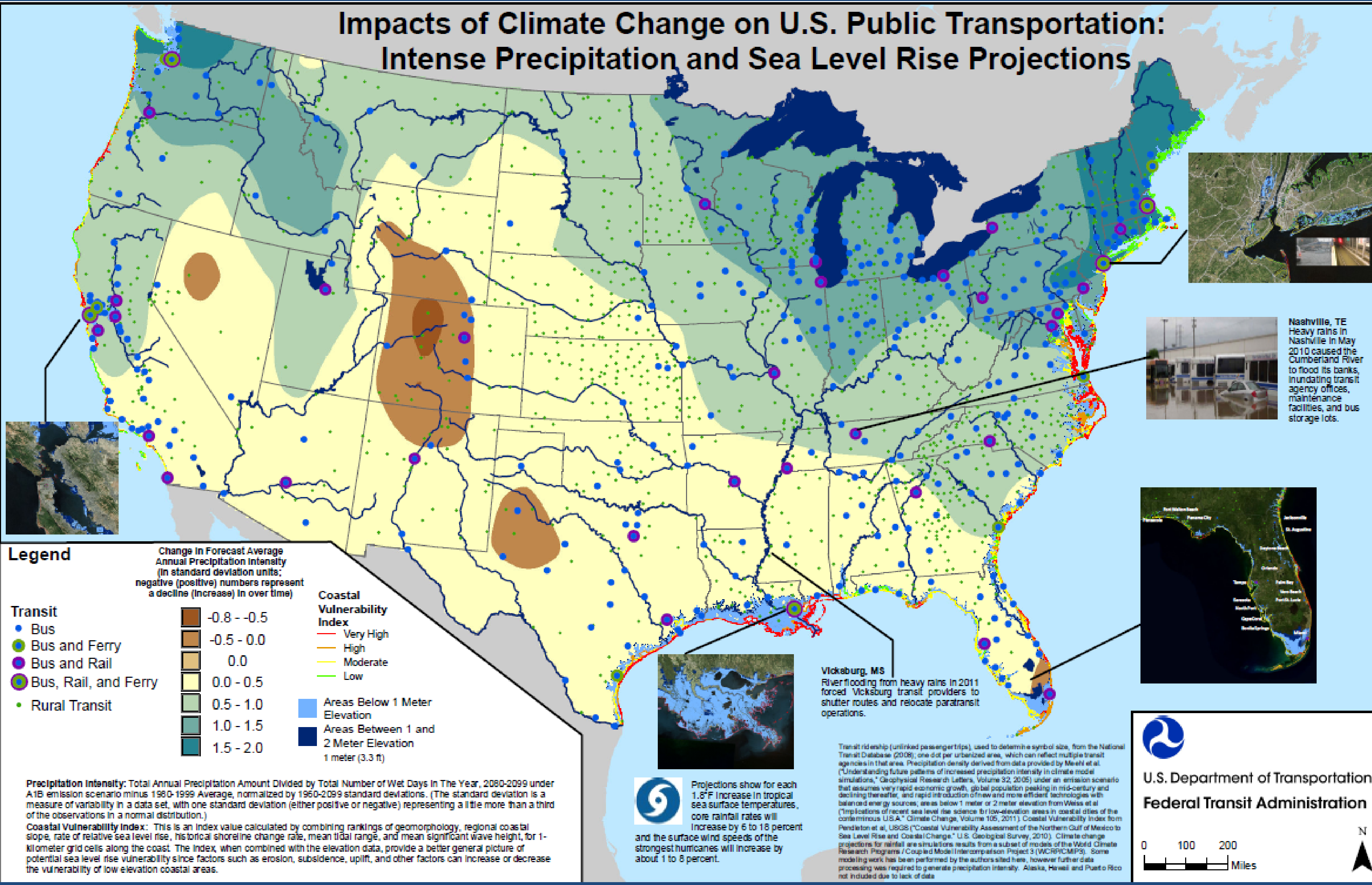
Boston

Dark blue hashed area = current 100-yr flood zone

Light blue = projected 100-yr flood zone

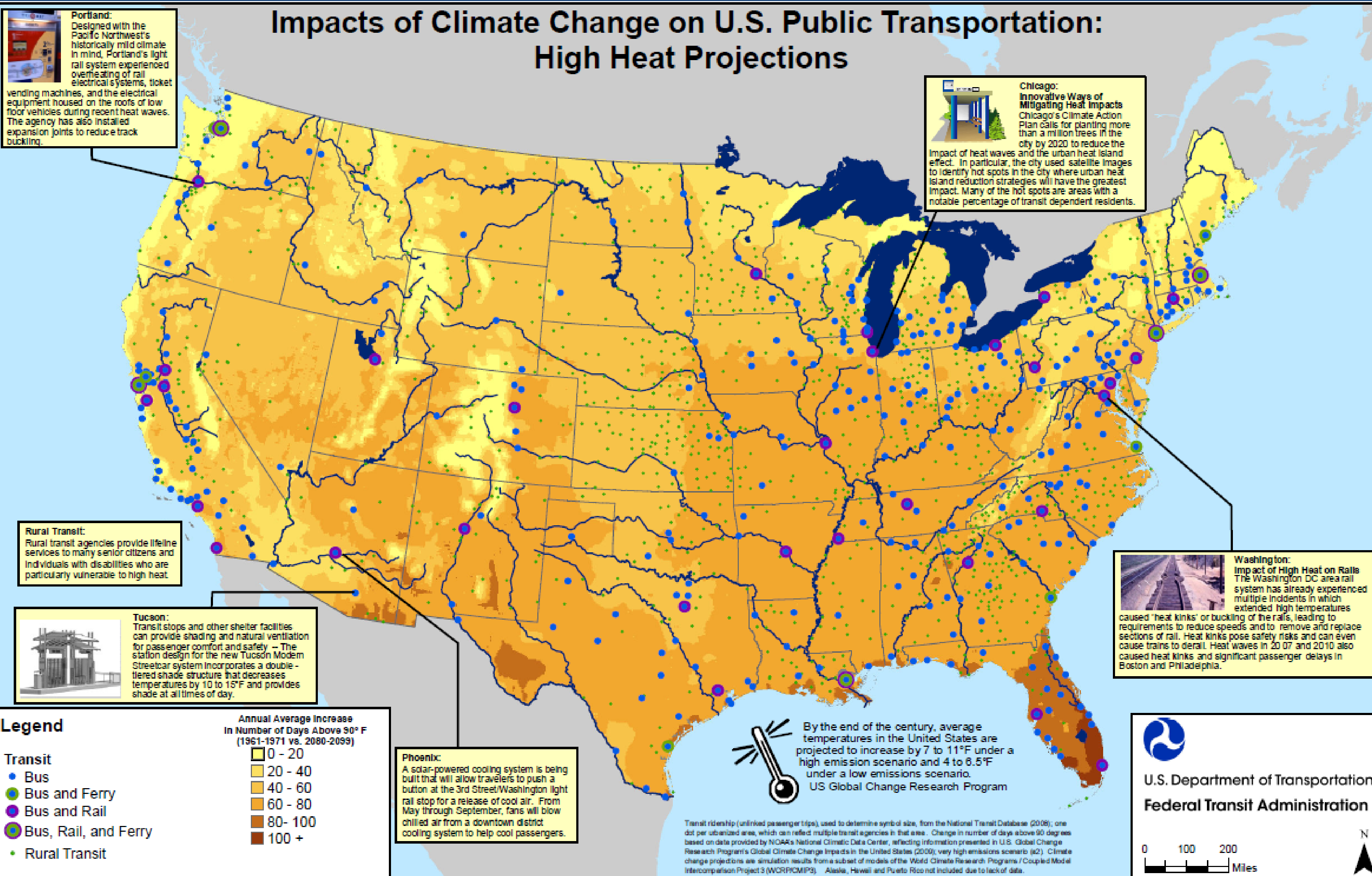
Source: UCS / NECIA

Rail Buckling



Impacts of Climate Change on U.S. Public Transportation:
Intense Precipitation and Sea Level Rise Projections
Nashville, TE
Heavy rains in Nashville in May 2010 caused the Cumberland River to flood its banks, inundating transit agency offices, maintenance facilities, and bus storage lots.
Vicksburg, MS
River flooding from heavy rains in 2011 forced Vicksburg transit providers to shutter routes and relocate paratransit operations.
Legend
Transit
Bus
Bus and Ferry
Bus and Rail
Bus, Rail, and Ferry
Rural Transit
Change in Forecast Average Annual Precipitation Intensity (in standard deviation units; negative (positive) numbers represent a decline (increase) in over time)
-0.8 - -0.5
-0.5 - 0.0
0.0
0.0 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
Coastal Vulnerability Index
Very High
High
Moderate
Low
Areas Below 1 Meter Elevation
Areas Between 1 and 2 Meter Elevation
1 meter (3.3 ft)
Precipitation Intensity: Total Annual Precipitation Amount Divided by Total Number of Wet Days In The Year, 2080-2099 under A1B emission scenario minus 1960-1999 Average, normalized by 1960-2099 standard deviations. (The standard deviation is a measure of variability in a data set, with one standard deviation (either positive or negative) representing a little more than a third of the observations in a normal distribution.)
Coastal Vulnerability Index: This is an index value calculated by combining rankings of geomorphology, regional coastal slope, rate of relative sea level rise, historical shoreline change rate, mean tidal range, and mean significant wave height, for 1-kilometer grid cells along the coast. The index, when combined with the elevation data, provide a better general picture of potential sea level rise vulnerability since factors such as erosion, subsidence, uplift, and other factors can increase or decrease the vulnerability of low elevation coastal areas.
Projections show for each 1.8°F increase in tropical sea surface temperatures, core rainfall rates will increase by 6 to 18 percent and the surface wind speeds of the strongest hurricanes will increase by about 1 to 8 percent.
Transit ridership (unlinked passenger trips), used to determine symbol size, from the National Transit Database (2008); one dot per urbanized area, which can reflect multiple transit agencies in that area. Precipitation density derived from data provided by Meehl et al. ("Understanding future patterns of increased precipitation intensity in climate model simulations," Geophysical Research Letters, Volume 32, 2005) under an emission scenario that assumes very rapid economic growth, global population peaking in mid-century and declining thereafter, and rapid introduction of new and more efficient technologies with balanced energy sources; areas below 1 meter or 2 meter elevation from Weiss et al ("Implications of recent sea level rise science for low-elevation areas in coastal cities of the conterminous U.S.A." Climate Change, Volume 105, 2011). Coastal Vulnerability Index from Pendleton et al, USGS ("Coastal Vulnerability Assessment of the Northern Gulf of Mexico to Sea Level Rise and Coastal Change." U.S. Geological Survey, 2010). Climate change projections for rainfall are simulations results from a subset of models of the World Climate Research Programs / Coupled Model Intercomparison Project 3 (WCRP/CMIP3). Some modeling work has been performed by the authors sited here, however further data processing was required to generate precipitation intensity. Alaska, Hawaii and Puerto Rico not included due to lack of data
U.S. Department of Transportation
Federal Transit Administration
0
100
200
Miles
N

Impacts of Climate Change on U.S. Public Transportation: High Heat Projections



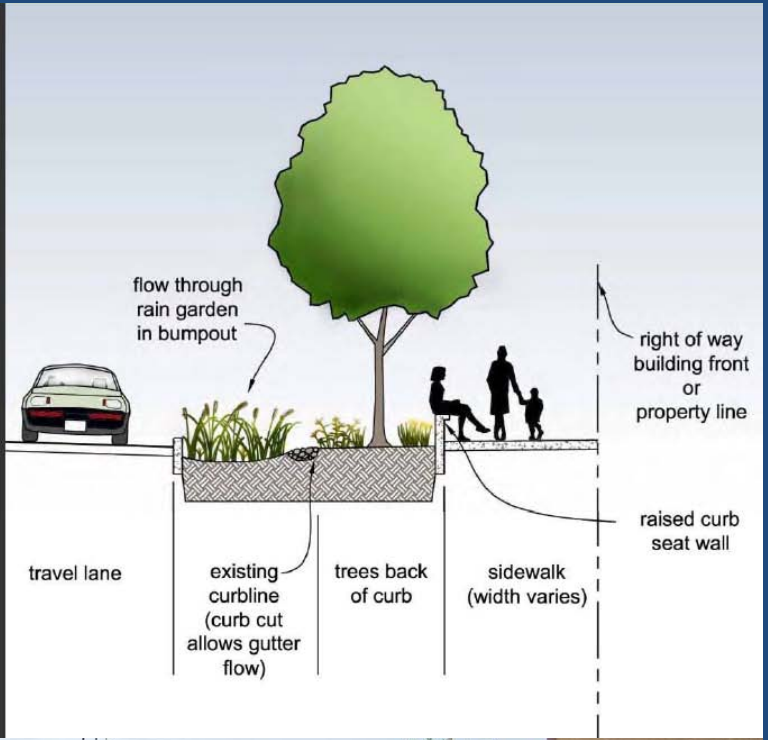
State of the Practice: Transit & Adaptation

Transit Agency	Adaptation Actions
New York MTA	1st report on climate change hazards at a US transit agency. Partnered with state and local adaptation efforts. Raised ventilation grates.
Los Angeles MTA	Conducting climate change risk assessment of assets, to be completed July
New Jersey Transit	Conducting climate change risk assessment of assets, to be completed Oct. Participating in FHWA adaptation pilot
Waves Transit, AL	Part of multi-modal US DOT Gulf Coast Study, Phase II
TriMet	Participating in regional adaptation efforts
Cape Cod Transit	Part of interagency climate change pilot, assessment of sea level rise impacts.
Honolulu Transit	Participating in FHWA adaptation pilot
King County Metro	Stakeholder in county adaptation efforts, which are at forefront of field
Transport for London	Adaptation included in risk and asset management systems. Adding air conditioning, addressing flooding to existing system. Climate impacts incorporated into design of major project – “Crossrail.”
Istanbul	New rail link built for 3 ft sea level rise + 1 in 10,000 yr flood
Taipei	After typhoon dumped 50 inches of rain in two days, set new standards for entrances: 2-4’ above ground + 6” above 100 yr flood, tunnel floodgates

Kansas City Bus Rapid Transit

Flow - through rain garden in bumpout designed to collect runoff from road and sidewalk.

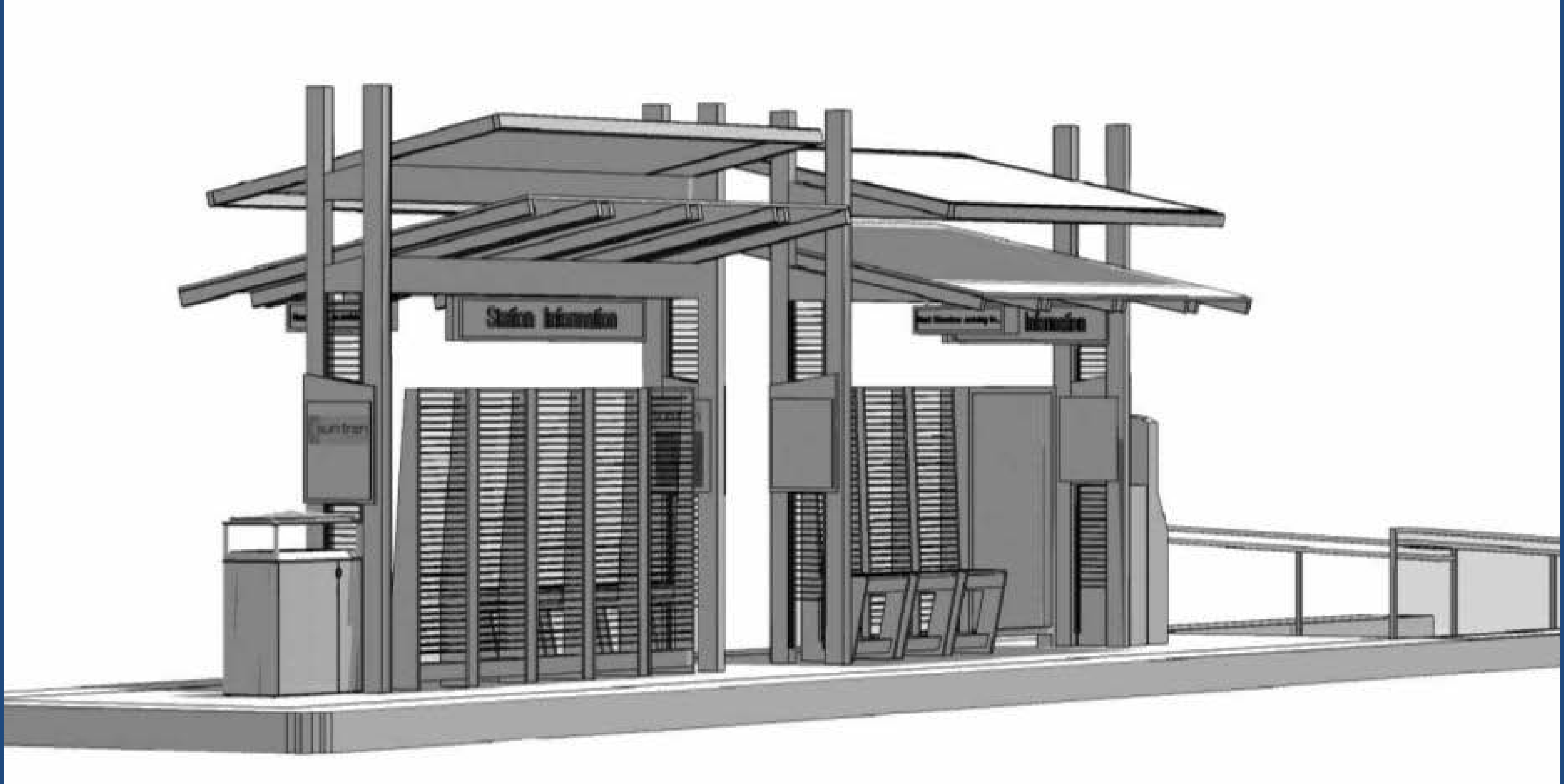
Trees planted back of curb at higher soil level.



Rain Gardens

Pervious Pavement

Tucson Streetcar
Double-Tiered Shade Structures



Mainstreaming Adaptation into Transit Agency Structures & Processes

- Asset management systems: offer useful framework for incorporating climate adaptation into capital plans and budgets.
- Metropolitan and Statewide Transportation Planning
- Environmental Management Systems
- Environmental Review and Project Development
- Floodplain Assessment
- Real Estate Acquisition and Relinquishment of Assets
- Design and Construction
- Retrofit
- Maintenance
- Emergency Preparedness, Response, and Recovery
- Performance Measures
- Organizational Culture and Budget Priorities

Element of Asset Management System	Opportunity to Incorporate Climate Change Adaptation
Goals and Policies	Incorporate climate change considerations into asset management goals and policies; these could be general statements concerning adequate attention of potential issues, or targeted statements at specific types of vulnerabilities (e.g., sea-level rise).
Asset Inventory	Map infrastructure assets in vulnerable areas, using GIS where possible; inventory critical assets that are susceptible to climate change impacts.
Condition Assessment and Performance Monitoring	Monitor asset condition in conjunction with environmental conditions (e.g., temperature, precipitation, winds) to determine if climate change affects performance; incorporating risk appraisal into performance modeling and assessment; identification of high risk areas and highly vulnerable assets. Use of "smart" technologies to monitor the health of infrastructure assets.
Alternatives Evaluation and Program Optimization	Include alternatives that use probabilistic design procedures to account for the uncertainties of climate change; possible application of climate change–related evaluation criteria, smart materials, mitigation strategies, and hazard avoidance approaches.
Short and Long Range Plans	Incorporate climate change considerations into activities outlined in short- and long-range plans; incorporate climate change into design guidelines; establish appropriate mitigation strategies and agency responsibilities
Program Implementation	Include appropriate climate change strategies into program implementation; determine if agency is actually achieving its climate change adaptation and monitoring goals.
Performance Monitoring	Monitor asset management system to ensure that it is effectively responding to climate change; possible use of climate change–related performance measures; "triggering" measures used to identify when an asset or asset category has reached some critical level

Source: Michael D. Meyer, Adjo Amekudzi, and John Patrick O'Har entitled, "Transportation Asset Management Systems and Climate Change Adaptive Systems Management Approach."

Stage in Planning Process	Opportunity to Include Climate Change Adaptation
Establish a vision	Emphasize preservation of the system in the face of shifts in climate.
Set goals, objectives, and performance measures	Establish objectives for asset conditions. Include performance measures related to adaptation.
Stakeholder identification and outreach	Engage environmental and state and local government agencies, additional infrastructure providers, and other organizations relevant to climate action planning. Coordinate to leverage adaptation work of other stakeholders.
Conduct analyses	Assess the vulnerability of the transportation system to climate change during this stage, in which agencies characterize the existing system relative to performance criteria, gather input from stakeholders and the public on priority deficiencies, and forecast future issues.
Develop alternative plan scenarios	Identify alternatives that facilitate adaptation to climate change. Specific strategies and improvement projects can be included in the alternatives developed. In this stage agencies develop various approaches for achieving the stated objectives and distill several diverse, manageable alternatives. Agencies typically identify fiscal constraints and opportunities at this stage as well.
Evaluate alternatives	Examine the impacts of proposed adaptation strategies to ensure that the selected alternative appropriately addresses climate change. It is important to note that decisions often include tradeoffs among community goals.
Programming	Use performance measures related to climate change to prioritize projects for funding. The transportation improvement program (TIP) details what near-term projects are going to be built and when, based on funding cycles.
Project Development	Incorporate adaptive design considerations based on a risk assessment process.
System monitoring	Monitor the vulnerability and resilience of the transportation system to climate impacts.

Thank You!

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