Appendix I
Adaptation Strategy Fact Sheets

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Adaptation Strategy Fact Sheets

Prevent System Failure (SF)

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North Jersey Transportation Planning Authority
Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Updated June 2019

Adaptation Strategy Identification	Adaptation Strategy	Applicability to Each Asset						Type of Event		Project Stage
		Bridges	Culverts	Facilities	Rail Tracks	Roads, Transit (bus lines)	Transit (rolling stock)	Heat	Flooding	
Reduce Thermal Expansion (TE)										
TE1	Design rail tracks for higher maximum temperatures in replacement or new rail infrastructure				X			X		Design, Operation & Maintenance (O&M)
TE2	Lower speeds and use shorter trains to shorten braking distance and to allow for lighter loads to reduce track stress in extreme heat events				X		X	X		O&M
TE3	Use bridge joints that can accommodate exceptional thermal expansion	X						X		Design
TE4	Monitor sagging of large suspension bridges during extreme heat	X						X		O&M
TE5	Increase seat lengths of expansion joints and/or the range of finger joints in bridges	X						X		Design
TE6	Monitor for temperatures of assets and heat-related impacts by installing sensor systems	X		X	X	X	X	X		Design, O&M
TE7	Conduct regular maintenance and restore infrastructure previously impacted by heat events	X	X	X	X	X	X	X		O&M
Use Heat-Resistant Materials (HR)										
HR1	Establish design standards for higher maximum temperature	X		X	X	X	X	X		Policy
HR2	Incorporate design standards for higher maximum temperature	X		X	X	X	X	X		Policy
HR3	Use heat-resistant materials, including heat-resistant asphalt, concrete, or painted roadways	X		X	X	X	X	X		Policy, Design
HR4	Overlay or rebuild roads with new or more rut-resistant asphalt or concrete					X		X		Design, O&M
HR5	Encourage construction of green roofs to cool buildings through evaporation/transpiration of vegetated surfacing			X				X		Policy, Design
HR6	Plant trees and other vegetation to shade assets			X	X	X		X	X	Design
Prevent System Failure (SF)										
SF1	Install energy system back-up such as generators, batteries, or other alternate sources of power during an emergency or long power-outage	X		X	X		X	X	X	Design, O&M
SF2	Modernize the electric grid to allow for "islanding"/microgrids and encourage the construction of alternative energy systems/use of renewable energy sources as the primary energy source	X		X	X		X	X	X	Design
SF3	Incorporate redundant power and communication lines and systems	X		X	X	X		X	X	Design
SF4	Develop procedures and plans for when peak power demand exceeds capacity during heat events			X	X	X	X	X		Policy
SF5	Construct temporary floating bridges in cases where permanent bridges are damaged	X							X	Design, O&M
SF6	Upgrade emergency communication systems and Intelligent Transportation Systems (ITS)	X	X	X	X	X		X	X	Policy, Design

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		Bridges	Culverts	Facilities	Rail Tracks	Roads, Transit (bus lines)	Transit (rolling stock)	Heat	Flooding	
SF7	Protect fuel supplies along evacuation routes and near shelters			X			X		X	Policy, Design
SF8	Develop new critical use transportation facilities outside future flooding levels			X					X	Policy, Design
SF9	Develop and use redundant evacuation routes to allow for faster movement out of flooded areas					X			X	Policy, O&M
SF10	Bury utilities wherever feasible			X	X	X			X	Policy, Design
Increase or Improve Stormwater Drainage (SW)										
SW1	Construct stormwater retention or detention basins			X	X	X			X	Design
SW2	Install internal drainage system using basins and sump pumps			X	X	X			X	Design, O&M
SW3	Install green infrastructure: bioretention ponds, bioswales and rain gardens			X		X			X	Design
SW4	Install green infrastructure: pervious pavements			X		X			X	Design
SW5	Install green infrastructure: tree planting			X					X	Design
SW6	Maintain buffer or clear zone between edge of highways/rail lines/power lines and adjacent tree belts/woodlands in order to minimize damage and obstruction caused by falling trees and limbs			X	X	X			X	Design
SW7	Conduct routine maintenance of culverts and storm sewers to remove sediment and improve stormwater conveyance.		X	X	X	X			X	O&M
SW8	Increase capacity of stormwater infrastructure and drainage system		X	X	X	X			X	Design
SW9	Remove obstacles within streams and rivers to allow a higher capacity of flow in high precipitation events	X	X						X	O&M
SW10	Enlarge culverts to increase the capacity		X						X	Design
SW11	Upgrade bridge deck and road drainage systems to manage a higher capacity of stormwater	X				X			X	Design
SW12	Replace culverts with bridges		X						X	Design
SW13	Ensure bridge openings and culverts are clear for appropriate flood management	X	X						X	O&M
SW14	Dredge rivers and lakes to aid in the conveyance of floodwaters		X	X	X	X			X	O&M
Increase Flood Protection (FP)										
FP1	Anchor tanks to resist flood loads and buoyancy forces from floodwaters			X					X	Design, O&M
FP2	Anchor and secure rolling stock during flooding events						X		X	O&M
FP3	Relocate rolling stock assets outside of areas prone to flooding or storm surge						X		X	Policy, O&M

North Jersey Transportation Planning Authority
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Updated June 2019

Adaptation Strategy Identification	Adaptation Strategy	Applicability to Each Asset						Type of Event		Project Stage
		Bridges	Culverts	Facilities	Rail Tracks	Roads, Transit (bus lines)	Transit (rolling stock)	Heat	Flooding	
FP4	Incorporate dry floodproofing: Install flood-resistant barriers or impermeable elements at structure's openings to prevent interior flooding and to resist flood loads			X					X	Design
FP5	Incorporate wet floodproofing: Install flood openings and water-resistant materials to allow building to withstand some exposure to floodwaters and the associated loads/pressures			X					X	Design
FP6	Elevate existing transportation assets	X		X	X	X			X	Design
FP7	Construct catchment devices upstream of bridges to catch floating, debris and minimize effect of debris and ice floes on bridges	X							X	Design
FP8	Elevate critical mechanical and electrical equipment			X					X	Design
FP9	Protect and restore wetlands to protect infrastructure			X	X	X			X	Policy, Design
FP10	Construct and raise protective dikes, bulkheads, berms and levees, including tide gates as necessary			X	X	X			X	Design
FP12	Incorporate a higher BFE in design changes as needed	X		X	X	X			X	Policy, Design
FP13	Deploy temporary barriers to protect critical assets during flooding events			X	X	X	X		X	O&M
FP14	Reconstruct transportation assets at a less vulnerable location	X		X	X	X			X	Policy, Design
FP15	Install sensors along or within assets to monitor for water level and changing conditions	X		X	X	X			X	Design, O&M
Reduce Flood Damage (FD)										
FD1	Protect bridge piers and abutments with riprap	X							X	Design
FD2	Alter, upgrade, or retrofit bridge movement system (e.g. bearings) to prevent excessive lateral or vertical displacement due to buoyancy forces or water pressure	X							X	Design, O&M
FD3	Retrofit/replace/relocate existing bridges for new scour conditions	X							X	Design, O&M
FD4	Monitor bridge for scour and other conditions that could undermine a bridge's structural integrity during a flooding event	X							X	O&M
FD5	Use vegetation or earthwork to stabilize river and stream embankments and provide riverine buffers	X		X	X	X			X	Design, O&M
FD6	Ensure roadway and rail tracks are clear of rocks, debris and downed vegetation				X	X	X		X	O&M
FD7	Use moisture-resistant materials that are more resilient to flooding conditions			X			X		X	Policy, Design
FD8	Use new asphalt/concrete mixtures able to withstand flood conditions	X		X		X			X	Policy, Design

North Jersey Transportation Planning Authority
Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Updated June 2019

Adaptation Strategy Identification	Adaptation Strategy	Applicability to Each Asset						Type of Event		Project Stage
		Bridges	Culverts	Facilities	Rail Tracks	Roads, Transit (bus lines)	Transit (rolling stock)	Heat	Flooding	
FD10	Improve temporary and permanent erosion control standards of construction sites	X	X	X	X	X			X	Policy, Design, O&M
FD11	Conduct regular maintenance and restore infrastructure that was previously impacted from flooding events	X	X	X	X	X	X		X	O&M
FD12	Construct permanent floating bridges to withstand changes in water levels	X							X	Design
Region-wide Adaptation Strategies (RW)										
Region-wide Adaptation Strategies are intended to be executed on a county, regional, or statewide level would result in improved hydrologic, environmental and health outcomes, including: less sprawl, increased										
Natural Systems										
RW1	Require low-impact development (LID) and green infrastructure strategies to retain and infiltrate precipitation on site for new and re- developments								X	Policy
RW2	Preserve and enhance the tree canopy to reduce urban heat island effects and reduce emissions from cooling load							X		Policy
RW3	Protect, expand, and restore natural systems and vegetative buffers along inland waterways								X	Policy
Community Development										
RW4	Develop relocation, retreat, and/or evacuation plans								X	Policy
RW5	Limit or prohibit development in floodplains to protect life, property, and floodplain functior								X	Policy
RW6	Encourage "Smart Growth" approaches and "Complete Streets" principles to counter suburban sprawl, decrease energy use, reduce parking demand, reduce emissions, and promote resilience; such as walkable, livable, compact development							X	X	Policy
RW7	Promote Transit-Oriented Development (TOD), including compact, mixed-use development and affordable housing within walkable, multimodal, "Complete							X	X	Policy
Technology										
RW8	Research and incorporate emerging technologies in design policies and standards							X	X	Policy, Design

Notes:

* FP11: Establish a higher base flood elevation (BFE) was combined with FP12 Incorporate a higher BFE in design changes as needed

** FD9: Install pavement grooving and cross-sectional sloping to encourage drainage of water out of the roadway and provide traction was determined to be infeasible in the region due to safet concerns for motorcyclists and possibly higher O&M costs due to damage caused from water going into the grooves and freezing.

North Jersey Transportation Planning Authority
Definitions for Terms Used in the Adaptation Strategy Fact Sheets

Updated June 2019

The evaluation of each adaptation strategy on the following tabs includes the following information:

- Brief description of the adaptation strategy
- Technical, implementation, and financial considerations for the strategy, including information on local context, where applicable
- Applicable asset type (bridges, culverts, facilities, rail, roads including bus routes, transit rolling stock)
- Applicable event type(s) (heat or flooding)
- Recommended project stage for implementation (policy, design, O&M)
- Parties assigned to consider implementation of adaptation strategies, such as the county or state agency
- Range of project timeframe (less than one year, one to five years, less than five years, five to ten years, or over ten years)
- Magnitude of project cost, relative to other adaptation strategies, based on adaptation strategy research
    - $ - Requires a relatively low investment of capital and/or resources
    - $$ - Requires a moderate amount of investment of capital and/or resources
    - $$$ - Requires a high amount of investment of capital and/or resources
    - $$$$- Requires a very high amount of investment of capital and/or resources
- Project co-benefits, i.e. benefits beyond adapting to the heat or flood event:
    - *Reduce GHG emissions* – strategies that reduce the emissions of GHG, which are gases that traps heat in the atmosphere and contribute to climate change. This reduction could be achieved by either eliminating a source of GHG or by the more efficient operation of assets.
    - *Improve water quality* – strategies that could have the potential to improve water quality of the surrounding ecosystem by using natural treatment or by preventing pollutants to enter local water supply.
    - *Improve air quality* – strategies that help improve air quality either by eliminating or reducing sources of air pollutants, or by utilizing natural processes that assist with the improvement of air quality.
    - *Improve or create greenspace* – strategies that improve existing green spaces or create new naturalized areas. Greenspaces are vegetated open spaces that are either natural or manmade and that can be open to the public and offer recreational opportunities.
    - *Improve aesthetic and visual qualities* – strategies that improve the aesthetics and visual qualities of a community. These are areas or assets that are visually pleasing that help enhance community character and quality of life.
    - *Improve localized ecosystem* – strategies that help conserve local environments and help foster the growth and improvement of the vegetation and wildlife. This is achieved by protecting and improving existing natural areas.
    - *Improve safety and reduce potential for loss of life* – strategies that help protect lives by limiting potential sources of danger or loss of life during an extreme heat or extreme flooding event. This can include strategies that allow communities to evacuate in a timely manner or by providing greater protection of heat- or flood-prone areas.
    - *Reduce loss of property or substantial property damage* – strategies that may reduce the damage of property and other transportation assets in an area during an extreme heat or extreme flooding event. This can include strategies that protect transportation assets and surrounding properties.
    - *Reduce negative business impacts from disruptions in transportation service* – strategies that may help businesses to stay open or return to normal operations during or after an extreme weather event. These strategies either prevent complete system failure or allow for a quick recovery. These strategies could also limit impacts to key commuting corridors and supply chain transportation routes.
    - *Maintain cultural resource* – strategies that can help protect important cultural resources that are vital to a community's character and preserve the local heritage. These include archaeological resources, historic resources or cultural landscapes.
    - *Contribute to Smart Growth initiatives* – strategies which contribute to Smart Growth initiatives which help protect a community's health and natural environment by means of efficient, low-impact development and conservation.

Appendix A: Adaptation Strategy Fact Sheets
Category: Reduce Thermal Expansion (TE)

Design rail tracks for higher maximum temperatures in replacement or new rail infrastructure

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE1

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [X] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This adaptation strategy focuses on designing rail for higher maximum temperature, i.e., higher rail-neutral temperature. High temperatures can cause the steel in rail to expand and weaken, causing buckling (or kinking), which can lead to train derailment. Rail tracks that are in the direct sunlight can become significantly hotter than the ambient temperature, leading to potential integrity issues on days of extreme heat. Rail can be designed for a higher maximum temperature by using pieces of rail that are stretched and then welded together to reduce compression or by allowing room for the rail to expand by having small breaks. The rail could also be painted white or with another low solar absorption coating to reduce the amount of heat absorbed. The paint or coating would be applied to the sides and flanges of the rail, not the top surface.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [ ] County
- [ ] NJTPA
- [X] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Low solar absorption coating and painting rail tracks are an emerging trend, and tasks and costs associated with maintenance are not yet known. It is not feasible to replace, coat or paint tracks simultaneously network-wide. Rather, it would be more cost-effective to replace, paint or coat track segments as and when needed.

Design rail tracks for higher maximum temperatures in replacement or new rail infrastructure

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Rail Administration (FRA). July 2018. *Low Solar Absorption Coating for Reducing Rail Temperature and Preventing Buckling* . FRA Office of Railroad Policy and Development, U.S. Department of Transportation. Accessed: https://fra.dot.gov/Elib/Document/18062.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Lower speeds and use shorter trains to shorten braking distance and to allow for lighter loads to reduce track stress in extreme heat events

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE2

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [X] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would require that trains run with lower speeds and shorter trains (using less cars) in order to shorten the braking distance during extreme heat events. This would reduce the amount of stress placed on the tracks.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [ ] County
- [ ] NJTPA
- [X] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [X] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Issuing slow orders in hot weather is a common practice for transit agencies. Running trains at lower speeds and using shorter trains would increase the travel time between destinations and would decrease the capacity of the line. For routes with higher demand, consideration would need to be taken with the implementation of this strategy, such as running trains more frequently to account for the loss of capacity per train. In addition, monitoring the frequency and timing of implementing this strategy could lead to incorporating allowance for this strategy into the train schedule.

This strategy is recommended when temperatures surpass a set temperature threshold, dependent on the infrastructure conditions. For instance, reducing train speeds by 10 miles per hour when temperatures reach 90°F.

Lower speeds and use shorter trains to shorten braking distance and to allow for lighter loads to reduce track stress in extreme heat events

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

Lower speeds and use shorter trains to shorten braking distance and to allow for lighter loads to reduce track stress in extreme heat events

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE2

References:

California Department of Transportation. February 2013. *Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs* . Accessed: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf.

Federal Transit Administration (FTA). August 2011. F*looded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

FTA. August 2013. *A Vulnerability and Risk Assessment of SEPTA's Regional Rail: A Transit Climate Change Adaptation Assessment Pilot.* FTA Report No. 0071. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.septa.org/sustain/ClimateAdaptationReport.pdf.

Use bridge joints that can accommodate exceptional thermal expansion

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE3

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy calls for the use of bridge joints that can accommodate thermal expansion during extreme heat events. An expansion joint is designed to absorb any thermal expansion of the roadway or bridge. Allowing for the extraordinary expansion to occur safely would prevent any unnecessary movement in the bridge and would prevent any added compression.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

The use of this strategy would only be applicable with new construction or replacement projects.

Use bridge joints that can accommodate exceptional thermal expansion

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

California Department of Transportation. February 2013. *Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs* . Accessed: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf.

Monitor sagging of large suspension bridges during extreme heat

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE4

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Since a suspension bridge's deck is supported by vertical cables, any expansion or lengthening of these cables could cause the bridge to sag. High temperatures can lead to cable expansion beyond expansion designed for normal thermal conditions. This strategy would require that suspension bridges be monitored for sagging, particularly during warmer months and higher temperatures.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Monitor sagging of large suspension bridges during extreme heat

A.S. Category: Reduce Thermal Expansion

A.S. Identification: TE4

Technical, Implementation, and Financial Considerations:

This strategy would require that accurate baseline data on cable forces, vibration of the main span and sagging of the main span is recorded through a Structural Health Monitoring (SHM) System. An asset management system for storing the data may be used.

This process could be time-consuming and costly. A SHM System would be placed on each bridge and would include accelerometers to record vibration on cables and other bridge elements, strain gages to monitor deflection of the bridge elements and also cable forces, and other sensors that collect relevant bridge performance data. The collected data would then be transferred to a data acquisition unit (or multiple units depending on the design of the system) that will then transfer the data to a central data collection/storage/management server.

Transfer of data from sensors to data acquisition or the server can be done via cables, Bluetooth or wifi, or other wireless or remote technologies. Also, powering sensors or other SHM units can be done with cable power, batteries, or solar systems.

The recorded data on the server can then be analyzed, processed, and visualized by a software package that is calibrated for the specific bridge, to identify abnormal behavior (or performance) of bridge elements, which would trigger certain activities to keep the bridge and the users safe.

Other technologies that can be used in conjunction with the SHM methods, are remote sensing, 3D scanning, and LiDAR that can assist in capturing geometry of the bridge (especially for long-span or cable-stayed bridges with access difficulties) and thus can identify changes in the geometry that would warrant more in-depth evaluation of the bridge during extreme heat or extreme wind events.

Monitor sagging of large suspension bridges during extreme heat

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Cho, Soojin, et. Al. 2010. "Structural health monitoring system of a cable-stayed bridge using a dense array of scalable smart sensor network." Prepared for Sensors and Smart Structures Technologies for Civil, Mechanical, and Aerospace Systems Conference. Accessed: http://sstl.cee.illinois.edu/papers/Cho2010SPIE.pdf.

Lin Heng, et. al. July 2017. "Study on Health Monitoring System Design of Cable-Stayed Bridge." In: Rodrigues H., Elnashai A., Calvi G. (eds) Facing the Challenges in Structural Engineering. GeoMEast 2017. Sustainable Civil Infrastructures. Springer, Cham. Accessed: https://link.springer.com/chapter/10.1007/978-3-319-61914-9_17.

Increase seat lengths of expansion joints and/or the range of finger joints in bridges

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE5

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Expansion joints allow for bridges to expand and contract with changes in temperatures. With higher temperatures for longer periods of time, bridge materials may expand more than expected. By increasing the seat length on expansion joints and range of finger joints in bridges, the bridge material is allowed to have additional expansion compared to a bridge with smaller lengths or ranges in their expansion joints. This will help reduce the added stresses from bridge materials expanding beyond their designed limits.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Replacing a bridge's expansion joints or finger joints would require that a segment of the bridge be shut down during the replacement. Expansion joints need to be replaced periodically and the seat length could be increased during this routine replacement. It is recommended that this strategy be considered in conjunction with other bridge upgrades or changes, as applicable and feasible.

Increase seat lengths of expansion joints and/or the range of finger joints in bridges

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE5

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Chang, Luh-Maan and Yao-Jong Lee. February 2001. "Final Report: Evaluation and Policy for Bridge Deck Expansion Joints." FHWA/IN/JTRP-2000/1. Joint Transportation Research Program. Project No.: C-36-56UU. File No: 7-4-46. SPR 2198. In cooperation with Indiana Department of Transportation and the Federal Highway Administration. Accessed: https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1554&context=jtrp.

Connecticut Department of Transportation (CDOT). January 2018. *CDOT Bridge Design Manual - Section 14: Joints and Bearings* . Accessed: https://www.codot.gov/library/bridge/bridge-manuals/lrfd-bridge-design-manual/section-14-joints-and-bearings.

Iowa Department of Transportation (Iowa DOT). January 1, 2014. *Bridge Maintenance Manual.* Office of Bridges and Structures. Accessed: https://siims.iowadot.gov/IowaDOT_BridgeMaintenanceManual.pdf.

Monitor for temperatures of assets and heat-related impacts by installing sensor sytems

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE6

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve installing remote temperature sensors to monitor the heat of various assets, including roadways, rail tracks, bridges, and facilities. Extreme heat could lead to buckling, expansion, softening and rutting of roadways, rail and bridges; and failure of electrical and electronic equipment in facilities and rolling stock. The sensors could detect changes in pressure and temperatures and can set off alerts when those metrics are approaching certain thresholds. The number of sensors would be dependent upon the type of asset and microclimatic conditions in the region; for example, one sensor would be adequate for each bridge type in a region and for each major facility. For highways and rail tracks, sensors should be placed to provide representative sampling of heat readings in areas known to experience higher temperatures than ambient temperatures in the region (e.g. highly urbanized areas and highways with vast expanses of pavement).

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Monitor for temperatures of assets and heat-related impacts by installing sensor sytems

A.S. Category: Reduce Thermal Expansion

A.S. Identification: TE6

Technical, Implementation, and Financial Considerations:

Sensors could be installed with wire and cables reporting back to a central system or wirelessly reporting data via the cellular network, radio (with antennae), or internet. The latter system would require a power source at the sensor, such as a battery or solar power. A wired system would likely take more time to install than a wireless system. However, a wireless system may require more O&M costs, as each battery or solar power would need to be maintained.

Information received from the sensors could be used to inform and localize other adaptation strategies. For instance, instead of reducing train speeds network-wide when ambient temperatures hit a certain threshold, trains could be reduced along certain track segments when the sensors set off an alert.

Monitor for temperatures of assets and heat-related impacts by installing sensor sytems

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE6
Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Chinowsky, Paul et al. June 2017. "Impacts of Climate Change on Operation of the U.S. Rail Network." Transport Policy. Accessed: https://www.sciencedirect.com/science/article/pii/S0967070X16308198.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

International Association of Public Transport (UITP). 2017. *Urban Rail, Climate Change and Resilience.* Accessed: https://www.uitp.org/sites/default/files/Knowledge/Climate_change_resilience_Rail_201701.pdf.

Conduct regular maintenance and restore infrastructure previously impacted by heat events

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE7

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve adding checks for deformations and stressed materials following extreme heat events to the regular maintenance routine, thereby increasing the frequency of regular inspections. Wherever damage is noted, repairs would be completed. In this way, the damage would not be compounded by additional exposure to high temperatures.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [X] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

To successfully implement this strategy, a robust asset management system is recommended. Information regarding the temperature design thresholds for the asset's materials would need to be collected prior to this strategy being implemented. This strategy requires personnel to make site visits to the impacted infrastructure on a regular basis and after heat events to monitor for integrity of the asset. This may be a time-intensive effort depending on the existing conditions of the assets and the resources available to inspect the assets regularly.

Conduct regular maintenance and restore infrastructure previously impacted by heat events

A.S. Category: Reduce Thermal Expansion
A.S. Identification: TE7

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

California Department of Transportation. February 2013. *Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs* . Accessed: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Appendix A: Adaptation Strategy Fact Sheets
Category: Use Heat-Resistant Materials (HR)

Establish design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR1

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve establishing design standards that would increase the maximum temperature for construction materials. This would include requiring materials, such as certain asphalt-concrete mixtures, glazing materials, or reflective sealcoats, that can withstand higher temperatures and perform or operate as designed.

Project Stage:
- [X] Policy
- [ ] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would require that design standards across engineering, planning and environmental disciplines be uniform. Proper communication should occur between various departments and agencies including NJDOT, NJ Department of Environmental Protection, NJ Department of Community Affairs, Division of Codes and Standards and county planning, public works and engineering departments.

Establish design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

Establish design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR1

References:

American Public Transportation Association (APTA). March 31, 2011. "Transit Sustainability Guidelines: Framework for Approaching Sustainability and Overview of Best Practices." APTA Sustainable Urban Design Standards Working Group and Climate Change Working Group. APTA SUDS-CC-RP-004-11. Accessed: https://www.apta.com/resources/standards/Documents/APTA-SUDS-CC-RP-004-11.pdf.

Capatides, Christina. CBS News. September 24, 2018. "Los Angeles is painting some of its streets white and the reasons are pretty cool." Accessed: https://www.cbsnews.com/news/los-angeles-is-painting-some-of-its-streets-white-and-the-reasons-why-are-pretty-cool/.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Sacramento Area Council of Governments (SACOG). August 2015. *Sacramento Region Transportation Climate Adaptation Plan* . Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

Incorporate design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR2

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve incorporating established design standards for higher temperatures within existing municipality or agency design standards or other standards set by the asset owner. This would include incorporating standards for more heat-resistant materials, such as certain asphalt-concrete mixtures, glazing materials, or reflective sealcoats, in future projects.

Project Stage:
- [X] Policy
- [ ] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would require that design standards across engineering, planning and environmental disciplines be uniform. Proper communication should occur between various departments and agencies including NJDOT, NJ Department of Environmental Protection, NJ Department of Community Affairs, Division of Codes and Standards and county planning, public works and engineering departments.

Incorporate design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

Incorporate design standards for higher maximum temperature

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR2

References:

American Public Transportation Association (APTA). March 31, 2011. "Transit Sustainability Guidelines: Framework for Approaching Sustainability and Overview of Best Practices." APTA Sustainable Urban Design Standards Working Group and Climate Change Working Group. APTA SUDS-CC-RP-004-11. Accessed: https://www.apta.com/resources/standards/Documents/APTA-SUDS-CC-RP-004-11.pdf.

Capatides, Christina. CBS News. September 24, 2018. "Los Angeles is painting some of its streets white and the reasons are pretty cool." Accessed: https://www.cbsnews.com/news/los-angeles-is-painting-some-of-its-streets-white-and-the-reasons-why-are-pretty-cool/.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Sacramento Area Council of Governments (SACOG). August 2015. *Sacramento Region Transportation Climate Adaptation Plan* . Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

Use heat-resistant materials, including heat-resistant asphalt, concrete, or painted roadways

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR3

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve implementing design standards that would help mitigate the damage to assets caused from extreme heat. Sustained extreme heat can cause bridges, rail and roadways to sustain more damage from buckling, softening asphalt, and rutting, which could lead to cracking, potholing and bleeding. Utilizing heat-resistant materials such as certain asphalt-concrete mixtures, glazing materials or reflective sealcoats can minimize the amount of absorbed heat. Asphalt-concrete mixtures can be laid wherever pavement is called for (along roadways or bridges), glazing materials can be used on rolling stock and reflective sealcoats can be placed on facility roofs, roadways, bridges or rail tracks.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could be difficult to implement on roadways and/or bridges in areas with large amounts of truck traffic, due to the potential increased wear and tear. There are also safety considerations due to the potential glare from reflective sealcoats. It is recommended that this strategy be considered in conjunction with other asset upgrades or changes, including strategies that mitigate flood-related impacts.

Use heat-resistant materials, including heat-resistant asphalt, concrete, or painted roadways

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

Use heat-resistant materials, including heat-resistant asphalt, concrete, or painted roadways

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR3

References:

American Public Transportation Association (APTA). March 31, 2011. "Transit Sustainability Guidelines: Framework for Approaching Sustainability and Overview of Best Practices." APTA Sustainable Urban Design Standards Working Group and Climate Change Working Group. APTA SUDS-CC-RP-004-11. Accessed: https://www.apta.com/resources/standards/Documents/APTA-SUDS-CC-RP-004-11.pdf.

Capatides, Christina. CBS News. September 24, 2018. "Los Angeles is painting some of its streets white and the reasons are pretty cool." Accessed: https://www.cbsnews.com/news/los-angeles-is-painting-some-of-its-streets-white-and-the-reasons-why-are-pretty-cool/.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Sacramento Area Council of Governments (SACOG). August 2015. Sacramento Region Transportation Climate Adaptation Plan. Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

Overlay or rebuild roads with new or more rut-resistant asphalt or concrete

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR4

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Rutting can occur on roadways due to the combined effects of higher temperatures and traffic load. Rutting is when depressions in pavement occur, causing cracks and an uneven and distorted surface, which could cause safety issues. Certain pavement mixes, such as stone matrix asphalt and concrete, are deemed to be more rut resistant and can be used in these situations.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [X] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could be difficult to implement in areas with large amounts of truck traffic, due to the potential increased wear and tear. It is recommended that this strategy be considered in conjunction with other roadway or pavement upgrades or changes, including strategies that mitigate flood-related impacts. During planning and design, permeability of the material and potential weathering due to salting should be considered.

Overlay or rebuild roads with new or more rut-resistant asphalt or concrete

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). August 2015. "Tech Brief: Climate Change Adaptation for Pavements." FHWA-HIF-15-015. Accessed: https://www.fhwa.dot.gov/pavement/sustainability/hif15015.pdf.

Encourage construction of green roofs to cool buildings through evaporation/transpiration of vegetated surfacing

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR5

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Green roofs use a vegetative layer grown on a rooftop to help reduce temperatures inside of a building through evaporative cooling and evapotranspiration of vegetation. These roofs remove heat, reduce temperatures of the roof surface and surrounding air and provide shade.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [ ] County
- [X] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Green roofs are difficult to implement under a building renovation project since the combination of plant growing medium (e.g. soil media), rainwater absorbed by the medium, and the plants themselves, add significant weight for which the building's structural members may not have designed to handle. Therefore, this strategy is more practical in new construction. In addition, the roof would need various layering components and barriers to limit the damage of water and root systems to the structure. The use of larger vegetation on roofs could cause safety hazards during high winds and storms.

Encourage construction of green roofs to cool buildings through evaporation/transpiration of vegetated surfacing

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR5

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

General Services Administration (GSA). May 2011. *The Benefits and Challenges of Green Roofs on Public and Commercial Buildings.* Accessed: https://www.gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf.

Plant trees and other vegetation to shade assets

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR6

Event Type:
- [X] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Trees are used to provide shade for assets, reduce ambient air temperature through evapotranspiration, and help mitigate stormwater-related flooding (SW5). In addition, trees can remove pollutants from the atmosphere, thereby improving air quality.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could require increased maintenance and higher costs associated with clearing branches, so that limbs do not fall onto overhead lines or in rights-of way. If trees are not properly spaced and trimmed, safety issues may arise. Thus, trees would need to be planted in areas where they would not interfere with the functions of the transportation assets, including when downed by storm events.

Plant trees and other vegetation to shade assets

A.S. Category: Use Heat-Resistant Materials
A.S. Identification: HR6

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2013. *A Vulnerability and Risk Assessment of SEPTA's Regional Rail: A Transit Climate Change Adaptation Assessment Pilot* . FTA Report No. 0071. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.septa.org/sustain/ClimateAdaptationReport.pdf.

U.S. Environmental Protection Agency (EPA). "Using Trees and Vegetation to Reduce Heat Islands." Accessed: https://www.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands.

Appendix A: Adaptation Strategy Fact Sheets
Category: Prevent System Failure (SF)

Install energy system back-up such as generators, batteries, or other alternate sources of power during an emergency or long power-outage

A.S. Category: Prevent System Failure
A.S. Identification: SF1

Event Type:
- [X] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve installing a back-up energy system for assets in case of power failures. These back-up systems can involve generators, batteries, or other sources of power such as reciprocating engines, steam turbines, microturbines or fuel cells, as well as uninterruptible power supplies for traffic signals. This strategy would allow for systems to continue running in cases where the local power grid fails.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [X] Other: Local power utilities

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Alternate sources of power can have limited production and current battery technology has limited storage capacity. Therefore, it is important to still reserve energy consumption during times of power grid failure. On-site or nearby fuel storage for extended power outages should be considered.

Install energy system back-up such as generators, batteries, or other alternate sources of power during an emergency or long power-outage

A.S. Category: Prevent System Failure
A.S. Identification: SF1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report.* Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Transportation Research Board. February 2016. *Transportation Research Circular: Surface Transportation System Resilience to Climate Change and Extreme Weather Events: First International Conference* . Number E-C204. Accessed: http://onlinepubs.trb.org/onlinepubs/circulars/ec204.pdf.

Modernize the electric grid to allow for "islanding"/microgrids and encourage the construction of alternative energy systems/use of renewable energy sources as the primary energy source

A.S. Category: Prevent System Failure
A.S. Identification: SF2

Event Type:
- [X] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

A microgrid is a localized group of electricity sources and loads that may operate independently from the traditional electric grid. Creating microgrids would allow for various assets to operate when other systems have power failures due to storms or brownouts/blackouts. Microgrids and the use of renewable energy sources such as solar power, would reduce the extent of system disruptions during an event.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Local power utilities

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

Creating a microgrid within an area could be challenging in areas with pre-existing grid structures. The fuel source and extent of the microgrid would need to be considered. More critical assets that would and could independently function when surrounding areas are experiencing power failure should be given priority for this strategy. Microgrids can be utilized not just for emergency situations, but to support other systems in order to manage the associated cost and maintenance of said systems.

Modernize the electric grid to allow for "islanding"/microgrids and encourage the construction of alternative energy systems/use of renewable energy sources as the primary energy source

A.S. Category: Prevent System Failure
A.S. Identification: SF2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [X] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Transportation Research Board. February 2016. *Transportation Research Circular: Surface Transportation System Resilience to Climate Change and Extreme Weather Events: First International Conference* . Number E-C204. Accessed: http://onlinepubs.trb.org/onlinepubs/circulars/ec204.pdf.

NJ TRANSIT. Resilience Program: NJ TRANSITGRID. Accessed: http://njtransitresilienceprogram.com/nj-transitgrid-overview/.

Incorporate redundant power and communication lines and systems

A.S. Category: Prevent System Failure
A.S. Identification: SF3

Event Type:
- [X] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Redundant power and communication lines allow for the system to function in case there is any physical damage to any of the lines, transformers or substations. This strategy is important for any asset that has a high demand including major transit hubs. This strategy is not only important in cases of flooding or extreme heat, but also for other events such as a fire. Incorporating redundant lines and systems allow for the transportation asset to function properly if damage occurred on the power or communication line and/or system.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Local power utilities

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Consideration should be given to where and how the redundant lines are installed to ensure that they will not be impacted by the same event that causes failure to the primary lines.

Incorporate redundant power and communication lines and systems

A.S. Category: Prevent System Failure
A.S. Identification: SF3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Transportation Research Board. 2008. *Potential Impacts of Climate Change on U.S. Transportation.* TRB Special Report 290. Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Develop procedures and plans for when peak power demand exceeds capacity during heat events

A.S. Category: Prevent System Failure
A.S. Identification: SF4

Event Type:
- [X] Heat Events
- [ ] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

During heat events, more stress from additional loads are put on the local power supply and could exceed the peak power capacity. This strategy would involve developing procedures and plans to reduce a system's load during these events and allow for the system to continue running. This could include turning off equipment or loads that are not essential for day-to-day operations or not needed to protect human health.

Project Stage:
- [X] Policy
- [ ] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [X] Other: Local power utilities

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Coordination should occur between various departments and agencies including NJDOT, NJ TRANSIT, NJ Department of Environmental Protection Emergency Management Program, and county planning, public works and engineering departments. Such coordination would ensure that all agencies are on the same page with regards to what is necessary for operation or human health.

Develop procedures and plans for when peak power demand exceeds capacity during heat events

A.S. Category: Prevent System Failure
A.S. Identification: SF4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to SMART Growth initiatives

References:

Sacramento Area Council of Governments (SACOG). August 2015. *Sacramento Region Transportation Climate Adaptation Plan* . Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

Construct temporary floating bridges in cases where permanent bridges are damaged

A.S. Category: Prevent System Failure
A.S. Identification: SF5

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

In some cases, a bridge could be damaged after a weather event and would require an extensive amount of time to clean up and repair, which could cut off transportation between communities. This strategy would involve creating a temporary floating bridge, sometimes called a pontoon bridge, to allow for traffic to resume while the permanent bridge is replaced or repaired. These bridges rely on buoyancy to remain afloat.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Temporary floating bridges are typically meant to be just that. They can be quicker to construct in times of need, but they are not as durable as a permanent bridge. Also, they tend to have lower load capacities and would not allow for normal high traffic in a busy corridor. These bridges might not be allowed in areas where there is not only a high volume of traffic, but also a large amount of freight passage. Temporary floating bridges are also sensitive to high winds.

Construct temporary floating bridges in cases where permanent bridges are damaged

A.S. Category: Prevent System Failure
A.S. Identification: SF5

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Inland Marine Underwriters Association. 1993. "Pontoon Bridges." Accessed: https://www.imua.org/Files/reports/Pontoon_Bridges.html.

Think Defence. December 11, 2011. "UK Military Bridging - Floating Equipment." Accessed: https://www.thinkdefence.co.uk/2011/12/uk-military-bridging-floating-equipment/.

Upgrade emergency communication systems and Intelligent Transportation Systems (ITS)

A.S. Category: Prevent System Failure
A.S. Identification: SF6

Event Type:
- [X] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve upgrading emergency communication and real-time notification (Intelligent Transportation Systems) of travelers on transportation networks to ensure: 1) timely notification of impending weather and climate events; 2) awareness of evacuation routes; 3) awareness of travel delays and availability of alternate travel routes; and, 4) coordinate notifications across multiple agencies (local, regional, state, federal).

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Upgrade emergency communication systems and Intelligent Transportation Systems (ITS)

A.S. Category: Prevent System Failure

A.S. Identification: SF6

Technical, Implementation, and Financial Considerations:

The State of New Jersey has an existing ITS program, managed by the NJDOT's Bureau of Mobility and Systems Engineering.

This strategy would require planning and coordination among federal, state, regional and local agencies regarding emergency evacuation routes and emergency traffic diversion routes and how notifications will be developed and disseminated.

In addition, it is recommended that redundancy in the communications systems is instituted. Such redundancy would entail multiple channels of communications including variable message signs, smart phone messages, road navigation aps (e.g. Google Maps, Waze), radio and TV stations, emergency broadcast systems and alerts to emergency responders and transit providers.

This strategy is dependent upon accurate data regarding weather and climate events and traffic incidents. Such data could be informed by surveillance cameras situated along the transportation network and waterways and by incorporating modeling and visualization of water levels for flood warnings.

Upgrade emergency communication systems and Intelligent Transportation Systems (ITS)

A.S. Category: Prevent System Failure
A.S. Identification: SF6

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

CDM Smith. February 20, 2019. “Memorandum: NJTPA Passaic River Basin Climate Resilience Plan - Use of ITS in Incident and Emergency Management.”

Protect fuel supplies along evacuation routes and near shelters

A.S. Category: Prevent System Failure
A.S. Identification: SF7

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

Fuel supplies are an important resource during an event and are needed to run emergency generators, vehicles and other critical equipment. This strategy would involve ensuring fuel (gasoline and diesel) is available along evacuation routes and near shelters.

The U.S. Department of Energy (DOE) is the lead agency for the implementation of this strategy and coordinates with the Federal Emergency Management Agency (FEMA), other Federal agencies, State agencies and the energy industry to make sure fuel is available along evacuation routes during times of emergency.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [X] Other: DOE and FEMA

Project Timeframe:
- [X] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Primary, secondary and tertiary evacuation routes should be planned so that they pass by numerous fuel suppliers. State and Local agencies should work with private suppliers to coordinate deliveries leading up to and during storm events. In addition, State and Local agencies should identify which fuel stations would require back-up power in the case of a power outage.

Protect fuel supplies along evacuation routes and near shelters

A.S. Category: Prevent System Failure
A.S. Identification: SF7

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). March 7, 2012. *Mass Evacuation Incident Annex to the National Response Framework* . Accessed: https://www.fema.gov/media-library/assets/documents/25548.

FEMA. August 9, 2018. *National Engagement - Planning Considerations: Evacuation and Shelter-In-Place.* Accessed: https://www.fema.gov/media-library/assets/documents/168342.

Develop new critical use transportation facilities outside future flooding levels

A.S. Category: Prevent System Failure
A.S. Identification: SF8

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy is a form of retreat, which involves restricting the construction of new transportation assets to locations outside of the FEMA-designated floodplains and other areas where frequent flooding can occur.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would be difficult to implement in densely populated or urbanized areas due to lack of space for new road rights-of-way outside of the floodplain.

Develop new critical use transportation facilities outside future flooding levels

A.S. Category: Prevent System Failure
A.S. Identification: SF8

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). April 2013. *Reducing Flood Effects in Critical Facilities: Hurricane Sandy Recovery Advisory* . RA2. Accessed: https://www.fema.gov/media-library-data/1381404651877-881a2cf70a90ac63b9c067100ffccace/SandyRA2CriticalFacilities_508_FINAL2.pdf.

Develop and use redundant evacuation routes to allow for faster movement out of flooded areas

A.S. Category: Prevent System Failure
A.S. Identification: SF9

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy calls for the development of redundant evacuation routes for faster movement during emergency situations. This not only allows for a quicker evacuation, but also faster movement of rescue and recovery teams after an event. Redundant evacuation routes can also decrease the risk that all potential evacuation routes would be fully inundated during a flooding event.

Project Stage:
- [X] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [X] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Redundant evacuation routes would need to be chosen carefully so that any one event would not close all routes simultaneously. Some areas may not have an option for a redundant route due to geography and locations of populations relative to flood inundation areas.

Develop and use redundant evacuation routes to allow for faster movement out of flooded areas

A.S. Category: Prevent System Failure
A.S. Identification: SF9

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [x] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Transportation Research Board (TRB). 2008. *Potential Impacts of Climate Change on U.S. Transportation* . TRB Special Report 290. Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Bury utilities wherever feasible

A.S. Category: Prevent System Failure
A.S. Identification: SF10

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Burying utilities helps reduce the risk of damage and impact from storm events by protecting them from wind and downed trees. Buried utilities would need to be water-tight and weather-resistant and allow for occasional monitoring and maintenance to ensure that they are not damaged.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Local power utilities

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

Burying utilities can be time-consuming and costly, both for installation and maintenance. In addition, underground lines may experience damage due to subsurface flooding or tree roots uprooting the lines. Targeted undergrounding of lines may be most cost-effective.

Bury utilities wherever feasible

A.S. Category: Prevent System Failure
A.S. Identification: SF10

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Entergy. "Should Power Lines be Underground?" 2008. Accessed: http://www.entergy.com/2008_hurricanes/Underground-lines.pdf.

Larsen, Peter H. October 2016. *A Method to Estimate the Costs and Benefits of Undergrounding Electricity Transmission and Distribution Lines* . Ernest Orlando Lawrence Berkeley National Laboratory. LBNL-1006394. Accessed: https://emp.lbl.gov/sites/all/files/lbnl-1006394_pre-publication.pdf.

Appendix A: Adaptation Strategy Fact Sheets
Category: Increase or Improve Stormwater Drainage (SW)

Construct stormwater retention or detention basins

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW1

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Stormwater retention basins (also called wet ponds) and detention basins, are types of green infrastructure, which allow for the creation of greenery, open space and wildlife habitat. Retention basins hold pools of water permanently (the level falling and rising due to precipitation events), whereas detention basins hold pools of water temporarily (capturing runoff after precipitation events). These basins capture and store stormwater and help limit the amount of runoff flowing through other drainage systems. They are also able to improve the water quality of the stored runoff by using natural processes to filter pollutants. The vegetation associated with stormwater basins can help reduce particulate pollution and ground-level ozone, thereby improving air quality.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Though retention and detention basins are relatively inexpensive to construct, one important consideration is that large areas of land are needed to construct a new basin. In addition, if they are not designed properly, there could be negative water quality impacts.

A maintenance plan must be developed, and its design and maintenance should be in accordance with New Jersey regulations.

Construct stormwater retention or detention basins

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

New Jersey Department of Environmental Protection (NJDEP). Updated September 2014. *New Jersey Stormwater Best Management Practices Manual. "* Chapter 9.11: Wet Ponds." Accessed: https://www.state.nj.us/dep/stormwater/bmp_manual/NJ_SWBMP_9.11.pdf.

NJDEP. Updated September 2014. *New Jersey Stormwater Best Management Practices Manual.* "Chapter 9.4: Extended Detention Basins." Accessed: https://www.state.nj.us/dep/stormwater/bmp_manual/NJ_SWBMP_9.4.pdf.

U.S. Environmental Protection Agency (EPA). "Using Trees and Vegetation to Reduce Heat Islands." Accessed: https://www.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands.

Install internal drainage system using basins and sump pumps

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW2

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Sump pumps are used to drain areas that are not capable of draining excess water in a natural manner. Sump pumps can be used to drain floodwaters from areas such as a basement. A storm pump or lift station could also be used for larger-scale basins. The use of sump pumps and lift stations allows for areas to flood, but would then allow for a quicker recovery.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy works to remove standing water from roadways, rail and facilities. It could be useful in areas where flood protection of transportation assets is not feasible as a result of neighboring businesses or space. This strategy may not be practical on a large-scale basis due to the magnitude of water needing to be removed.

Sump pumps require periodic testing and maintenance and all components must be designed for submersible use.

Install internal drainage system using basins and sump pumps

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Federal Emergency Management Agency (FEMA). April 2013. *Reducing Flood Effects in Critical Facilities: Hurricane Sandy Recovery Advisory* . RA2. Accessed: https://www.fema.gov/media-library-data/1381404651877-881a2cf70a90ac63b9c067100ffccace/SandyRA2CriticalFacilities_508_FINAL2.pdf.

Install green infrastructure: bioretention ponds, bioswales and rain gardens

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW3

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Green infrastructure encompasses a variety of practices that involve designing or enhancing the natural environment to promote sustainable practices, particularly with regards to stormwater management. Such practices include bioretention ponds, bioswales and rain gardens, which are meant to collect, infiltrate and filter stormwater runoff from pervious surfaces (roofs and roadways). In addition, the plantings associated with green infrastructure helps improve local air quality by absorbing some pollutants.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Bioswales are best situated along roadways, median strips or other narrow areas. Bioretention ponds and rain gardens are best situated in any unpaved area.

A maintenance plan must be developed for each bioswale, bioretention pond and rain garden, and its design and maintenance should be in accordance with New Jersey regulations.

Install green infrastructure: bioretention ponds, bioswales and rain gardens

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

Install green infrastructure: bioretention ponds, bioswales and rain gardens

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW3

References:

New Jersey Department of Environmental Protection (NJDEP). "What is Green Infrastructure?" Accessed: https://www.nj.gov/dep/gi/.

NJDEP. Updated February 2016. *New Jersey Stormwater Best Management Practices Manual* . "Chapter 9.1: Bioretention Systems." Accessed: https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.1.pdf.

NJDEP. Updated September 2014. *New Jersey Stormwater Best Management Practices Manual* . "Chapter 9.12: Grass Swales." Accessed: https://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.12.pdf.

U.S. Environmental Protection Agency (EPA). "What is Green Infrastructure?" Accessed: https://www.epa.gov/green-infrastructure/what-green-infrastructure.

EPA. "Using Trees and Vegetation to Reduce Heat Islands." Accessed: https://www.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands.

Install green infrastructure: pervious pavements

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW4

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Pervious pavements are a form of green infrastructure that infiltrate, treat and can store rainwater. They can be either pervious concrete, interlocking concrete pavers or porous asphalt.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy does not require any additional land and therefore is easier to implement in areas where space would be limited. However, pervious pavements must be sited where soil is sandy enough to allow for infiltration.

It is recommended that this strategy be considered in conjunction with other roadway or pavement upgrades or changes including strategies that mitigate heat-related impacts such as HR1, HR2 and HR3.

Install green infrastructure: pervious pavements

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

New Jersey Department of Environmental Protection (NJDEP). "What is Green Infrastructure?" Accessed: https://www.nj.gov/dep/gi/.

NJDEP. Updated November 2016. *New Jersey Stormwater Best Management Practices Manual* . "Chapter 9.7: Pervious Paving Systems." Accessed: https://www.njstormwater.org/pdf/2016-11-07-pervious-paving-final.pdf.

U.S. Environmental Protection Agency (EPA). "What is Green Infrastructure?" Accessed: https://www.epa.gov/green-infrastructure/what-green-infrastructure.

Install green infrastructure: tree planting

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW5

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Planting trees is a form of green infrastructure that slows and reduces stormwater by absorbing and intercepting precipitation. In addition, trees can provide shade (HR6), remove air pollutants from the atmosphere and provide greenery and wildlife habitat.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could require increased maintenance and higher costs associated with clearing branches, so that limbs do not fall onto overhead lines or in rights-of way. If trees are not properly spaced and trimmed, safety issues may arise. Thus, trees would need to be planted in areas where they would not interfere with the functions of the transportation assets, including when downed by storm events.

Install green infrastructure: tree planting

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW5

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2013. *A Vulnerability and Risk Assessment of SEPTA's Regional Rail: A Transit Climate Change Adaptation Assessment Pilot* . FTA Report No. 0071. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.septa.org/sustain/ClimateAdaptationReport.pdf.

U.S. Environmental Protection Agency (EPA). "Using Trees and Vegetation to Reduce Heat Islands." Accessed: https://www.epa.gov/heat-islands/using-trees-and-vegetation-reduce-heat-islands.

Maintain buffer or clear zone between edge of highways/rail lines/power lines and adjacent tree belts/woodlands in order to minimize damage and obstruction caused by falling trees and limbs

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW6

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve ensuring that an appropriate buffer zone exists between trees and roadways, rail, and facilities. This buffer would safeguard against any damage and safety hazards to the roadway, rail and/or facilities and their respective users. This buffer would constitute a grassy or otherwise vegetated area, which would serve to capture some stormwater runoff and enhance infiltration.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [X] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could be difficult to implement in areas with limited space.

Maintain buffer or clear zone between edge of highways/rail lines/power lines and adjacent tree belts/woodlands in order to minimize damage and obstruction caused by falling trees and limbs

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW6

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

U.S. Environmental Protection Agency (EPA). "Manage Flood Risk." Accessed: https://www.epa.gov/green-infrastructure/manage-flood-risk.

Conduct routine maintenance of culverts and storm sewers to remove sediment and improve stormwater conveyance

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW7

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Culverts and storm sewers are instrumental in the drainage of stormwater after an event. However, these can often trap sediment that reduce their functionality. This strategy would involve the proper routine maintenance and clearing of sediment from culverts and storm sewers. If properly and periodically cleared, the culverts and storm sewers along rail tracks, roadways and by facilities, could perform as designed during an extreme weather event and would not create an additional impedance on the drainage of floodwaters.

In addition, this strategy can also improve water quality, not only because sediment is removed before it is washed into natural systems, but also because sediment is comprised of microparticles that bond to toxins and other impurities that would otherwise be suspended in stormwater. By routinely removing, and properly disposing of, the sediment and trapped toxins, the toxins do not reach natural systems and cause damage to water quality and wildlife.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [X] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy requires that culverts and storm sewers are properly maintained on a periodic basis. An asset management system identifying the location of all culverts and storm sewers is recommended, though it may be costly and time-consuming.

Conduct routine maintenance of culverts and storm sewers to remove sediment and improve stormwater conveyance

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW7

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2013. *A Vulnerability and Risk Assessment of SEPTA's Regional Rail: A Transit Climate Change Adaptation Assessment Pilot* . FTA Report No. 0071. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.septa.org/sustain/ClimateAdaptationReport.pdf.

Increase capacity of stormwater infrastructure and drainage system

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW8

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Stormwater infrastructure is designed for proper drainage during precipitation events. However, an existing system may be overwhelmed during a storm event and thereby cause localized flooding. This strategy would involve increasing the capacity of the local stormwater system. This could include increasing the size of drainage pipes or retention basins, increasing the number of convergence points or combined sewer overflow points.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Increasing the capacity of the existing stormwater infrastructure could be costly, as it may require that assets such as pipelines be replaced. In addition, an asset management system that includes the location and capacity of the existing stormwater drainage network is recommended. Capacity performance can be measured through reports of localized flooding and incorporated into the asset management system. In this way, efforts to increase drainage capacity can be limited to specific segments of the drainage system (and thereby minimizing the cost).

Increase capacity of stormwater infrastructure and drainage system

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW8

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). October 2017. *Post Hurricane Sandy Transportation Resilience Study in New York, New Jersey, and Connecticut.* FHWA-HEP-17-097. Accessed: https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/hurricane_sandy/fhwahep17097.pdf.

Sacramento Area Council of Governments (SACOG). August 2015. Sacramento Region Transportation Climate Adaptation Plan. Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Remove obstacles within streams and rivers to allow a higher capacity of flow in high precipitation events

A.S. Category: Increase or Improve Stormwater Drainage

A.S. Identification: SW9

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would ensure that streams and rivers near culverts and bridges are free from any undesirable or unneeded obstacles, which could impede the flow of water and lead to flooding of these assets. Such obstacles would include downed trees or other woody debris (woody material at least four inches in diameter and six feet long that protrudes or lays within a stream or river channel), and/or boulders that accumulate in such a way as to create a partial or complete obstruction of water flow.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy requires care during implementation to ensure removal of any obstacles does not cause detriment to the stream or river's ecosystem. The nature of the obstacle should be documented and both a work plan and a safety plan should be developed prior to any removal.

Removing an obstacle along the stream or river could have a legislative barrier and require consultation with the U.S. Army Corps of Engineers, New Jersey Department of Environmental Protection, and any other agency that has jurisdiction over that waterway.

Periodic field inspections for potential obstacles should be undertaken and field notes could be incorporated into an asset management system.

Remove obstacles within streams and rivers to allow a higher capacity of flow in high precipitation events

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW9

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Clinton River Watershed Council. *Field Manual on Maintenance of Large Woody Debris for Municipal Operation and Maintenance Crews.* Accessed: http://www.crwc.org/wp-content/uploads/LWD-Manual-Final.pdf.

Connecticut Department of Environmental Protection. "Large Woody Debris Fact Sheet." Inland Fisheries Division, Habitat Conservation and Enhancement Program. Accessed: https://www.ct.gov/deep/lib/deep/fishing/restoration/LargeWoodyDebrisFactSheet.pdf.

Enlarge culverts to increase the capacity

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW10

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [X] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Culverts allow for stormwater and floodwaters to pass through them. With increasing amounts of floodwaters, the existing culverts may become overwhelmed, causing flooding, erosion, and scour. By increasing the capacity of the culverts, through either expanding the actual size of the culvert or placing others next to it, additional floodwaters would be allowed to drain, thereby minimizing the potential for flooding of transportation assets.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Culvert design must be in compliance with New Jersey Department of Environmental Protection (NJDEP) policies and regulations and may require a permit from the U.S. Army Corps of Engineers, NJDEP, or other regulatory authorities.

An inventory of all culverts, their frequency of flooding and proximity to vulnerable roadways or bridges, would identify which are undersized and should be prioritized for being enlarged. Such an inventory could be time-consuming and costly, but could be incorporated into an overall asset management system.

Undersized culverts require more frequent maintenance than culverts more appropriately sized to meet the site's level of water conveyance. Thus, the cost of installation and maintenance of an enlarged culvert may be comparable or less than that of an undersized culvert over its lifetime.

Enlarge culverts to increase the capacity

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW10

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Natural Resilient Communities. "Flood Friendly Culverts." Accessed: http://nrcsolutions.org/flood-friendly-culverts/.

Transportation Research Board (TRB). 2008. *Potential Impacts of Climate Change on U.S. Transportation. TRB Special Report 290* . Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Upgrade bridge deck and road drainage systems to manage a higher capacity of stormwater

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW11

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

To ensure usability of bridges and roadways during and after precipitation events, proper drainage is needed. This strategy would upgrade the bridge deck and roadway drainage systems to have a higher capacity. Proper drainage of roadways and bridges create safer driving conditions and prolong the lifespan of the asset.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

An asset management system inventorying the stormwater collection and conveyance system along bridges and roadways is recommended. Like with SW8, reports of localized flooding could be geocoded into the system in order to gauge system performance and to prioritize certain segments of the network for upgrades. Such a process could be time-consuming and costly.

Upgrade bridge deck and road drainage systems to manage a higher capacity of stormwater

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW11

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

California Department of Transportation. February 2013. *Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs* . Accessed: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf.

Federal Highway Administration (FHWA). "Signalized Intersection Safety Standards: Improve Drainage in Intersection and on Approaches." *NCHRP Report 500, Vol. 12: A Guide for Reducing Collisions at Signalized Intersections* . Strategy G1. Accessed: https://safety.fhwa.dot.gov/intersection/other_topics/fhwasa08008/sg1_improve_drainage.pdf.

Replace culverts with bridges

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW12

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [X] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve replacing culverts with bridges to increase the capacity of stormwater conveyance. A culvert, due to its size, has a limited drainage capacity, which can lead to a backup of stormwater during high precipitation events or when its opening is covered by debris. A bridge, by its nature, provides a larger opening, better enabling greater water flows and debris to move through.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

Construction of a bridge is a costly endeavor and would require a larger amount of area surrounding the culvert in question.

The Federal Emergency Management Agency (FEMA) prefers bridges to culverts, as the former, when designed and constructed properly, does not alter the natural flow of water and are less likely to impede the passage of fish. Construction of a new bridge may require coordination with FEMA.

Replace culverts with bridges

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW12

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). June 2009. *Private Water Crossings: Considerations before you build or rebuild.* FEMA P-778. Accessed: https://www.fema.gov/media-library-data/20130726-1724-25045-9448/fema_p_778_508compliant.pdf.

Dupont, Joe. Idaho Department of Lands. "Costs of Upgrading Stream Crossings. Session Two." Accessed: https://www.st.nmfs.noaa.gov/st5/Salmon_Workshop/8_Dupont.pdf.

Ensure bridge openings and culverts are clear for appropriate flood management

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW13

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would require that there are appropriate O&M practices in place to clear debris from bridge openings and culverts to allow for increased drainage of stormwater. Such debris would include accumulation of litter and storm-related wreckage (which may include cars, roofs, utility poles, etc.). Trash of this kind could cause structural damage to bridges by catching against or beneath them, and could cause flooding by impeding the water flow beneath the bridge and through culverts. In addition, it could lead to scour and erosion.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could work in tandem with SW7 (which deals with clearing sediment) and SW9 (which deals with clearing large woody debris and other naturally-occurring obstacles). Like with SW7 and SW9, this strategy requires periodic maintenance. Personnel should regularly visit bridges and culverts to clear debris and add visits following storm events.

This strategy requires a robust inventory of bridges and culverts and their locations. An asset management system is recommended.

Ensure bridge openings and culverts are clear for appropriate flood management

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW13

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). October 2017. *Post Hurricane Sandy Transportation Resilience Study in New York, New Jersey, and Connecticut* . FHWA-HEP-17-097. Accessed: https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/hurricane_sandy/fhwahep17097.pdf.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Dredge rivers and lakes to aid in the conveyance of floodwaters

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW14

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would dredge waterways to facilitate the conveyance of stormwater runoff and floodwaters. Sand and silt are transported down waterways and sedimentation eventually fill these waterways and restricts the flow of water through the system. Dredging also allows for safer passage of navigable watercraft.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: NJDEP

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Dredging requires coordination with the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency and the New Jersey Department of Environmental Protection. Disposal of dredged material would need to be coordinated by federal, state or local governments and any other applicable private entity such as a port authority.

Dredging may serve to protect and restore the marine ecosystems by reducing the amount of pollutants in the waterways. However, dredging alters the aquatic habitat in such a way as to displace certain species and can limit the biodiversity of the site. Before considering this strategy, a thorough site-specific study should be completed to understand the potential overall impacts of dredging on the natural environment.

Dredge rivers and lakes to aid in the conveyance of floodwaters

A.S. Category: Increase or Improve Stormwater Drainage
A.S. Identification: SW14

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

National Ocean Service, National Oceanic and Atmospheric Administration (NOAA). "What is dredging?" Accessed: https://oceanservice.noaa.gov/facts/dredging.html.

NOAA. December 2011. *Review of the Ecological Effects of Dredging in the Cultivation and Harvest of Molluscan Shellfish.* NOAA Technical Memorandum NMFS-NE-220. Accessed: https://repository.library.noaa.gov/view/noaa/3971/noaa_3971_DS1.pdf.

Penn State News. June 7, 2013. "Research shows river dredging reduced fish numbers, diversity." Accessed: https://news.psu.edu/story/278878/2013/06/07/research/research-shows-river-dredging-reduced-fish-numbers-diversity.

Appendix A: Adaptation Strategy Fact Sheets
Category: Increase Flood Protection (FP)

Anchor tanks to resist flood loads and buoyancy forces from floodwaters

A.S. Category: Increase Flood Protection
A.S. Identification: FP1

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Aboveground storage tanks and containers are especially vulnerable to floodwaters and can break away during flood events due to flood loads and buoyancy forces. These tanks and containers typically hold various types of fuel or chemicals that can be toxic to the environment in the event of a release. Any potential damage could cause a spill and would result in hazardous materials and substances being released into the environment. These tanks or containers could also damage other infrastructure when swept away by flood waters. This strategy would involve anchoring tanks to resist the flood loads and buoyancy forces from floodwaters. This can include installing a concrete base or some anchors buried in the ground that have sufficient weight to resist flood waters; securing tanks to anchors with metal straps or mounting tanks on wheels to enable relocation to higher ground prior to flood events.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

The cost of anchoring a tank is considered relatively inexpensive compared with the cost of replacement or cleanup if they were damaged during an event. Federal, state and some local regulations sometimes have their own requirements for the anchoring of tanks that depend on the size, location and characteristics of the tank or container.

Anchor tanks to resist flood loads and buoyancy forces from floodwaters

A.S. Category: Increase Flood Protection
A.S. Identification: FP1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Federal Emergency Management Agency (FEMA). April 2011. *Anchor Fuel Tanks: Protecting Your Property from Flooding* . Accessed: https://www.fema.gov/media-library-data/20130726-1627-20490-6014/how2005_fuel_tanks_4_11.pdf.

FEMA. February 2017. Protecting Building Utility Systems from Flood Damage: Principles and Practices for the Design and Construction of Flood Resistant Building Utility Systems. FEMA P-348, Edition 2. Accessed: https://www.fema.gov/media-library/assets/documents/3729.

Anchor and secure rolling stock during flooding events

A.S. Category: Increase Flood Protection
A.S. Identification: FP2

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

During a flooding event, rolling stock can be vulnerable to damage from floodwaters. Impacts from these events would not only damage the rolling stock asset, but could potentially create more damage elsewhere depending on where the asset is carried. Anchoring and securing of rolling stock would help the assets resist the flood loads and buoyancy forces.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would require human intervention and notice prior to a flooding event. Only temporary anchoring systems would be allowed as rolling stock assets would not be able to be permanently anchored.

Anchor and secure rolling stock during flooding events

A.S. Category: Increase Flood Protection
A.S. Identification: FP2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Beym, Jessica. August 12, 2018. "Dealership's cars swept away like bumper boats in flash flood." nj.com. Accessed: https://articles.nj.com/passaic-county/index.ssf/2018/08/dealerships_cars_swept_away_like_bumper_boats_in_f.amp?__twitter_impression=true.

Relocate rolling stock assets outside of areas prone to flooding or storm surge

A.S. Category: Increase Flood Protection
A.S. Identification: FP3

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

During a flooding event, rolling stock can be vulnerable to damage from floodwaters. Relocating rolling stock assets outside of areas that are prone to floodwaters or storm surge ensure that assets are not in areas where they could be exposed to flood loads and buoyancy forces. Relocating rolling stock can be either temporary or permanent. It can include relocating storage yards out of floodprone areas or the temporary moving of assets after notice is given of an upcoming flooding event.

Project Stage:
- [X] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Relocating rolling stock is relatively inexpensive, however, it could be difficult to relocate rolling stock permanently if space outside of the floodplain or other flood inundation areas is limited. Also, if temporarily relocating rolling stock to higher ground prior to a flooding event, a large amount of human intervention would be needed during a critical and limited amount of time. If given enough notice, agencies could proactively shut down transit service, allowing for enough time to relocate their entire fleet.

Relocate rolling stock assets outside of areas prone to flooding or storm surge

A.S. Category: Increase Flood Protection
A.S. Identification: FP3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). October 2017. *Post Hurricane Sandy Transportation Resilience Study in New York, New Jersey, and Connecticut* . FHWA-HEP-17-097. Accessed: https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/hurricane_sandy/fhwahep17097.pdf.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Incorporate dry floodproofing: Install flood-resistant barriers or impermeable elements at structure's openings to prevent interior flooding and to resist flood loads

A.S. Category: Increase Flood Protection

A.S. Identification: FP4

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Dry floodproofing involves protecting facilities from floodwaters by incorporating flood-resistant barriers to the buildings' openings (i.e. windows, doors, or garages). Such strategies include applying impermeable membranes and sealants to exterior wall faces; installing impermeable flooring (such as polished concrete); sealing off exterior openings; and placing portable watertight barriers (such as flood doors or shields) in front of exterior openings prior to storm events.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Dry floodproofing usually requires human intervention and adequate warning time for installation of protective measures prior to a storm event.

Incorporate dry floodproofing: Install flood-resistant barriers or impermeable elements at structure's openings to prevent interior flooding and to resist flood loads

A.S. Category: Increase Flood Protection

A.S. Identification: FP4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Federal Emergency Management Agency (FEMA). November 2013. *Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York.* FEMA P-942. Accessed: https://www.fema.gov/media-library/assets/documents/85922#.

Incorporate wet floodproofing: Install flood openings and water-resistant materials to allow building to withstand some exposure to floodwaters and the associated loads/pressures

A.S. Category: Increase Flood Protection

A.S. Identification: FP5

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Whereas dry floodproofing involves preventing floodwaters from entering a structure, wet floodproofing involves allowing floodwaters to enter the structure but in a limited and controlled way. Wet floodproofing measures include installing openings (such as flood vents) or breakaway walls to allow water to pass through (and to equalize the hydrostatic pressure from the floodwaters), and using water-resistant materials.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy does not prevent flooding, but rather seeks to minimize its damage. Following a flood event, the facilities may still require extensive cleanup.

The Federal Emergency Management Agency's National Flood Insurance Program requires wet floodproofing for buildings within the floodplain and lower (even partially) than the base flood elevation.

Incorporate wet floodproofing: Install flood openings and water-resistant materials to allow building to withstand some exposure to floodwaters and the associated loads/pressures

A.S. Category: Increase Flood Protection

A.S. Identification: FP5

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Federal Emergency Management Agency (FEMA). November 2013. *Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York* . FEMA P-942. Accessed: https://www.fema.gov/media-library/assets/documents/85922#.

Elevate existing transportation assets

A.S. Category: Increase Flood Protection
A.S. Identification: FP6

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve raising the transportation asset above the base flood elevation, which is the level floodwaters are anticipated to rise to during the base flood (per the Federal Emergency Management Agency). In this way, the asset would be above the floodwaters, and thereby protected from damage.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

Site-specific analyses for each asset is recommended in order to determine what site modifications and structural reinforcements would be necessary to elevate the asset.

Elevation can be costly and time-consuming and thus this strategy may be most practically implemented during the design phase of new infrastructure.

Elevate existing transportation assets

A.S. Category: Increase Flood Protection
A.S. Identification: FP6

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Transportation Research Board (TRB). 2008. *Potential Impacts of Climate Change on U.S. Transportation* . TRB Special Report 290. Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Construct catchment devices upstream of bridges to catch floating debris and minimize effect of debris and ice floes on bridges

A.S. Category: Increase Flood Protection
A.S. Identification: FP7

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve installing catchment devices upstream of bridges to capture waterborne debris and thereby minimizing potential structural impacts to the bridges. These devices, otherwise called debris control structures, include debris deflectors or debris fins (v-shaped structures or walls built in the stream channel that deflect or orient large debris in such a way as to pass smoothly through the bridge opening), crib structures (walls with cribbing or sheathing between the piles of the bridge piers), and debris racks (fence-like structures with spaced vertical posts that capture large debris.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

The strategy's application is site-specific. The selection of a catchment device is dependent upon the stability of the waterflow direction, flow velocity, and the orientation of the bridge and its components

Catchment devices should be inspected periodically and cleaned out as needed to ensure effectiveness.

Construct catchment devices upstream of bridges to catch floating debris and minimize effect of debris and ice floes on bridges

A.S. Category: Increase Flood Protection
A.S. Identification: FP7

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). October 2005. *Debris Control Structures: Evaluation and Countermeasures.* Third Edition. Hydraulic Engineering Circular 9. Publication No. FHWA-IF-04-016. Accessed: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/04016/hec09.pdf.

Iowa State University, Bridge Engineering Center. June 2012. *Debris Mitigation Methods for Bridge Piers. Final Report. InTrans Project 11-395* . Accessed: https://iowadot.gov/bridge/special_projects/debris_mit_4_piers_w_cvr.pdf.

Pennsylvania Department of Transportation (PennDOT). Summer 2012. “Debris Control for Bridges and Culverts.” PennDOT Local Technical Assistance Program (LTAP) Information Sheet #152. Accessed: http://www.dot7.state.pa.us/BPR_pdf_files/Documents/LTAP/TS_152.pdf.

Elevate critical mechanical and electrical equipment

A.S. Category: Increase Flood Protection
A.S. Identification: FP8

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy involves elevating critical mechanical and electrical equipment above the base flood elevation (a Federal Emergency Management Agency regulatory standard, describing the anticipated level of floodwaters during the base flood). In this way, the equipment would be protected from flood-related damage.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy is useful in cases where elevating the entire asset would not be feasible or where only the critical components would need to be protected while the remaining portions of the systems could be protected with wet floodproofing.

Elevate critical mechanical and electrical equipment

A.S. Category: Increase Flood Protection
A.S. Identification: FP8

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to SMART Growth initiatives

References:

City of New Haven. July 2017. *City of New Haven Commercial Industrial Toolbox Final Report* . Accessed: https://circa.uconn.edu/new-haven-commercial-industrial-toolbox/#.

Federal Emergency Management Agency (FEMA). November 2013. *Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York* . FEMA P-942. Accessed: https://www.fema.gov/media-library/assets/documents/85922#.

Protect and restore wetlands to protect infrastructure

A.S. Category: Increase Flood Protection
A.S. Identification: FP9

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve deploying mechanisms to help protect and restore wetlands. Wetlands are a vital part of our ecosystem and provide a natural barrier and protection from flooding. Wetlands can function as sponges and retain stormwater and floodwaters and slowly release the water. They provide water storage and a "braking" action which lowers flood heights. When wetlands are damaged or low performing, they do not function well at retaining water and providing a natural barrier.

Such mechanisms include conserving wetlands and adjacent buffer areas as open space, planting native vegetation, and restoring the original site's physical attributes (such as channels and reconnections to adjacent ecosystems).

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [X] Other: New Jersey Department of Environmental Protection

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Protection and restoration of wetlands require coordination with New Jersey Department of Environmental Protection and local agencies, and potentially other agencies such as the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, National Marine Fisheries Service, and the U.S. Department of Agriculture.

Protection of wetlands may require local covenants or ordinances prohibiting development.

Protect and restore wetlands to protect infrastructure

A.S. Category: Increase Flood Protection
A.S. Identification: FP9

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

New Jersey Department of Environmental Protection (NJDEP). "Freshwater Wetlands." Accessed: https://www.nj.gov/dep/landuse/fww/fww_main.html.

U.S. Environmental Protection Agency (EPA). "Why are Wetlands Important?" Accessed: https://www.epa.gov/wetlands/why-are-wetlands-important.

EPA. "Principles of Wetland Restoration." Accessed: https://www.epa.gov/wetlands/principles-wetland-restoration.

Construct and raise protective dikes, bulkheads, berms and levees, including tide gates as necessary

A.S. Category: Increase Flood Protection
A.S. Identification: FP10

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Dikes, bulkheads, berms, levees and tide gates help protect larger areas from being inundated with storm surges or floodwaters from waterways. However, with rising sea levels, previously designed elevations may not provide adequate protection during flooding events. This strategy would construct additional infrastructure where applicable or raise existing protective infrastructure. This type of infrastructure provides area-wide protection.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: New Jersey Department of Environmental Protection

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

When constructing or raising a levee or berm, coordination with U.S. Army Corps of Engineers and New Jersey Department of Environmental Protection would be required, along with any other agency that would have jurisdiction.

A tide gate would not be applicable in all locations and is better suited for areas further downstream.

Site-specific environmental reviews should be conducted for each potential site of protective infrastructure placement. Consideration should be given to the possible impacts to natural (local ecosystem) and built (communities and infrastructure) environments.

Construct and raise protective dikes, bulkheads, berms and levees, including tide gates as necessary

A.S. Category: Increase Flood Protection
A.S. Identification: FP10

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Transportation Research Board. 2008. *Potential Impacts of Climate Change on U.S. Transportation* . TRB Special Report 290. Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Incorporate a higher base flood elevation (BFE) in design changes as needed

A.S. Category: Increase Flood Protection
A.S. Identification: FP12

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

A BFE is a Federal Emergency Management Agency (FEMA) regulatory standard. It is the elevation to which floodwater levels are projected to rise during a flood that has a one-percent chance of equaling or exceeding that level in any given year. This type of flood is referred to as the "base flood" or "100-year flood." Typically, the BFE is set by FEMA on a Flood Insurance Rate Map (FIRM), which also includes an area's flood zones. A community that participates in FEMA's National Flood Insurance Program must elevate or floodproof all structures to the BFE. However, the flooding from some storms, such as Hurricane Sandy, exceeded the BFE by several feet in certain areas. Thus, elevating assets above the BFE can substantially lower their flood risk and should be considered during the design process.

Alternatively, an agency can opt to raise their BFE above the FEMA-required minimum as a design standard, and thus new projects would be required to comply with the increased elevation.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [ ] NJTRANSIT
- [ ] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

If new design standards are established, they should be reviewed periodically to ensure they meet or exceed the local community's floodplain management ordinance.

Incorporate a higher base flood elevation (BFE) in design changes as needed

A.S. Category: Increase Flood Protection
A.S. Identification: FP12

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). "Base Flood Elevation." Accessed: https://www.fema.gov/base-flood-elevation.

FEMA. April 2013. *Designing for Flood Levels Above the BFE After Hurricane Sandy.* Hurricane Sandy Recovery Advisory. RA5. Accessed: https://www.fema.gov/media-library-data/1381405016896-8bdeadf634c366439c35568a588feb24/SandyRA5DesignAboveBFE_508_FINAL2.pdf.

Deploy temporary barriers to protect critical assets during flooding events

A.S. Category: Increase Flood Protection
A.S. Identification: FP13

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

Temporary barriers, such as sandbags, are deployed prior to a flooding event to protect critical assets and are removed once flooding subsides. They may be filled with sand or water to provide weight and stability, and they do not require any permanent fixtures to be deployed.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [X] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [X] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Temporary barriers are generally an inexpensive method to protect critical assets. However, disposal costs may be high, as they are likely to absorb pollutants from the floodwaters, and are thereby then considered hazardous waste.

Human intervention is needed to set up these barriers and ample warning time prior to a flooding event is also needed. Staff responsible for setting up these barriers must be trained in advance to ensure their successful deployment.

Consideration should be given as to where they will be stored when not in use. In addition, when stored, they should be checked periodically to safeguard against deterioration.

Deploy temporary barriers to protect critical assets during flooding events

A.S. Category: Increase Flood Protection
A.S. Identification: FP13

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). July 2013. *Floodproofing Non-Residential Buildings* . FEMA P-936. Accessed: https://www.fema.gov/media-library/assets/documents/34270.

Reconstruct transportation assets at a less vulnerable location

A.S. Category: Increase Flood Protection
A.S. Identification: FP14

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve relocating critical and highly vulnerable assets to an area that would be less vulnerable to flooding. Relocation could require that existing assets be demolished or abandoned.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

This strategy is highly effective in preventing damage and allowing the usability of an asset during event; however, relocating an asset may not be feasible for a variety of reasons. The high costs associated with acquiring a site, securing rights-of-way and construction may limit which assets can be considered for relocation. Securing land to site the relocated asset while ensuring connectivity to the overall network may be prohibitive. In addition, assets that serve as the only means of egress to vulnerable communities should not be considered for relocation.

Relocating transportation assets that may not be compatible with residential uses due to noise, traffic or air emissions concerns needs to be considered carefully so as not to negatively impact residential areas, especially within environmental justice communities.

An environmental review analyzing potential impacts of the relocation to both the existing and proposed site and community is recommended prior to implementation.

Reconstruct transportation assets at a less vulnerable location

A.S. Category: Increase Flood Protection
A.S. Identification: FP14

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Transportation Research Board. 2008. *Potential Impacts of Climate Change on U.S. Transportation* . TRB Special Report 290. Accessed: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-

Install sensors along or within assets to monitor for water level and changing conditions

A.S. Category: Increase Flood Protection
A.S. Identification: FP15

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve the installation of sensors along or within assets to monitor the water level and changing conditions. Sensors and monitors would be placed in areas where assets are the most vulnerable to rising floodwaters, which could inform the emergency communication and Intelligent Transportation Systems (SF6) and would allow proactive measures to be deployed in the case of changing water levels. Such measures could include laying sandbags (FP13) or installing dry or wet floodproofing (FP4 or FP5).

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Sensors need to be installed by the asset owner and often require more personnel and time to install. Debris from a flooding event or storm could wipe out the sensors.

Conventional water level sensors use wired technology to communicate data to a central monitoring station. Newer sensor options include reporting data via the cellular network, radio (with antennae), or internet. This would require a power source at the sensor such as a battery or solar power. A wired system would likely take more time to install than a wireless system. However, a wireless system may require more O&M costs, as each battery or solar power would need to be maintained.

Install sensors along or within assets to monitor for water level and changing conditions

A.S. Category: Increase Flood Protection
A.S. Identification: FP15

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Appendix A: Adaptation Strategy Fact Sheets
Category: Reduce Flood Damage (FD)

Protect bridge piers and abutments with riprap

A.S. Category: Reduce Flood Damage
A.S. Identification: FD1

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would have bridge piers and abutments be protected against scour conditions with riprap. Scouring is the removal of soil or streambed material around bridge piers or abutments from moving water, which can compromise the structural integrity of the bridge.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy is important for bridges that are identified as having critical scour conditions. This strategy requires special monitoring of these more vulnerable structures. The costs of implementing this strategy depends on the type of bridge, type of piers and abutments, whether the substructure rests on bedrock or on less stable soils, and the depth and velocity of water. There may be navigational challenges in implementing corrective measures since protective riprap might pose obstacles or hazards for watercraft.

Consultation with the New Jersey Department of Environmental Protection is required prior to installation of riprap.

Protect bridge piers and abutments with riprap

A.S. Category: Reduce Flood Damage
A.S. Identification: FD1

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). April 2012. *Evaluating Scour at Bridges: Fifth Edition.* Publication No. FHWA-HIF-12-003. Hydraulic Engineering Circular No. 18. Accessed: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Alter, upgrade, or retrofit bridge movement system (e.g. bearings) to prevent excessive lateral or vertical displacement due to buoyancy forces or water pressure

A.S. Category: Reduce Flood Damage

A.S. Identification: FD2

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

During a flooding event, bridges can be exposed to excessive lateral or vertical pressures and displacement due to buoyancy forces or water pressure. Excessive pressures can cause a bridge to fail if it is not adequately supported. This strategy would provide changes or upgrades to bridges that would allow the asset to be exposed to these pressures for extended periods of time without failure. This alteration, upgrading and retrofitting can be done through installing bearings.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would prevent a disruption in the system after an event and could reduce the resources needed for recovery. It is recommended that a detailed asset management system be put in place to monitor the bridges and their pressure loads.

Alter, upgrade, or retrofit bridge movement system (e.g. bearings) to prevent excessive lateral or vertical displacement due to buoyancy forces or water pressure

A.S. Category: Reduce Flood Damage
A.S. Identification: FD2

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). November 2018. *Foundation Reuse for Highway Bridges.* Publication No. FHWA-HIF-18-055. Infrastructure Office of Bridges and Structures. Accessed: https://www.fhwa.dot.gov/publications/research/infrastructure/structures/18055/hif18055.pdf.

Retrofit/replace/relocate existing bridges for new scour conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD3

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would retrofit, replace or relocate existing bridges that have critical scour conditions. Scouring is the removal of soil or streambed material around bridge piers or abutments from moving water, which can cause structural damage to the affected bridge. The upgraded or new bridge foundation would be designed for a higher level of scour than the existing bridge. For instance, siting a new bridge perpendicular to the flow of water (as opposed to parallel), or installing round-nosed piers (as opposed to square-nosed piers).

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

This strategy is important for bridges that are identified as having critical scour conditions. It is recommended that a detailed asset management system be put in place to monitor the bridges and their scour conditions.

The costs of implementation this strategy would vary depending on the length, location, configuration and sub-structure elements of the bridge, as well as the availability of land for potential relocation.

For relocation, a site-specific analysis should be conducted to ensure connectivity to the transportation network and minimal impacts to the natural and built environments.

Retrofit/replace/relocate existing bridges for new scour conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). April 2012. *Evaluating Scour at Bridges: Fifth Edition* . Publication No. FHWA-HIF-12-003. Hydraulic Engineering Circular No. 18. Accessed: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Monitor bridge for scour and other conditions that could undermine a bridge's structural integrity during a flooding event

A.S. Category: Reduce Flood Damage

A.S. Identification: FD4

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would require the monitoring of bridges for scour or other critical conditions, such as lateral movement, that could cause failure. Scouring is erosion caused by moving water, which can cause bridge failure. Monitoring would include periodic site inspections to assess conditions of the bridge substructure and superstructure (both above and underwater), as well as conditions up- and downstream from the bridge. Monitoring also could include the installation of sensors, sounding rods, or sonars at piers and/or abutments.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

The Federal Highway Administration mandates a Plan of Action be prepared for each scour critical bridge as required by the National Bridge Inspection Standards (NBIS) and a scour monitoring program is a part of the Plan of Action. Site inspections of state and federal bridges would need to occur in accordance with the NBIS and the developed Plan of Action. To effectively monitor conditions for scour, both above and underwater inspections for each bridge should occur periodically. This level of effort, if not already being done, may be time-intensive and costly.

In addition, the monitoring devices should be inspected during each site visit to ensure effectiveness. The type of monitoring device used for each bridge may vary, based on the location and accessibility of the scour (or potential for scour), the frequency of readings and cost.

Monitor bridge for scour and other conditions that could undermine a bridge's structural integrity during a flooding event

A.S. Category: Reduce Flood Damage
A.S. Identification: FD4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Highway Administration (FHWA). April 2012. *Evaluating Scour at Bridges: Fifth Edition* . Publication No. FHWA-HIF-12-003. Hydraulic Engineering Circular No. 18. Accessed: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf.

Use vegetation or earthwork to stabilize river and stream embankments and provide riverine buffers

A.S. Category: Reduce Flood Damage
A.S. Identification: FD5

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Planting vegetation or performing earthwork along river and stream embankments can help stabilize the land and provide a riverine buffer. This buffer would control for soil erosion, add greenery and wildlife habitat, absorb and/or filter out contaminants, and serve to capture and store stormwater, thereby limiting the impact from a flooding event. Options for vegetation could be grasses, native vegetation, hydroseed, or rolled shaped coverings.

Project Stage:
- [ ] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [X] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy is not practical in locations where there are steep slopes (a 4:1 vertical to horizontal ratio, or greater).

The New Jersey Department of Environmental Protection should be consulted prior to implementation of this strategy.

Use vegetation or earthwork to stabilize river and stream embankments and provide riverine buffers

A.S. Category: Reduce Flood Damage
A.S. Identification: FD5

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

NC Cooperative Extension - Backyard Stream Repair Program Team. 2015. *Small-scale Solutions to Eroding Streambanks.* Accessed: https://www.ncforestservice.gov/publications/BYSRGuide2015.pdf.

Ensure roadway and rail tracks are clear of rocks, debris and downed vegetation

A.S. Category: Reduce Flood Damage
A.S. Identification: FD6

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [ ] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would require proper and routine cleanup and clearing of rocks, debris and downed vegetation. This maintenance would not only need to occur after an event, but periodically to limit the amount of disruption of a storm event.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

It is recommended that each municipality develop an emergency debris management plan, as prescribed by the New Jersey Department of Environmental Protection. This plan should be reviewed and updated annually.

Cleanup crews may need to be placed on stand-by when a storm event is predicted, in order to ensure adequate staffing for quick and efficient cleanup following the storm.

Ensure roadway and rail tracks are clear of rocks, debris and downed vegetation

A.S. Category: Reduce Flood Damage
A.S. Identification: FD6

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

California Department of Transportation. February 2013. *Addressing Climate Change Adaptation in Regional Transportation Plans: A Guide for California MPOs and RTPAs* . Accessed: http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/FR3_CA_Climate_Change_Adaptation_Guide_2013-02-26_.pdf.

Federal Transit Administration (FTA). August 2013. *A Vulnerability and Risk Assessment of SEPTA's Regional Rail: A Transit Climate Change Adaptation Assessment Pilot* . FTA Report No. 0071. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.septa.org/sustain/ClimateAdaptationReport.pdf.

New Jersey Department of Environmental Protection (NJDEP), Division of Solid and Hazardous Waste. "Emergency Debris Planning." Accessed: https://www.nj.gov/dep/dshw/debris/planning.html.

Use moisture-resistant materials that are more resilient to flooding conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD7

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [ ] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy involves using moisture-resistant and flood-resistant materials, such as paint or non-corrosive materials, that can be exposed to long periods of high water before being damaged. This would reduce the amount of damage from a flooding event.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

To be cost-effective, moisture-resistant and flood-resistant materials should be used in areas and elevations that would be prone to flooding.

Use moisture-resistant materials that are more resilient to flooding conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD7

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency (FEMA). July 2013. *Floodproofing Non-Residential Buildings* . FEMA P-936. Accessed: https://www.fema.gov/media-library/assets/documents/34270.

Use new asphalt/concrete mixtures able to withstand flood conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD8

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [X] Facilities
- [ ] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Asphalt and concrete can be used in some cases to withstand flood conditions. This can include mixtures that can be exposed to high waters for extended periods of time without excessive wear and tear or mixtures that can absorb high amounts of water and thus potentially limit the impact to surrounding assets in lower flooding conditions. Concrete is naturally more resilient to flooding and can get stronger with age.

Project Stage:
- [X] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [ ] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [X] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

Some concrete and asphalt mixtures are not permeable, which could produce additional runoff. It is recommended that this strategy be considered in conjunction with other roadway or pavement upgrades or changes including strategies that mitigate heat-related impacts.

Use new asphalt/concrete mixtures able to withstand flood conditions

A.S. Category: Reduce Flood Damage
A.S. Identification: FD8

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Sacramento Area Council of Governments (SACOG). August 2015. *Sacramento Region Transportation Climate Adaptation Plan* . Accessed: https://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf.

Improve temporary and permanent erosion control standards of construction sites

A.S. Category: Reduce Flood Damage
A.S. Identification: FD10

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

Erosion control standards prevent the excessive eroding of loose soil at a site due to means such as stormwater. They also prevent the eroded material and sediment from polluting the stormwater runoff and protect or reestablish vegetation and water bodies. Most agencies enforce some form of erosion control standards at construction sites. This strategy would require that more improved and stringent temporary and permanent erosion control standards at construction sites be implemented to better limit these impacts.

Project Stage:
- [X] Policy
- [X] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [X] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [ ] $
- [X] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy would require that current standards be reviewed and updated as necessary. This may require coordination between agencies, including New Jersey Department of Agriculture, New Jersey Department of Environmental Protection and the New Jersey Soil Conservation Districts, to ensure effectiveness.

Improve temporary and permanent erosion control standards of construction sites

A.S. Category: Reduce Flood Damage
A.S. Identification: FD10

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

New Jersey Department of Agriculture, State Soil Conservation Committee. January 2014. *The Standards for Soil Erosion and Sediment Control in New Jersey.* 7th Edition. Accessed: https://nj.gov/agriculture/divisions/anr/pdf/2014secappendices.pdf.

New Jersey Department of Transportation. 2008. *Soil Erosion and Sediment Control Standards. Accessed: https://www.state.nj.us/transportation/eng/documents/SESC/pdf/SESCStandards2008.pdf* .

Conduct regular maintenance and restore infrastructure that was previously impacted from flooding events

A.S. Category: Reduce Flood Damage
A.S. Identification: FD11

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [X] Culverts
- [X] Facilities
- [X] Rail Tracks
- [X] Roads, Transit (bus lines)
- [X] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve providing regular routine maintenance to infrastructure and to restore infrastructure that was previously impacted or damaged by flooding events. Regularly maintaining and restoring infrastructure would ensure that assets are not further damaged by additional exposure to floodwaters and can perform as designed.

Project Stage:
- [ ] Policy
- [ ] Design
- [X] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [ ] Other: _____

Project Timeframe:
- [ ] < 1 year
- [X] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [ ] > 10 years

Project Cost:
- [X] $
- [ ] $$
- [ ] $$$
- [ ] $$$$

Technical, Implementation, and Financial Considerations:

To successfully implement this strategy, a robust asset management system is recommended. This strategy requires personnel to make site visits to the impacted infrastructure on a regular basis and after flooding events to monitor for integrity of the asset. This may be a time-intensive and costly effort depending on the existing conditions of the asset and the resources available to inspect the assets regularly.

Conduct regular maintenance and restore infrastructure that was previously impacted from flooding events

A.S. Category: Reduce Flood Damage
A.S. Identification: FD11

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Federal Transit Administration (FTA). August 2011. *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation* . FTA Report No. 0001. FTA Office of Research, Demonstration and Innovation, U.S. Department of Transportation. Accessed: https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.

Construct permanent floating bridges to withstand changes in water levels

A.S. Category: Reduce Flood Damage
A.S. Identification: FD12

Event Type:
- [ ] Heat Events
- [X] Flooding Events

Asset Type:
- [X] Bridges
- [ ] Culverts
- [ ] Facilities
- [ ] Rail Tracks
- [ ] Roads, Transit (bus lines)
- [ ] Transit (rolling stock)

Adaptation Strategy Description

This strategy would involve creating a permanent floating bridge, often called a pontoon bridge, that relies on buoyancy forces to stay afloat. Due to its floating nature, it can be more resilient to changes in water levels. A permanent floating bridge is more robust than a temporary floating bridge (SF5) and can withstand typical traffic loads.

Project Stage:
- [ ] Policy
- [X] Design
- [ ] O&M

Parties Responsible for Implementation:
- [X] County
- [ ] NJTPA
- [X] NJTRANSIT
- [X] NJDOT
- [ ] Emergency Management
- [X] Other: Federal Highway Administration

Project Timeframe:
- [ ] < 1 year
- [ ] 1-5 years
- [ ] < 5 years
- [ ] 5-10 years
- [X] > 10 years

Project Cost:
- [ ] $
- [ ] $$
- [ ] $$$
- [X] $$$$

Technical, Implementation, and Financial Considerations:

Permanent floating bridges can be more economically feasible than traditional bridges in very deep bodies of water with soft beds. Floating bridges will need to account for waterway traffic to pass through on navigable waters, either underneath like the Ford Island Bridge in Hawaii or the Nordhordland Bridge in Norway, or by opening for traffic like the Berbice Bridge in Guyana.

Construct permanent floating bridges to withstand changes in water levels

A.S. Category: Reduce Flood Damage
A.S. Identification: FD12

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Lewis, Scott. February 20, 2018. "The 10 Longest Floating Bridges in the World: A survey of pontoon bridges that push the limits of the technology." Engineering News-Record (ENR). Accessed: https://www.enr.com/articles/44013-the-10-longest-floating-bridges-in-the-world.

Washington State Department of Transportation. "SR 520 Bridge Replacement and HOV Program - Floating Bridge Facts." Accessed: https://www.wsdot.wa.gov/Projects/SR520Bridge/About/BridgeFacts.htm.

Appendix A: Adaptation Strategy Fact Sheets
Category: Region-wide Adaptation Strategies (RW)

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Require low impact development (LID) and green infrastructure strategies to retain and infiltrate precipitation on site for new and re- developments

A.S. Category: Region-wide Adaptation Strategies: Natural Systems

A.S. Identification: RW1

Event Type: ☐ Heat Events ☒ Flooding Events

Adaptation Strategy Description

LID and green infrastructure are stormwater management strategies meant to reduce runoff and waterborne contaminants by capturing, infiltrating and filter runoff as close to its source(s) as possible. Such techniques minimize potential flooding impacts, improve water quality, improve aquatic habitat (by minimizing erosion), improve groundwater recharge, improve air quality (by reducing ground-level ozone) and provide for and preserve open space and wildlife habitat. Examples of LID and green infrastructure include retention and detention basins (SW1), bioretention ponds, bioswales and rain gardens (SW3), pervious pavements (SW4), and tree planting (SW5). When applied region-wide to development and redevelopment, the benefits are compounded, and entire watersheds and communities are better protected.

Project Stage: ☒ Policy ☐ Design ☐ O&M

Parties Responsible for Implementation:

☒ County ☒ NJTPA ☐ NJTRANSIT ☐ NJDOT ☐ Emergency Management

☐ Other: _____

Project Timeframe: ☐ < 1 year ☒ 1-5 years ☐ < 5 years ☐ 5-10 years ☐ > 10 years

Project Cost: ☒ $ ☐ $$ ☐ $$$ ☐ $$$$

Technical, Implementation, and Financial Considerations:

It is recommended that local municipalities' comprehensive plans, zoning and floodplain management ordinances and other regulations and policies be reviewed and/or revised to encourage and allow for LID and green infrastructure.

Poorly maintained green infrastructure can limit its function and asset owners will need to provide the appropriate O&M resources and funding.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Require low impact development (LID) and green infrastructure strategies to retain and infiltrate precipitation on site for new and re- developments

A.S. Category: Region-wide Adaptation Strategies: Natural Systems

A.S. Identification: RW1

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

U.S. Environmental Protection Agency (EPA). September 2015. *Benefits of Low Impact Development: How LID Can Protect Your Community's Resources.* LID Barrier Busters Fact Sheet Series. Accessed: https://www.epa.gov/sites/production/files/2015-09/documents/bbfs1benefits.pdf.

EPA. September 2015. *Terminology of Low Impact Development: Distinguishing LID from other Techniques that Address Community Growth Issues.* LID Barrier Busters Fact Sheet Series. Accessed: https://www.epa.gov/sites/production/files/2015-09/documents/bbfs2terms.pdf.

New Jersey Department of Environmental Protection. February 2004. *NJ Stormwater Best Management Practices Manual. "Chapter 2: Low Impact Development Techniques."* Accessed: https://www.njstormwater.org/bmp_manual/NJ_SWBMP_2%20print.pdf.

Preserve and enhance the tree canopy to reduce urban heat island effects and reduce emissions from cooling loads

A.S. Category: Region-wide Adaptation Strategies: Natural Systems
A.S. Identification: RW2

Event Type: [X] Heat Events [ ] Flooding Events

Adaptation Strategy Description

This strategy would involve the preservation and enhancement of existing tree canopies throughout the region. Trees are used to provide shade for assets and people and can reduce the ambient air temperatures through evapotranspiration (HR6) by as much as 6° F. Thus, when the tree canopy is increased, the energy used for cooling is reduced. In addition, trees can help mitigate flooding (SW5) and improve air quality by absorbing and intercepting precipitation and removing air pollutants, respectively.

Project Stage: [X] Policy [ ] Design [ ] O&M

Parties Responsible for Implementation: [X] County [X] NJTPA [ ] NJTRANSIT [ ] NJDOT [ ] Emergency Management [ ] Other: _____

Project Timeframe: [ ] < 1 year [X] 1-5 years [ ] < 5 years [ ] 5-10 years [ ] > 10 years

Project Cost: [X] $ [ ] $$ [ ] $$$ [ ] $$$$

Technical, Implementation, and Financial Considerations:

This strategy could require increased maintenance and higher costs associated with clearing branches, so that limbs do not fall onto overhead lines or in rights-of-way. If trees are not properly spaced and trimmed, safety issues may arise. Thus, trees would need to be planted in areas where they would not interfere with the functions of the transportation assets, including when downed by storm events. It is recommended that local municipalities' account for these considerations in their comprehensive plans, zoning and floodplain management ordinances and other regulations and policies.

Preserve and enhance the tree canopy to reduce urban heat island effects and reduce emissions from cooling loads

A.S. Category: Region-wide Adaptation Strategies: Natural Systems
A.S. Identification: RW2

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Pandit, Ram and David N. Laband. 2010. "Energy savings from tree shade." *Ecological Economics 69.* pp1324-1329. Accessed: https://www.auburn.edu/academic/forestry_wildlife/forest_policy_ctr/documents/energy-savings-ecol-econ.pdf.

U.S. Department of Energy. "Landscaping for Shade." Accessed: https://www.energy.gov/energysaver/landscaping-energy-efficient-homes/landscaping-shade.

Protect, expand, and restore natural systems and vegetative buffers along inland waterways

A.S. Category: Region-wide Adaptation Strategies: Natural Systems
A.S. Identification: RW3

Event Type: ☐ Heat Events ☒ Flooding Events

Adaptation Strategy Description

Natural systems (such as wetlands [FP9]) and vegetative buffers (FD5) along inland waterways can provide a defense against extreme weather and flooding events. They intercept and slowly release stormwater, minimizing flooding impacts. They also absorb and/or filter out pollutants, stabilizes stream and river banks, control for erosion, and provide open space and wildlife habitat. This strategy would help protect, expand and restore these natural systems and buffers region-wide, enabling the preservation and restoration of entire watersheds.

Project Stage: ☒ Policy ☐ Design ☐ O&M

Parties Responsible for Implementation:
☒ County ☒ NJTPA ☐ NJTRANSIT ☐ NJDOT ☐ Emergency Management
☐ Other: _____

Project Timeframe: ☐ < 1 year ☒ 1-5 years ☐ < 5 years ☐ 5-10 years ☐ > 10 years

Project Cost: ☒ $ ☐ $$ ☐ $$$ ☐ $$$$

Technical, Implementation, and Financial Considerations:

These natural systems and buffer areas may be regulated by various federal, state or local governments and agencies and would require coordination between them. The expansion of these natural systems would be difficult in regions where area is limited. The protection and restoration of these systems and areas is recommended as a first step prior to expansion.

Protect, expand, and restore natural systems and vegetative buffers along inland waterways

A.S. Category: Region-wide Adaptation Strategies: Natural Systems
A.S. Identification: RW3

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

NC Cooperative Extension - Backyard Stream Repair Program Team. 2015. *Small-scale Solutions to Eroding Streambanks* . Accessed: https://www.ncforestservice.gov/publications/BYSRGuide2015.pdf.

U.S. Environmental Protection Agency (EPA). "Why are Wetlands Important?" Accessed: https://www.epa.gov/wetlands/why-are-wetlands-important.

EPA. "Principles of Wetland Restoration." Accessed: https://www.epa.gov/wetlands/principles-wetland-restoration.

Develop relocation, retreat, and/or evacuation plans

A.S. Category: Region-wide Adaptation Strategies: Community Development
A.S. Identification: RW4

Event Type: [ ] Heat Events [X] Flooding Events

Adaptation Strategy Description

Relocation, retreat, and evacuation plans offer proactive guidance how to manage and implement these activities. Relocation refers to moving structures and assets outside of floodprone areas. Retreat plans would outline methods to ensure that there is a buffer between development and vulnerable areas. Such methods could include establishing setback provisions and other development restrictions and instituting a buyout program to acquire private properties within vulnerable areas. Evacuation plans would present the evacuation route and procedures to be followed during a community-wide emergency.

Project Stage: [X] Policy [ ] Design [ ] O&M

Parties Responsible for Implementation:
[X] County [X] NJTPA [ ] NJTRANSIT [ ] NJDOT [X] Emergency Management
[ ] Other: _____

Project Timeframe: [ ] < 1 year [ ] 1-5 years [X] < 5 years [ ] 5-10 years [ ] > 10 years

Project Cost: [X] $ [ ] $$ [ ] $$$ [ ] $$$$

Technical, Implementation, and Financial Considerations:

Relocation, retreat, and evacuation plans would require a robust public engagement and outreach strategy throughout their development and implementation. Dissemination of an evacuation plan is of particular importance.

This strategy could be incorporated into the State's and/or local community's existing Hazard Mitigation Plan.

Develop relocation, retreat, and/or evacuation plans

A.S. Category: Region-wide Adaptation Strategies: Community Development
A.S. Identification: RW4

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [ ] Improve water quality
- [ ] Improve air quality
- [ ] Improve or create green space
- [ ] Improve aesthetic and visual qualities
- [ ] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [ ] Contribute to Smart Growth initiatives

References:

Siders, Anne. October 2013. *Managed Coastal Retreat: A Legal Handbook on Shifting Development Away from Vulnerable Areas.* Columbia Law School, Center for Climate Change Law. Accessed: http://columbiaclimatelaw.com/files/2016/11/Siders-2013-10-Managed-Coastal-Retreat.pdf.

Limit or prohibit development in floodplains to protect life, property, and floodplain function

A.S. Category: Region-wide Adaptation Strategies: Community Development
A.S. Identification: RW5

Event Type: ☐ Heat Events ☒ Flooding Events

Adaptation Strategy Description

Floodplains are essential components of the natural environment. They decrease the volume and velocity of floodwaters by infiltrating and temporarily storing water, thereby slowing its release. This process reduces erosion and allows for groundwater recharge. In addition, floodplains provide rich wildlife habitat, as well as energy and nutrients. However, development within a floodplain can limit and prevent its natural functions. As a result, a community is less protected from flooding impacts.

This strategy would allow the floodplain to retain its function by limiting or prohibiting any future development within the floodplain.

Project Stage: ☒ Policy ☐ Design ☐ O&M

Parties Responsible for Implementation:
☒ County ☒ NJTPA ☐ NJTRANSIT ☐ NJDOT ☐ Emergency Management
☐ Other: _____

Project Timeframe: ☐ < 1 year ☒ 1-5 years ☐ < 5 years ☐ 5-10 years ☐ > 10 years

Project Cost: ☒ $ ☐ $$ ☐ $$$ ☐ $$$$

Technical, Implementation, and Financial Considerations:

Variations of this strategy are implemented in areas that enact a floodplain management ordinance in accordance to the Federal Emergency Management Agency's (FEMA's) National Flood Insurance Program (NFIP). However, limiting or prohibiting development within the floodplain could face opposing political pressures, especially in densely populated areas.

Limit or prohibit development in floodplains to protect life, property, and floodplain function

A.S. Category: Region-wide Adaptation Strategies: Community Development
A.S. Identification: RW5

Project Co-Benefits:

- [ ] Reduce greenhouse gas emissions
- [X] Improve water quality
- [ ] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [X] Improve safety and reduce potential loss of life in community
- [X] Reduce loss of property and reduce substantial damage
- [X] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Federal Emergency Management Agency. "Benefits of Natural Floodplains." Accessed: https://www.fema.gov/benefits-natural-floodplains.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Encourage "Smart Growth" approaches and "Complete Streets" principles to counter suburban sprawl, decrease energy use, reduce parking demand, reduce emissions, and promote resilience; such as walkable, livable, compact development

A.S. Category: Region-wide Adaptation Strategies: Community Development

A.S. Identification: RW6

Event Type: [X] Heat Events [X] Flooding Events

Adaptation Strategy Description

This strategy would use a more land-efficient approach to growth and would limit or reduce a community's footprint. Smart Growth and Complete Streets approaches or strategies include encouraging denser and more walkable communities comprised of mixed uses (commercial, residential, office, entertainment and public space) and clustered together to reduce the extent of infrastructure (roads and utilities). This pattern of land use encourages people to live closer to where they work, to utilize non-motorized forms of travel, and to have reduced reliance on use of single-occupant autos. The combination of reduced travel demand, less parking demand, and more compact and vertical construction, all result in the construction of substantially less impervious surfacing (roofs, parking lots, streets, etc.) and thereby results in considerably less stormwater runoff and flooding. Implementation of this strategy often includes development of green infrastructure (which creates more permeable space) and planting of native vegetation and trees (which capture air and waterborne pollutants, as well as decrease the ambient air temperature).

Project Stage: [X] Policy [ ] Design [ ] O&M

Parties Responsible for Implementation:

[X] County [X] NJTPA [ ] NJTRANSIT [ ] NJDOT [ ] Emergency Management

[ ] Other: _____

Project Timeframe: [ ] < 1 year [X] 1-5 years [ ] < 5 years [ ] 5-10 years [ ] > 10 years

Project Cost: [X] $ [ ] $$ [ ] $$$ [ ] $$$$

Technical, Implementation, and Financial Considerations:

The implementation of this strategy would require coordination between various local, regional and state agencies.

Encourage "Smart Growth" approaches and "Complete Streets" principles to counter suburban sprawl, decrease energy use, reduce parking demand, reduce emissions, and promote resilience; such as walkable, livable, compact development

A.S. Category: Region-wide Adaptation Strategies: Community Development
A.S. Identification: RW6

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Smart Growth America. "What is smart growth?" Accessed: https://smartgrowthamerica.org/our-vision/what-is-smart-growth/.

U.S. Department of Transportation. "Complete Streets." Accessed: https://www.transportation.gov/mission/health/complete-streets.

North Jersey Transportation Planning Authority

Adaptation Strategies for Vulnerable Assets in the Passaic River Basin

Promote Transit-Oriented Development (TOD), including compact, mixed-use development and affordable housing within walkable, multimodal, “Complete Streets"

A.S. Category: Region-wide Adaptation Strategies: Community Development

A.S. Identification: RW7

Event Type: [X] Heat Events [X] Flooding Events

Adaptation Strategy Description

This strategy would limit or reduce the footprint of a community by encouraging development to be centralized around a transportation hub. TOD strategies include encouraging denser and more walkable communities comprised of mixed uses (commercial, residential, office, entertainment, and public spaces) and clustered together around transit stations to reduce the extent of infrastructure (transit networks, roads and utilities). This pattern of land use encourages people to live closer to where they work, to utilize transit and non-motorized forms of travel for most of their trips, and to have reduced reliance on use of single-occupant autos. The combination of reduced travel demand, less parking demand, and more compact and vertical construction, all result in the construction of substantially less impervious surfacing (roofs, parking lots, streets, etc.) and thereby results in considerably less stormwater runoff and flooding. Implementation of this strategy often includes development of green infrastructure (which creates more permeable space) and planting of native vegetation and trees (which capture air and waterborne pollutants, as well as decrease the ambient air temperature).

Project Stage: [X] Policy [ ] Design [ ] O&M

Parties Responsible for Implementation:

[X] County [X] NJTPA [ ] NJTRANSIT [ ] NJDOT [ ] Emergency Management

[ ] Other: _____

Project Timeframe: [ ] < 1 year [X] 1-5 years [ ] < 5 years [ ] 5-10 years [ ] > 10 years

Project Cost: [X] $ [X] $$ [ ] $$$ [ ] $$$$

Technical, Implementation, and Financial Considerations:

The implementation of this strategy would require coordination between various agencies. Both TOD and Complete Streets can be applied to existing communities and infrastructure.

Promote Transit-Oriented Development (TOD), including compact, mixed-use development and affordable housing within walkable, multimodal, “Complete Streets"

A.S. Category: Region-wide Adaptation Strategies: Community Development

A.S. Identification: RW7

Project Co-Benefits:

- [X] Reduce greenhouse gas emissions
- [X] Improve water quality
- [X] Improve air quality
- [X] Improve or create green space
- [X] Improve aesthetic and visual qualities
- [X] Improve localized ecosystem
- [ ] Improve safety and reduce potential loss of life in community
- [ ] Reduce loss of property and reduce substantial damage
- [ ] Reduce negative business impacts from disruptions in service
- [ ] Maintain cultural resource
- [ ] Contribute to renewable energy initiatives
- [X] Contribute to Smart Growth initiatives

References:

Federal Transit Administration. "Transit-Oriented Development." Accessed: https://www.transit.dot.gov/TOD.

Research and incorporate emerging technologies in design policies and standards

A.S. Category: Region-wide Adaptation Strategies: Technology
A.S. Identification: RW8

Event Type: [X] Heat Events [X] Flooding Events

Adaptation Strategy Description

New innovative technologies to reduce the impacts of extreme heat and flooding events are constantly being researched and developed. This strategy would encourage the research and use of these new technologies for various assets by incorporating them in design policies and standards.

Project Stage: [X] Policy [X] Design [ ] O&M

Parties Responsible for Implementation: [X] County [X] NJTPA [ ] NJTRANSIT [ ] NJDOT [ ] Emergency Management [ ] Other: _____

Project Timeframe: [ ] < 1 year [ ] 1-5 years [ ] < 5 years [X] 5-10 years [ ] > 10 years

Project Cost: [X] $ [ ] $$ [ ] $$$ [ ] $$$$

Technical, Implementation, and Financial Considerations:

It should be noted that newly developed technologies may not have enough research on any co-impacts or effectiveness and should be used with discretion.

Research and incorporate emerging technologies in design policies and standards

A.S. Category: Region-wide Adaptation Strategies: Technology
A.S. Identification: RW8

Project Co-Benefits:

- ☐ Reduce greenhouse gas emissions
- ☐ Improve water quality
- ☐ Improve air quality
- ☐ Improve or create green space
- ☐ Improve aesthetic and visual qualities
- ☐ Improve localized ecosystem
- ☐ Improve safety and reduce potential loss of life in community
- ☐ Reduce loss of property and reduce substantial damage
- ☐ Reduce negative business impacts from disruptions in service
- ☐ Maintain cultural resource
- ☐ Contribute to renewable energy initiatives
- ☐ Contribute to Smart Growth initiatives

References: