NEC FUTURE

TIER 1 FINAL ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1 (PREFERRED ALTERNATIVE)

7.15 Climate Change and Adaptation

7.15 CLIMATE CHANGE AND ADAPTATION

7.15.1 Introduction

This chapter focuses on the effects of climate change on rail infrastructure associated with the Preferred Alternative.

The climate change analysis uses the same effects-assessment methodology and relies on the information presented in the Tier 1 Draft Environmental Impact Statement (Tier 1 Draft EIS) (see Volume 2, Chapter 7.15 and Appendix E.15). As described in Volume 2, Chapter 7.15, the Federal Railroad Administration (FRA) conducted analysis that identifies areas of the existing and proposed rail infrastructure that may be vulnerable to the effects of climate change, since it is important to recognize potential risk at this stage in order to design and implement appropriate adaptation and resiliency measures to address and reduce vulnerability. These analyses include sea level rise and storm surge, increased storm frequency and severity, and more-frequent and severe extreme heat and cold events. The FRA considered two future climate scenarios:

> **Climate Change and Adaptation**
>
> - Identifies areas at highest risk from inundation from sea level rise, storm surge flooding, and riverine flooding within counties with existing and proposed infrastructure.
> - Discusses resiliency benefits of new segments proposed by the Preferred Alternative.

- Near-term (mid-century) scenario equivalent to a 30- to 50-year horizon (e.g., 2040–2060), using a sea level rise projection of 1 foot (12 inches)
- Long-term (end-of-century) scenario equivalent to a 50- to 100-year horizon (e.g., 2075–2100+), using a sea level rise projection of 6 feet (72 inches)

The FRA used this multi-scenario approach to analyze different levels of climate change–related effects that encompass the range of sea level rise projections and forecast timeframes used by researchers and regulatory agencies in the Northeast.

This chapter also considers the mitigating effects of the Preferred Alternative on energy usage (presented in Chapter 7.14, Energy) and on greenhouse gases (GHG) emissions (presented in Chapter 7.13, Air Quality). GHG emissions are a key contributor to the changing global climate, which influences the frequency and intensity of storms, rising sea levels, heat waves, and cold snaps. GHG emissions are expected to decrease due to predicted shifts in mode choice from personal vehicle, bus, and aircraft to passenger rail and greater renewable energy usage.

The FRA reviewed and incorporated themes of climate change policies from various government agencies along the Northeast Corridor (NEC) and from the U.S. Department of Transportation's (U.S. DOT) 2014 Climate Adaptation Plan. Following the U.S. Environmental Protection Agency's climate change description, this analysis considered the impacts of sea level rise flooding, storm surge flooding, riverine flooding and extreme heat and cold events on rail assets associated with the Existing NEC + Hartford/Springfield Line and the Preferred Alternative. (Refer to Volume 2, Chapter 7.15, for further details on the NEC FUTURE climate change analysis.)

Limitations

The assessment of climate change effects aims to identify potential risks from climate change on the Preferred Alternative, based on the use of existing and readily available data and information that are consistent across the Study Area. This assessment estimated the change in flood hazard areas, but did not undertake flood modeling to develop new inundation maps for future climate scenarios for all counties within the Study Area.

When assessing risks associated with climate change, the FRA limited its assessment as follows:

- Site-specific modeling of inundation and flood risks was not conducted.
- Two sea level rise scenarios (1 foot and 6 feet) were applied consistently across the Study Area. This approach does not account for potential regional variation of projected sea level rise or land subsidence.
- There is potential overlap in the results of the coastal storm surge assessment and the riverine flooding assessment, since the riverine flooding assessment was based on the data used in the floodplain analysis, which includes both riverine and coastal floodplains.
- The projected changes in riverine flooding are based on the FIMA and FEMA 2013 Study.[1] This study considered changes in climate conditions and estimated percentage changes in flood hazard areas across the United States. The FRA applied the percentage increases in riverine flood hazard area for only the Affected Environment. A limitation to the approach used in this assessment is that if a county has zero acres at risk of inundation from riverine flooding under current climate conditions, it was estimated that they will also have zero acres at risk under mid- and end-of-century climate conditions. (For example, a 20 percent increase on zero acres equals zero acres).
- To avoid making false assumptions, the assessment of flood risk for mid-century and end-of-century scenarios assumes that no adaptation actions would be taken at a regional level. Adaptation actions may alter the flood risk or lessen the impacts of climate change on infrastructure along the Preferred Alternative. This assessment also did not consider vulnerability-reducing adaptation measures and design considerations that would be a part of the Preferred Alternative. As such, the risk of flooding to the Preferred Alternative is potentially lower than what is presented in this report. It is expected that as planning for the Preferred Alternative progresses, adaptation measures and design considerations will address areas of vulnerability identified through this analyses.
- For each climate impact category associated with flooding, the assessment focuses on identifying the spatial extent of inundation; the analysis does not consider the elevation of existing and future assets, but rather assumes there is potential for those assets within a flood hazard area to be inundated. In reality, if a rail asset were built at or above elevation or with

[1] Federal Insurance and Mitigation Administration (FIMA) & Federal Emergency Management Agency (FEMA). (2013). *The Impact of Climate Change and Population Growth on the National Flood Insurance Program through 2100*. *http://www.nfrmp.us/frmpw/2013webinarweek/docs/E3%20Coastal%20Climate%20Change/E3_FEMA_MarkCrowell_climate_change3.pdf*

other engineering features that would "harden" it to flooding, the asset may not be inundated during a flood event.

- The FRA conducted the assessment of GHG emissions as part of the Air Quality effects assessment. Chapter 7.13, Air Quality, discusses the process, findings, and limitations of the analysis of GHG emissions.

Refer to Volume 2, Appendix E.15, for further discussion regarding the limitations of the climate change analysis.

7.15.2 Resource Overview

Increases in GHG emissions contribute to changes in the global climate and weather events, which can lead to flooding, storm surges, and extreme heat and cold. As the climate continues to change, more-intense and more-frequent storms, rising sea levels, heat waves, and cold snaps[2] will worsen existing weather-related rail problems and create new hazards for rail asset owners and operators. Volume 2, Chapter 7.15, contains further details on types of hazards and their effects on rail assets. This analysis shows that some of the rail assets associated with the Existing NEC and those affiliated with the Preferred Alternative are in areas currently vulnerable to climate change effects, and that the risks increase over the mid-century and end-of-century.

The following are key findings of this analysis:

- **Benefits:**
  - Under the Preferred Alternative, analysis indicates there would be a net total decrease in GHG emissions in the year 2040. This decrease is due to predicted shifts in mode choice from personal vehicle, bus, and aircraft to passenger rail and predicted changes in greater renewable energy usage. Rail represents a mode choice that has lower GHG emissions when compared to auto or air. Mode shift is a result of improved services provided by the Preferred Alternative.
  - The Preferred Alternative would afford an opportunity to build and design new or modified rail assets in such a way that adaptation measures would be included to reduce inundation effects. Resiliency would also improve along the NEC with the implementation of adaptation measures as well as updates to a state of good repair.
  - Resiliency of passenger rail travel is increased most in areas where the Preferred Alternative proposes new or improved rail infrastructure inland, farther away from the Atlantic coastline, resulting in fewer acres at risk of inundation from sea level rise flooding and storm surge flooding.
  - The Preferred Alternative is forward thinking. Looking at the change in overall percentage of at-risk acreage between current and mid-century climate conditions, the risk of storm surge

[2] Climate Change Impacts in the United States. Retrieved August 15, 2014, from *http://www.globalchange.gov/browse/reports/global-climate-change-impacts-united-states;* and Transportation Research Board. (2008). Special Report 290: Potential Impacts of Climate Change on U.S. Transportation. National Research Council. Committee on Climate Change and U.S. Transportation. Washington, D.C.: Transportation Research Board. Retrieved 2014 from *http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf*

and sea level rise flooding within the Affected Environment of the Preferred Alternative would increase at a slower rate than for the Existing NEC. Similarly, from mid-century to end-of-century climate conditions, the risk of storm surge flooding within the Affected Environment of the Preferred Alternative would increase at a slower rate than for the Existing NEC. This slower rate is likely due to the following features of the Preferred Alternative:

- Incorporation of more construction types that are less vulnerable (aerial, embankment, major bridge and tunnel) than the construction types on the existing NEC
- Adoption of new segments, thereby increasing redundancy
- Incorporation of adaptation measures

- **Impacts:**
  - Along the NEC, counties within Connecticut and New Jersey are at the greatest risk of inundation.
  - Under the No Action Alternative, flooding risks, damage to assets, and disruption to services will continue to be a problem.
  - The Preferred Alternative proposes new or improved rail infrastructure in areas at risk of inundation under the current climate conditions; analysis shows that such areas currently at risk have an increased risk over future climate conditions.
  - The following counties have or are proposed to have rail assets proposed under the Preferred Alternative within areas that have the largest number of acres at risk of inundation by flooding type under current climate conditions:
    - Sea level rise: New London, CT; Harford, MD; Hudson, NJ; Philadelphia, PA; New Castle, DE; and Delaware, PA.
    - Storm surge flooding: New London, CT; New Haven, CT; New Castle, DE; Philadelphia, PA; and Hudson, NJ.
    - Riverine flooding: New London, CT; Harford, MD; New Haven, CT; Hartford, CT; and New Castle, DE.

7.15.3 Greenhouse Gas Emissions

GHG emissions are a key contributor to the changing global climate. Continued increases in global GHG emissions are projected to lead to more significant changes in extreme weather events and their associated risks to rail assets and operations. The analysis presented in Chapter 7.13, Air Quality; Chapter 7.14, Energy; and Chapter 5, Transportation, indicates that under the Preferred Alternative, there would be a net total decrease in GHG emissions in the year 2040 due to predicted shifts in mode choice as a result of implementing the Preferred Alternative and predicted changes in greater renewable energy usage.

7.15.4 Inundation Risks to Rail Infrastructure

The analysis presented in this section shows that portions of the NEC and the Preferred Alternative have some risk of inundation under current climate conditions, not taking into account elevation of asset, as discussed above. The extent of that risk increases under both the mid-century and end-of-century scenarios. The following subsections discuss the current, mid-century, and end-of-century inundation risks (sea level rise and coastal storm surge) for the Existing NEC + Hartford/Springfield Line and the Preferred Alternative. While the FRA assessed the mid-century and end-of-century riverine flood risk for the Affected Environment, because of limitations in readily available information, the FRA applied only the current climate conditions to the analysis of the Representative Route for riverine flooding (see Section 7.15.1.3).

7.15.4.1 Existing NEC + Hartford/Springfield Line

Much of the Existing NEC is along the eastern shoreline of the United States and either crosses or is adjacent to numerous streams, rivers, wetlands, and floodplains, rendering it susceptible to inundation from various sources (see Chapter 7.5, Hydrologic/Water Resources). Under current climate conditions, of the total area within the Affected Environment, 3 percent is at risk for flooding associated with sea level rise; 10 percent is at risk for flooding associated with storm surge flooding; and 20 percent is at risk for flooding associated with riverine flooding. Under the mid-century and end-of-century scenarios, the inundation risks from these sources increase. Under the end-of-century scenario, risks associated with sea level rise increase to 8 percent; increase to almost 17 percent with storm surge flooding; and increase to 33 percent with riverine flooding.

For each flooding hazard, Connecticut (Fairfield, New Haven, Middlesex, and New London Counties) contains the highest percentages of lands within the Affected Environment susceptible to each flooding hazard.

When focusing on the land encompassed by the right-of-way of the NEC—and not the broader Affected Environment—the percentage of land area within that right-of-way at risk is 1 percent (sea level rise), 8 percent (storm surge flooding), and 14 percent (riverine flooding). Under the end-of-century scenario, those flooding risks for the route of the NEC increase to approximately 6 percent (sea level rise) and 20 percent (storm surge flooding). (The FRA conducted the assessment of riverine flooding risk only for the current climate conditions.)

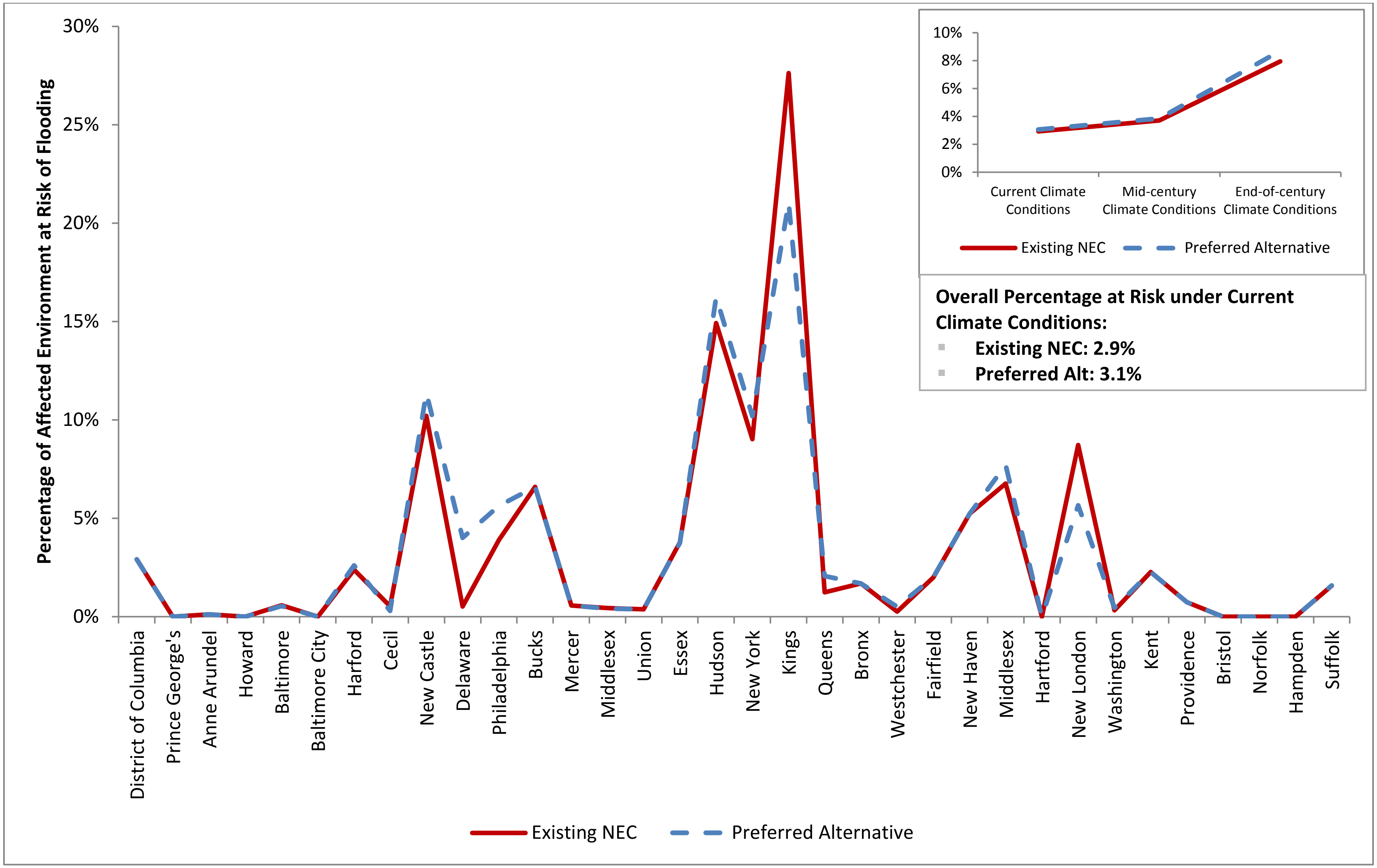
The greatest risk to the Existing Hartford/Springfield Line is from riverine flooding (25 percent) with much less risk from storm surge flooding (5 percent) and sea level rise flooding (less than 1 percent).

Figure 7.15-1 through Figure 7.15-3 show the risk profiles of each flooding hazard for each county in the Affected Environment for the current climate conditions for both the Preferred Alternative and the Existing NEC.

7.15.4.2 No Action Alternative

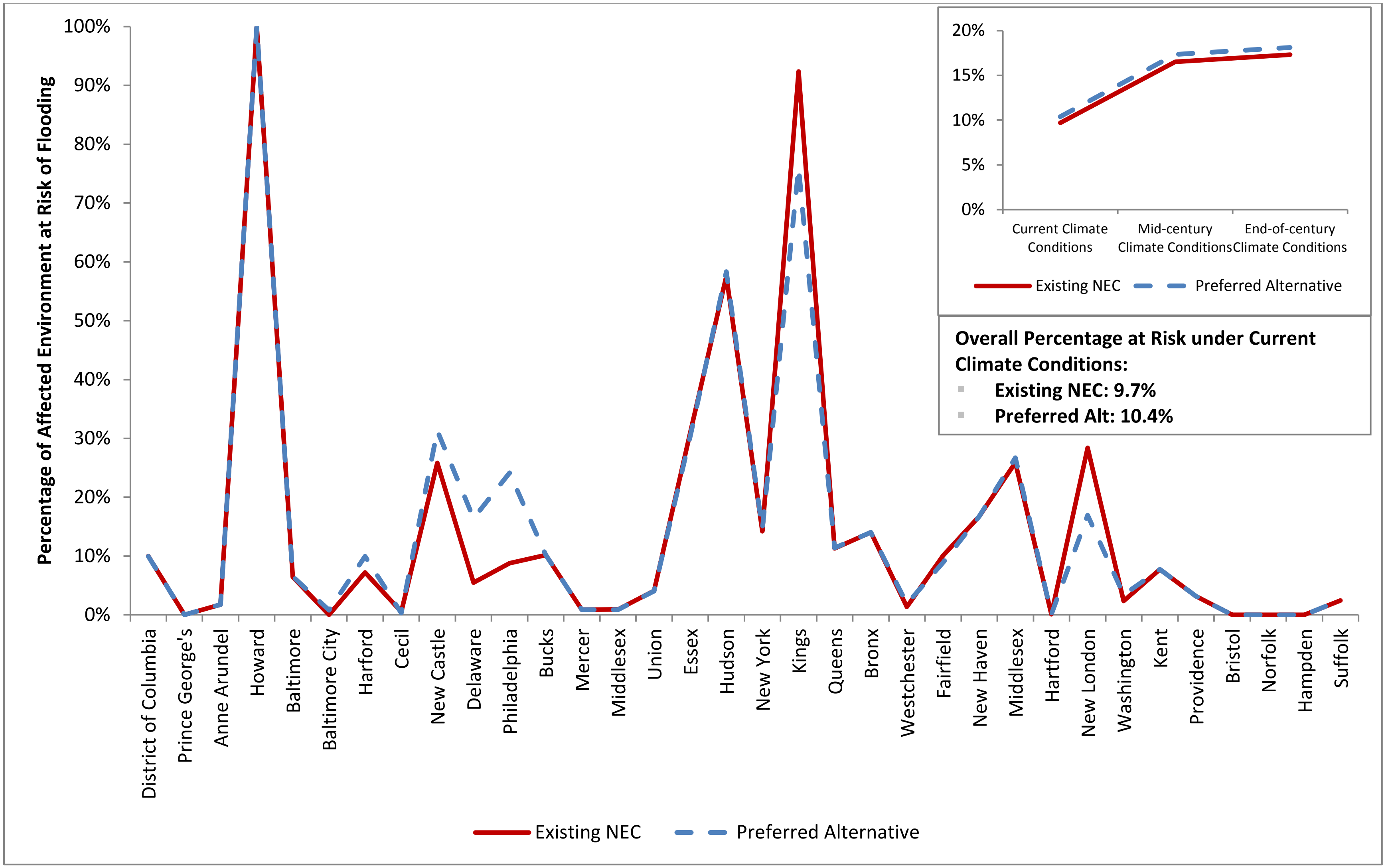
The No Action Alternative includes improvements that exist primarily along the Existing NEC + Hartford/Springfield Line. As such, the analysis presented for the Existing NEC + Hartford/Springfield Line provides a good proxy for identifying inundation risks associated with the No Action Alternative. As the climate changes, the risks associated with flooding are likely to increase, hastening the degradation of these rail assets. Without investment to provide more resilient infrastructure, repair and maintenance costs as well as disruptions to services are projected to increase under the No Action Alternative as a result of the effects of climate change.

Figure 7.15-1: Current Climate Conditions, Sea Level Rise Flooding: Affected Environment – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



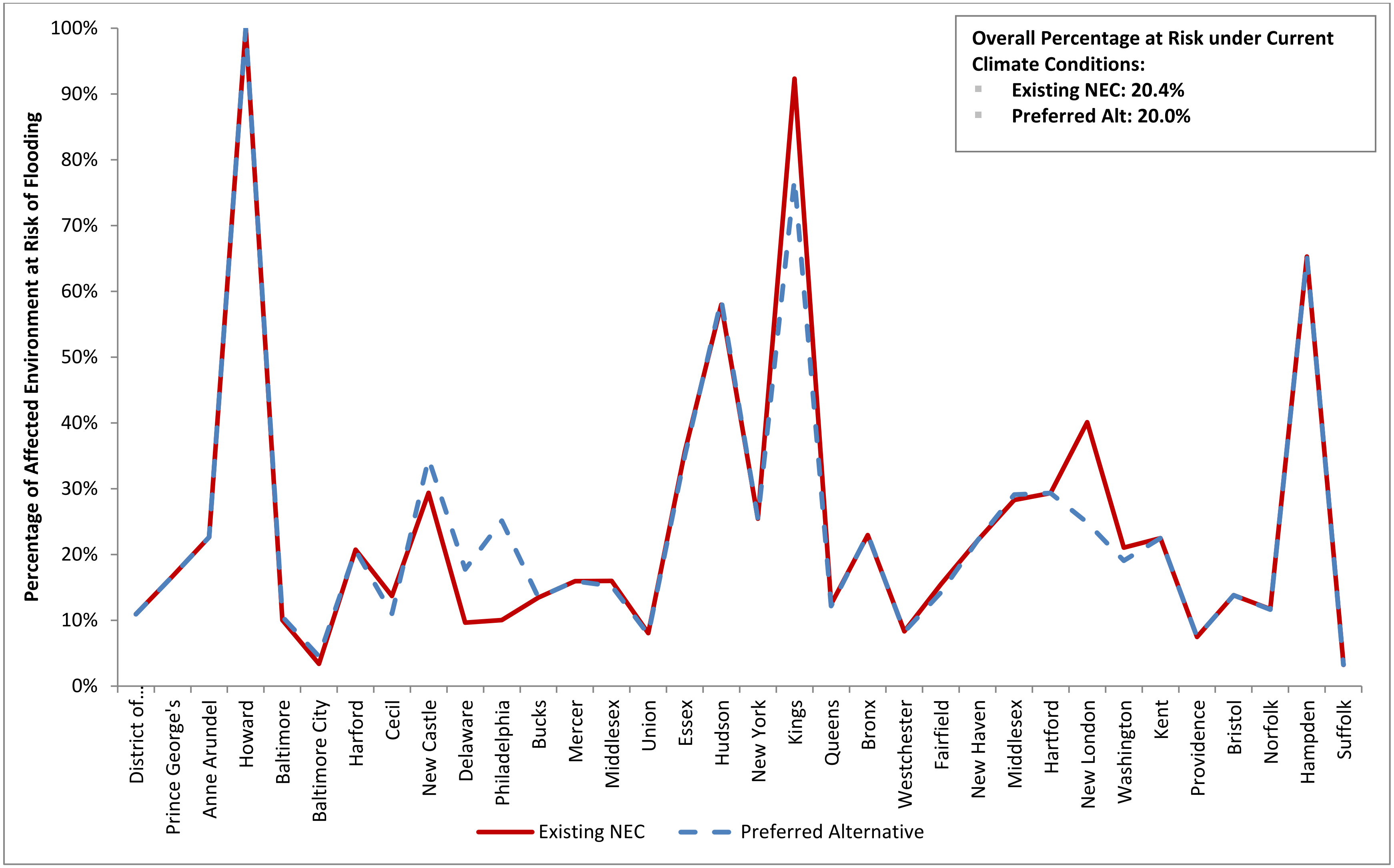
Source: NEC FUTURE team, 2016

Figure 7.15-2: Current Climate Conditions, Storm Surge Flooding: Affected Environment – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



Source: NEC FUTURE team, 2016

Figure 7.15-3: Current Climate Conditions, Riverine Flooding: Affected Environment – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



Source: NEC FUTURE team, 2016

7.15.4.3 Preferred Alternative

This analysis presents areas of inundation risks, by county, from sea level rise flooding, storm surge flooding, riverine flooding, and extreme heat and cold events for the broader Affected Environment of the Preferred Alternative and for the narrower Representative Route of the Preferred Alternative.

Affected Environment

Similar to the No Action Alternative, the rail assets included in the Preferred Alternative would be at risk from all flooding hazards under current climate conditions. Figure 7.15-1 through Figure 7.15-3 compare the percentage of the total acreage by county in the Affected Environment at risk for each flood hazard for the Existing NEC + Hartford/Springfield Line and Preferred Alternative. While the total percentage of Affected Environment at risk from flooding varies depending on the flood hazard, the Existing NEC + Hartford/Springfield Line has the highest overall percentage of acreage in the Affected Environment at risk for riverine flooding.

The percentage of the total acreage at risk in the Affected Environment of the Preferred Alternative is projected to increase for all flood hazards under the mid-century and end-of-century climate scenarios. (Refer to the graph inserts in Figure 7.15-1 through Figure 7.15-3.) For sea level rise flooding, the greatest increase in the number of acres at risk is likely to occur between mid-century and end-of-century climate conditions. For storm surge flooding, the greatest increase is likely to occur between current climate conditions and mid-century. For riverine flooding, the increase in number of acres at risk is likely to be relatively consistent between each time period; however, projection data was not available. Each flooding hazard is discussed in more detail below. Discussion of the Existing NEC is included to show relative changes in flooding hazards.

Representative Route

The percentage of the Representative Route at risk from flooding risks related to climate change is slightly higher or similar for the Preferred Alternative compared with the Existing NEC, especially under current climate conditions. While at the surface, this finding implies that the Preferred Alternative is slightly more vulnerable to flood risks considering climate change scenarios, the result is potentially misleading because the assumptions used to analyze the Preferred Alternative did not account for the adaptation measures and design considerations that would be incorporated to reduce flood vulnerability. The Preferred Alternative may still provide an advantage in improving resiliency to the impacts of climate change not only as a result of the rail asset upgrades and resilient infrastructure design considerations incorporated, but also because the Preferred Alternative improves redundancy by including new segments. By understanding these areas of vulnerability at this planning stage, the design and build stages of the Preferred Alternative can incorporate targeted resilience and adaptation measures.

Sea Level Rise Flooding

The percentage of the Representative Route at risk from sea level rise flooding in current conditions for the Existing NEC + Hartford/Springfield Line and the Preferred Alternative is 1.0 and 1.5 percent of the total acreage, respectively (Figure 7.15-4).

The total percentage of the Preferred Alternative's Representative Route at risk of sea level rise flooding is likely to increase to 1.9 percent under mid-century climate conditions and 6.8 percent under end-of-century climate conditions. The percentage of the Existing NEC + Hartford/Springfield Line at risk of sea level rise flooding would increase to 1.3 percent under mid-century climate conditions and 5.7 percent under end-of-century conditions. The Existing NEC + Hartford/Springfield Line has the lower percentage of the Representative Route at risk from sea level flooding under the current, mid-century, and end-of-century climate conditions (see insert in Figure 7.15-4).

Coastal Storm Surge Flooding

Under current climate conditions, the percentage of the Representative Route at risk from coastal storm surge flooding for the Existing NEC + Hartford/Springfield Line and the Preferred Alternative is 7.8 and 8.7 percent, respectively (Figure 7.15-5).

The total percentage of the Preferred Alternative's Representative Route at risk of coastal storm surge flooding is likely to increase to 18.7 percent under mid-century climate conditions and 19.8 percent under end-of-century climate conditions. Meanwhile, the total percentage of the Existing NEC + Hartford/Springfield Line at risk of coastal storm surge flooding would increase to 18.3 percent under mid-century climate conditions and 19.6 percent under end-of-century climate conditions.

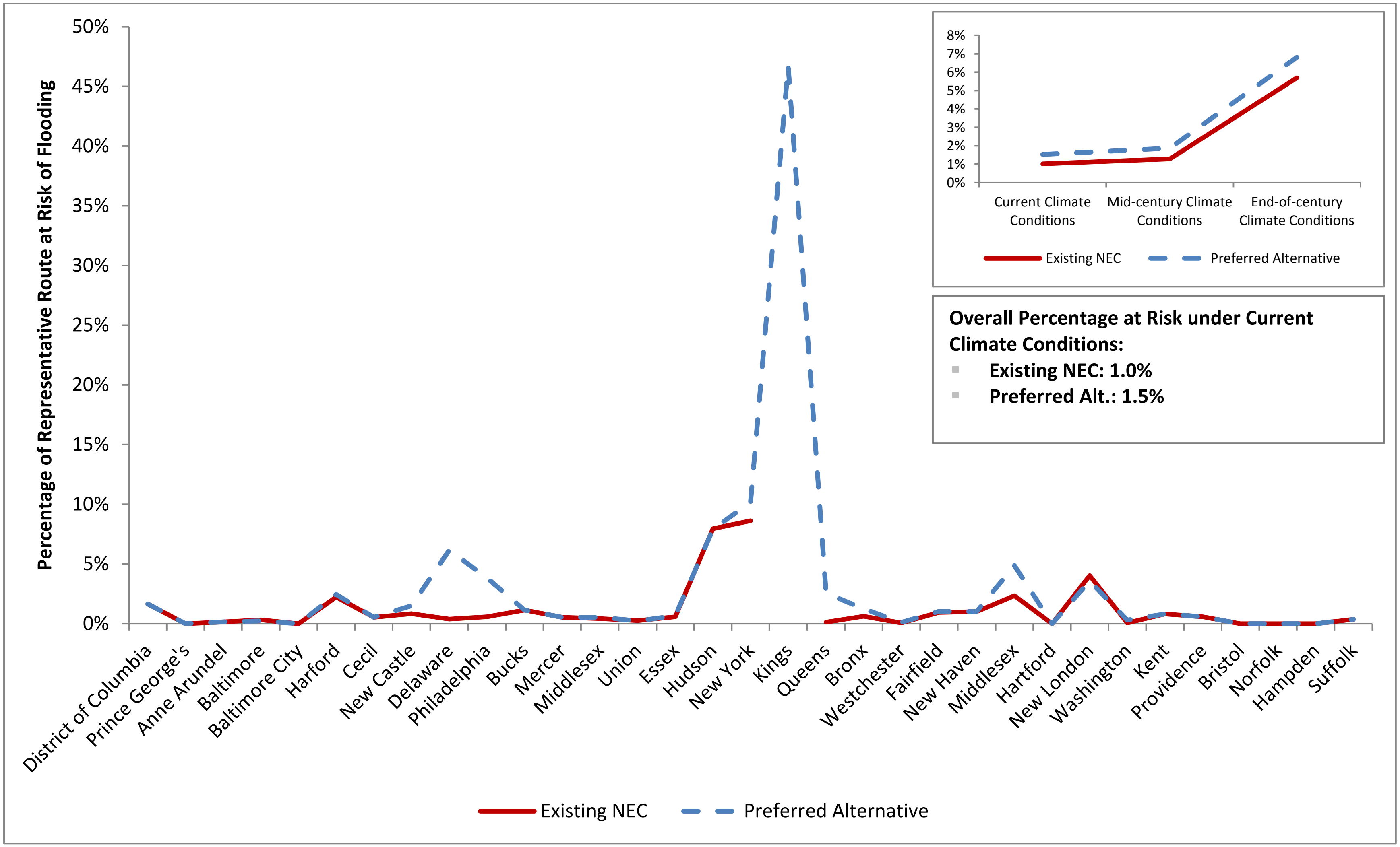
Note that in Figure 7.15-4 through Figure 7.15-6 no data is present for King's County, NY, for the Existing NEC + Hartford/Springfield Line. The reason for this absence of data is that within the Representative Route, the Existing NEC does not have any acreage or acreage at risk within Kings County, while the Preferred Alternative does have such acreage at risk for both sea level rise and storm surge flooding. Another point of note—the large percentage of acreage at risk in King's County along the Preferred Alternative is because most, if not all, of the small number of acres (4) located in the county are at risk of flooding.

Riverine Flooding

Under current climate conditions the percentage of the Representative Route at risk of riverine flooding for the Existing NEC + Hartford/Springfield Line and the Preferred Alternative is 14.2 and 13.8 percent, respectively (Figure 7.15-6).

As noted in Section 7.15.4, the FRA conducted an assessment of riverine flooding risk on the Representative Route only for the current climate conditions; however, it is likely that the total percentage of the Representative Route at risk of riverine flooding will also increase under mid-century and end-of-century climate conditions.

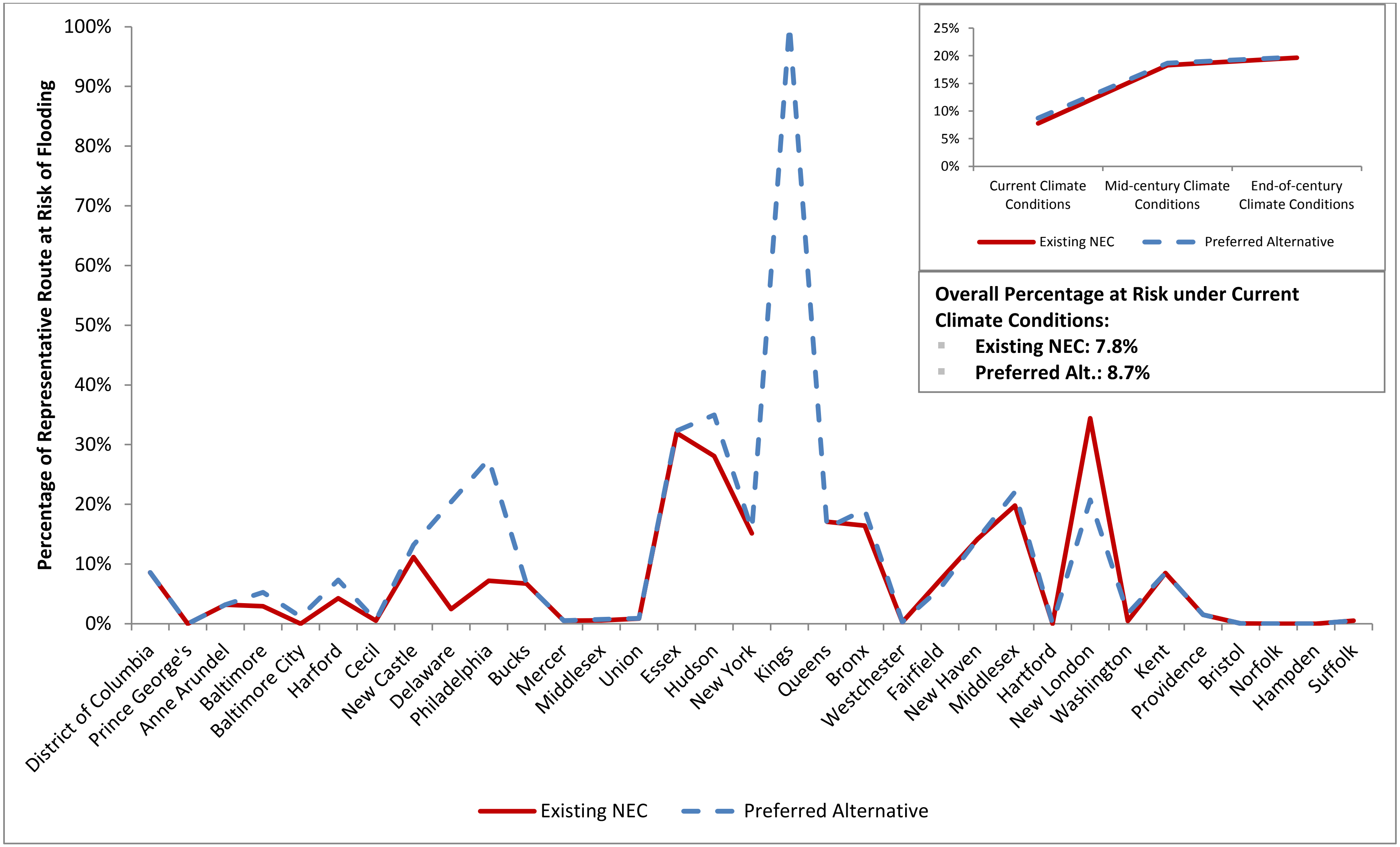
Figure 7.15-4: Current Climate Conditions, Sea Level Rise Flooding: Representative Route – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



Source: NEC FUTURE team, 2016

Note: The Existing NEC does not pass through Kings County, NY. For this reason, there is a gap in the Existing NEC line on the graph above. The Preferred Alternative does have 4 acres located in Kings County, NY, and in current climate conditions 2 of those 4 acres are at risk for sea level rise inundation, accounting for the spike seen in the graph above.

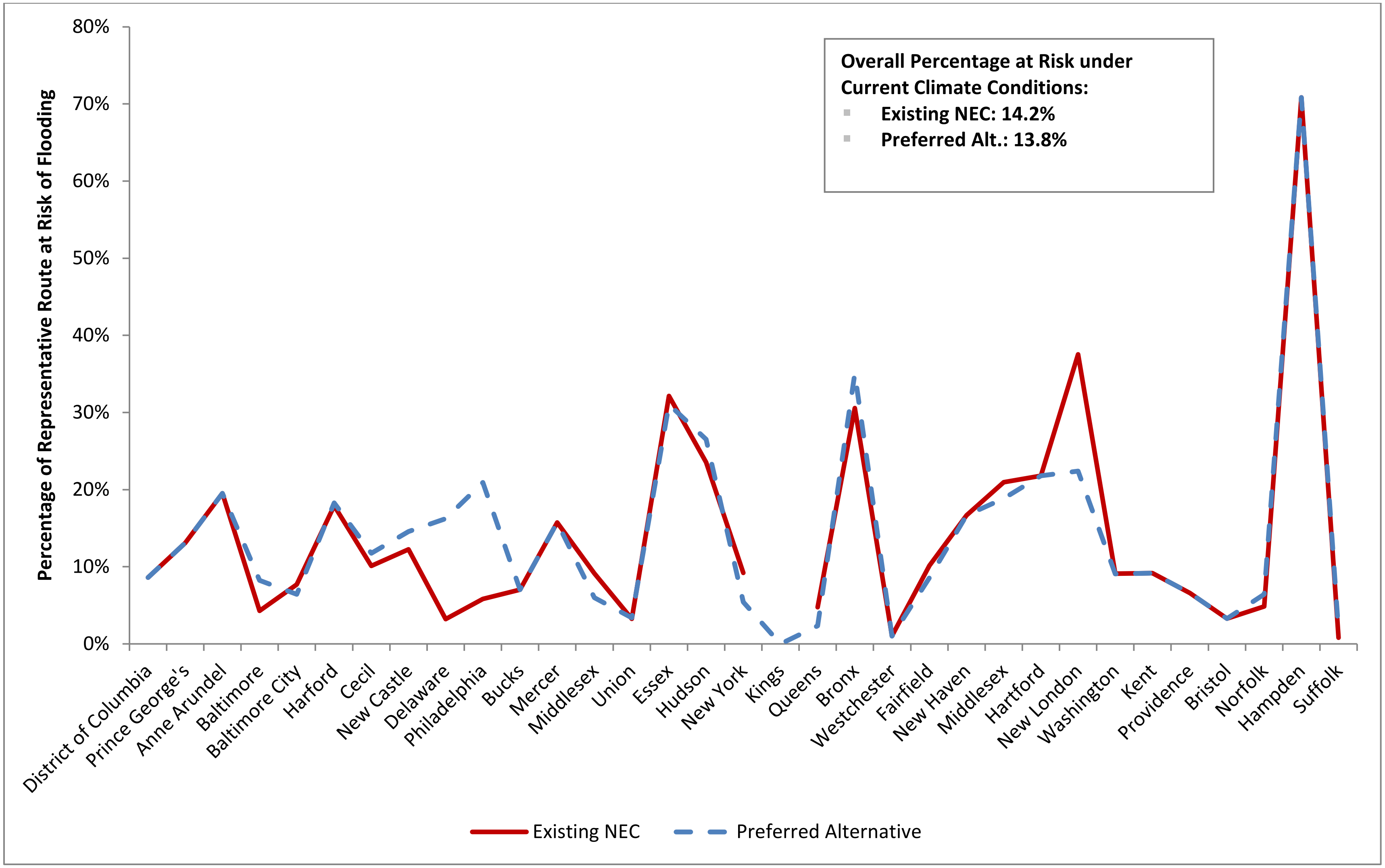
Figure 7.15-5: Current Climate Conditions, Storm Surge Flooding: Representative Route – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



Source: NEC FUTURE team, 2016

Note: The Existing NEC does not pass through Kings County, NY. For this reason, there is a gap in the Existing NEC line on the graph above. The Preferred Alternative does have 4 acres located in Kings County, NY, and in current climate conditions all 4 acres are at risk for storm surge inundation; accounting for the spike seen in the graph above.

Figure 7.15-6: Current Climate Conditions, Riverine Flooding: Representative Route – Percentage of Total County Acreage at Risk (Existing NEC + Hartford/Springfield Line and Preferred Alternative)



Source: NEC FUTURE team, 2016

Note: The riverine flooding data looks only at non-tunnel acreage; therefore, Kings County, NY, is not included in either the Existing NEC or the Preferred Alternative.

7.15.4.4 Assessment of Inundation Risk to Off-Corridor Segments of the Preferred Alternative

In Section 7.15.4.3, the analysis of inundation risk included the Existing NEC in the Preferred Alternative for the purposes of calculating the percentage of the Representative Route at risk from each flooding hazard. As a result, it was not obvious how the off-corridor segments of the Preferred Alternative would provide resilience and redundancy benefits by providing an alternate route that could assist in maintaining services if coastal or riverine inundation issues (or other hazards) affect assets along the Connecticut and Rhode Island coasts. The analysis presented in this section concentrates on the areas where off-corridor routing is proposed for the Preferred Alternative. The Preferred Alternative representative routes and construction characteristics are the basis for the analysis in the NEC FUTURE Tier 1 EIS. They illustrate necessary improvements to achieve the Preferred Alternative service and performance objectives. As part of the Tier 1 process, the FRA has determined the necessity for new segments in particular geographic sections of the NEC in order to meet the Purpose and Need, and has identified a representative route for each potential new segment. The FRA or another federal agency providing funding for a particular project will evaluate specific locations for new segments as part of the Tier 2 project studies, prior to making any decision regarding new segment locations. Resiliency benefits may change based on the final locations of new segments.

This section focuses on the acreage in the Representative Route at risk from all flooding hazards under current climate conditions along each off-corridor segment of the Preferred Alternative. The analyses highlight areas of vulnerability so adaptation measures can be taken into account as planning for NEC FUTURE progresses. As indicated in Section 7.15.4.3, the risks from each flooding hazard identified in this section are likely to increase under mid-century and end-of-century climate conditions.

Within the Representative Route, additional analysis focuses on at-grade and trench construction types since they are more sensitive to flood risk than other construction types (e.g., tunnel, aerial, embankment, and major bridge). Since these construction types are more sensitive, resilience measures would be taken into account during the design and build of these areas. While at-grade and trench construction types are the focus of the assessment, flooding impacts may still affect tunnels, embankments, and bridge construction types (for example, via scour or erosion).

Elements South of New York City

- **Maryland/Delaware – Bayview to Newport (new segment) –** This off-corridor segment of the Preferred Alternative includes the Bayview to Newport new segment between Baltimore City, MD, near Johns Hopkins University, and New Castle County, DE, near Banning Park, which primarily runs adjacent and northwest of the Existing NEC. Since this segment runs both adjacent and farther inland, it offers redundancy of service and a lower inundation risk than the Existing NEC. This new segment has only 1 percent of its Representative Route acreage at risk of sea level rise flooding, 5 percent at risk for coastal storm surge flooding, and 14 percent at risk of riverine flooding.

The Bayview to Newport segment has a small percentage of at-risk construction types vulnerable to inundation. Less than 0.5 percent is at-grade or trench construction type and at risk of storm surge, while only 1.7 percent is at-grade or trench and at risk for riverine flooding.

- **Delaware – Wilmington Segment (bypasses Wilmington Station) –** This off-corridor segment of the Preferred Alternative includes the Wilmington new segment, which begins where the Bayview to Newport new segment ends near Banning Park and runs entirely in New Castle County, DE. The segment runs south of the Existing NEC along Interstate 495 and the Delaware River until it rejoins in Edgemoor, DE. The percentage of the Representative Route at risk of inundation by sea level rise, storm surge, and riverine risks are 7 percent, 44 percent, and 44 percent respectively.

  Of the acreage at risk for storm surge flooding and riverine flooding in the Representative Route of the new segment, 20 percent is at-grade or trench construction type.

- **Pennsylvania – Philadelphia Segments (new segments) –** In Pennsylvania, new segments are proposed between Baldwin and Bridesburg. These segments of the Preferred Alternative include the Philadelphia Airport new segment between Delaware County and Philadelphia County, PA, and runs south of the Existing NEC closer to the Delaware River along Pennsylvania Route 291. The percentage of the total acreage in the Representative Route along the new segment at risk from sea level rise flooding, coastal storm surge flooding, and riverine flooding are 10 percent, 79 percent, and 79 percent, respectively.

  Considering the construction types that are most vulnerable to inundation from flooding, 32 percent of the acreage at risk is at-grade or trench. Further emphasizing the segment's resilience benefits, the new segment has less at-risk construction type acreage than the Existing NEC for both flooding types.

- **New Jersey – New Brunswick to Secaucus (new segment) –** This off-corridor segment of the Preferred Alternative includes the New Brunswick to Secaucus new segment between Middlesex County and Hudson County, NJ, and runs adjacent to the Existing NEC through Union and Essex Counties, rejoining by the Passaic River. Since this segment provides adjacent service through two counties, the redundancy of this area is greatly improved. This segment provides an alternate route for passengers, should the Existing NEC be affected by inundation or experience other disruption. The new segment has approximately 1 percent of the total acreage in this segment at risk to sea level rise flooding, 7 percent at risk for coastal storm surge flooding, and 8 percent at risk for riverine flooding.

  Considering the construction types that are most vulnerable to inundation from flooding, those at-risk of storm surge flooding account for 4.1 percent of the new segment and 5.3 percent when considering riverine flooding.

- **New Jersey – Secaucus/Bergen loop (new segment) –** This off-corridor segment of the Preferred Alternative includes the new 3-mile Secaucus/Bergen loop within Hudson County, NJ, and perpendicular to the Existing NEC at Secaucus Station, loops southeast, then northwest, before bearing northeast and running parallel to the Existing NEC for about 1.5 miles, ending just west of Secaucus Road. This segment provides redundancy in Secaucus, which, with its proximity to New York City, is a highly travelled area. The new segment has approximately 1 percent of its total acreage at risk for sea level rise flooding and 60 percent at risk for both coastal storm surge and riverine flooding. The at-risk riverine and storm surge flooding acreage reflects the new segment's close proximity to the Hackensack River.

Of the acreage at risk of storm surge flooding and riverine flooding in the Representative Route of the Bergen Loop, 33 percent relate to at-grade or trench construction type.

Elements North of New York City

- **New York/Connecticut – New Rochelle to Greens Farms (new segment)** – This off-corridor segment of the Preferred Alternative includes the New Rochelle-Greens Farms new segment between Westchester County, NY, and Fairfield County, CT, and runs southwest to the Existing NEC and adjacent to I-95. The segment diverges from the Existing NEC to stay with I-95 in Stamford, CT, crossing both Norwalk and Saugatuck Rivers ending west of the Greens Farms Station. The New Rochelle-Greens Farms new segment's Representative Route has approximately 1 percent of the total acreage in this segment at risk for sea level rise flooding, 2 percent for coastal storm surge flooding, and 4 percent at risk for riverine flooding.

  Considering the construction types that are most vulnerable to inundation from flooding, the new segment contains less than 0.5 percent at-grade or trench construction types at risk of storm surge flooding and 0.6 percent at risk for riverine flooding. As such, the majority of this new segment would have less at-risk construction types with adaptation and resiliency measures built in at places of vulnerability.

- **Connecticut/Rhode Island – Old Saybrook-Kenyon (new segment) –** This off-corridor segment of the Preferred Alternative includes the Old Saybrook-Kenyon new segment between Middlesex County, CT, and Washington County, RI. This segment is farther inland and generally parallel to the Existing NEC, offering both resiliency and redundancy to this portion of rail. The new segment has approximately 3 percent of the total acreage in this segment at risk for sea level rise flooding, 6 percent at risk for coastal storm surge flooding, and 9 percent at risk for riverine flooding. Considering the construction types that are most vulnerable to inundation from flooding, the Old-Saybrook-Kenyon segment has 0.7 percent at-grade and trench construction acreage at risk for storm surge flooding and 15.6 percent at risk for riverine flooding.

- **Connecticut/Massachusetts – Hartford/Springfield Line (upgraded track/electrification) –** This off-corridor segment of the Preferred Alternative includes the Existing Hartford/Springfield Line upgraded track between New Haven County, CT, and Hampden County, MA, which is off the Existing NEC. It follows I-91 through New Haven to Hartford County by Silver Lake, parallels the Connecticut River and eventually crosses it, then terminates in Springfield, MA. Riverine flooding is the largest risk along this corridor at 25 percent, since this corridor is not as close to the coast as many others. Also accounting for acres of at-grade and trench construction types, 4.3 percent are at risk for storm surge flooding and 24.5 percent are at risk for riverine flooding.

7.15.5 Stations at Risk

Table 7.15-1 summarizes the total number of stations along the Preferred Alternative at risk of inundation under each timeframe. Appendix EE.15, contains a detailed county-level listing of the stations at risk of inundation along the Preferred Alternative; while Volume 2, Appendix E.15, contains this information for each Action Alternative.

Riverine flooding accounts for the majority of the total number of stations at risk of inundation. Under current climate conditions along the Preferred Alternative, 38 stations would be at risk from sea level rise flooding and coastal storm surge flooding, while an additional 30 stations would be at risk of inundation when riverine flooding is considered. While the total number of stations at risk would increase under mid-century and end-of-century climate conditions, the risk profile from each flooding hazard is similar to that of the current climate conditions with riverine flooding accounting for a significant portion of the total number of stations at risk.

Table 7.15-1: Affected Environment (Current, Mid-Century, and End-of-Century Climate Conditions): Stations at Risk of Inundation from One or More Flood Hazards for Preferred Alternative

	Current	Mid-Century	End-of-Century
Total New Stations At Risk of Inundation	13	15	15
Total Existing Stations At Risk of Inundation	53	61	63
Total Modified Stations At Risk of Inundation	2	2	2
Total Number of Stations At Risk of Inundation	68	78	80

Source: NEC FUTURE team, 2016
Note: The numbers in this table represent the total number of stations at risk from one or more flood hazard.

7.15.6 Context Area

7.15.6.1 Sea Level Rise Flooding and Coastal Storm Surge Flooding

Considerable portions of the Affected Environment associated with the Existing NEC and the Preferred Alternative are already close to the coast and are at risk from sea level rise flooding and coastal storm surge flooding. Within the Context Area, any shift in the route closer to the coast would likely increase the risk of inundation from these flooding mechanisms. Conversely, shifting away from the coastline could reduce the area at risk.

7.15.6.2 Riverine Flooding

Considerable portions of the Affected Environment associated with the Existing NEC + Hartford/Springfield Line and the Preferred Alternative are already at risk from riverine flooding under current climate conditions. As the climate changes, the size of these flood hazard areas within the Context Area would likely increase.

A review of the flood hazard areas under current climate conditions identified that when compared to the Existing NEC + Hartford/Springfield Line, the Preferred Alternative route within the Context Area could lead to greater increases in flood risk in the following counties:

- Baltimore, Baltimore City, Harford, and Cecil, MD
- New Castle, DE
- Philadelphia, PA
- Middlesex, Somerset, Union, Essex, and Hudson, NJ
- New York, Kings, Queens, and Bronx, NY
- Fairfield, Middlesex, and New London, CT
- Washington, RI

The counties listed above are nearly identical with those identified as having increased riverine flooding risk in the Affected Environment of the Preferred Alternative, aside from the addition of Somerset, NJ; New York, Kings, and Queens, NY; and Suffolk, MA; and the elimination of Westchester, NY, and Norfolk, MA.

These findings are applicable to all three time periods (i.e., current climate, mid-century, and end-of-century). The number of acres at risk within the Context Area would increase as the hazard extents increase under each future scenario (e.g., with sea level rise and increases in the frequency and intensity of extreme rainfall events at mid-century and end-of-century).

7.15.7 Extreme Temperature Effects on Rail Infrastructure

The effects of climate change also extend to extreme changes in temperatures. Temperatures that are abnormally high or low can also result in effects to rail infrastructure. Exposing rail to prolonged periods of heat or cold temperatures can cause rail to crack, buckle, pull apart, or separate, resulting in service disruption and delays. The extreme temperature-related impacts to rail assets and operations include the following:

- Extreme Heat, which causes rail line buckling (also known as sun kinks or heat kinks) refers to an event when rails expand and can no longer be constrained by the materials that support the track (e.g., rail ties, and ballast; see Figure 7.15-7), overheated electrical equipment, overheated vehicles, failed air conditioning systems and threats to customer and worker health and safety.
- Extreme Cold, which causes rail line pull-aparts (refers to instances where rail lines contract, breaking or separating as a result), heavy snowfall blocking lines, ice reducing functionality of, or damaging, equipment and threats to customer and worker health and safety.

Figure 7.15-7: Example of Rail Buckle from Extreme Heat

Source: U.S. DOT Volpe Center in Federal Transit Administration. (2011). *Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation*. Retrieved 2015, from *https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_0001_-_Flooded_Bus_Barns_and_Buckled_Rails.pdf.*

Factors that influence the occurrence of pull-aparts or buckling include the temperature of the track at the time it is installed (i.e., the rail neutral temperature), the age of the track, maintenance of the track (e.g., if there has been adjustments in a prior season to accommodate heat or cold), the use of the track, solar radiation, wind, and the ambient air temperature.

Buckling is a catastrophic event that significantly increases the likelihood of derailment. However, pull-aparts are seen as a lower consequence risk event since they typically are detected through the signaling system or by train engineers, and small breaks can be driven over without causing a derailment.

7.15.7.1 Extreme Heat

Information provided by the FRA's Office of Research and Development indicates that there tend to be more buckles in the early summer, often as a result of unreported fixes of winter breaks where more track is added, which lowers the neutral temperature of the track. Slow orders (i.e., requests to operate the trains at a slower speed) are a key response to managing the impacts of extreme heat events. Slow orders minimize the likelihood of track buckling or derailment during an extreme heat event. A slow order may be for the whole day, or may be increased as the day continues.[3]

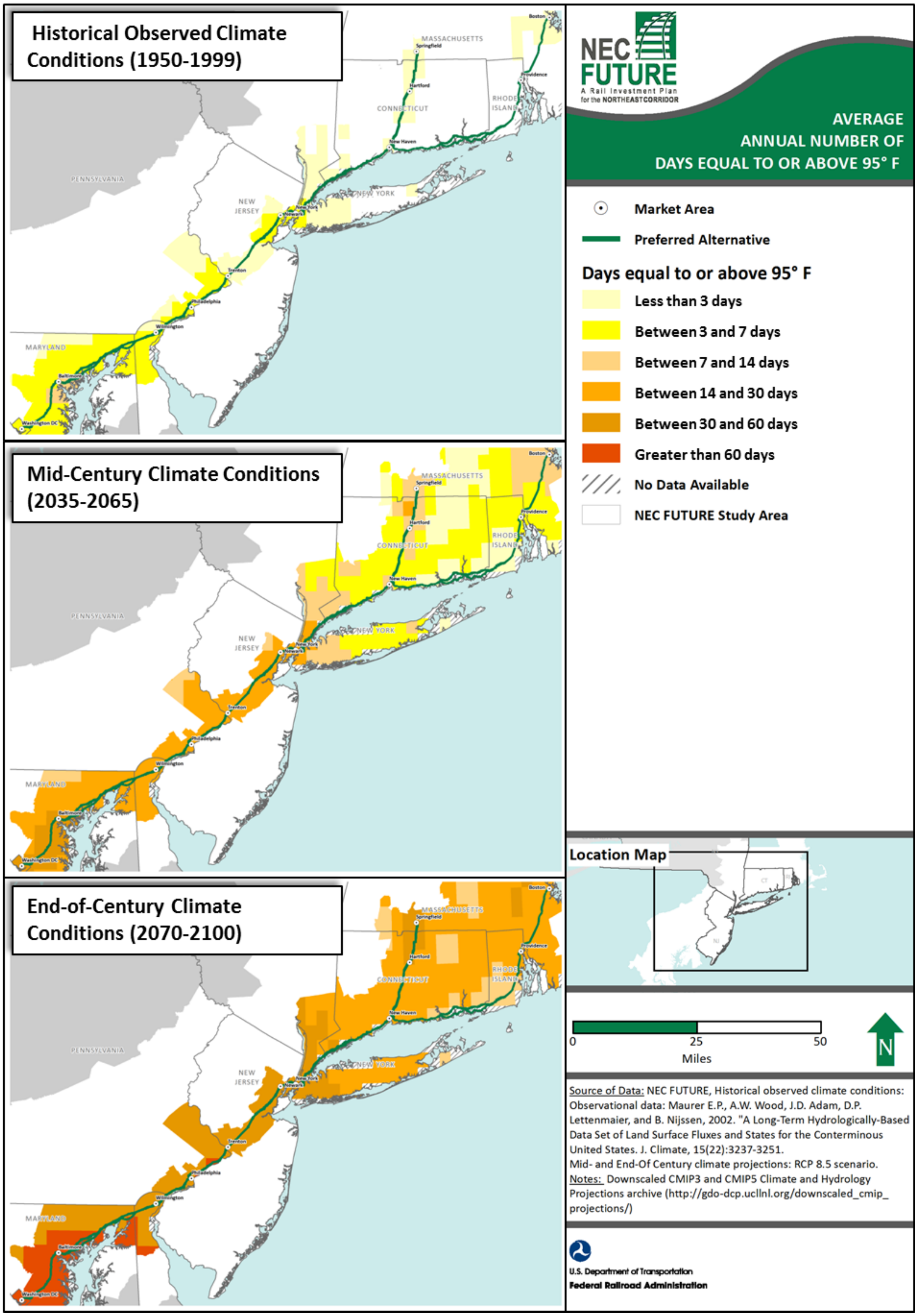
Each railroad has its own policy regarding slow orders and the relevant thresholds that trigger them:

- Union Pacific uses an empirical approach by adding an offset (e.g., 30°F) to the predicted ambient temperature and issues a slow order if the total exceeds a threshold. For example, blanket heat speed restriction Level 1 is issued at ambient temperatures of 80°F to 110°F and Level 2 at ambient temperatures of 90°F to 120°F, depending on the location.
- Amtrak uses sensors to measure the actual rail temperature to inform stages of speed reduction. Amtrak thresholds[4] are:
  - If measured rail temperature exceeds 130°F, then slow order to 100 mph.
  - If measured rail temperature exceeds 140°F, then slow order to 80 mph.

Recognizing there is a range of temperatures of interest, the FRA evaluated three temperature projections for the average number of days where the maximum temperatures exceed 80°F, 95°F, and 110°F (Figure 7.15-8) under historical average (1959–1999), mid-century, and end-of-century scenarios. State-based projections provide an average of the climate data available for grid references closest to the Preferred Alternative route, rather than an average for the entire state.

[3] Al-Nazer, L. F. (2014a, August 15). Heat Event Thresholds for Rail Performance – NEC Future EIS : Phone discussion. (N. F. Team, Interviewer)
[4] Email from Leith Al-Nezar (2014b, August 15). Washington, D.C., USA. U.S. DOT

Figure 7.15-8: Average Annual Number of Days Equal to or Above 95°F, by Climate Scenario



Source: NEC FUTURE team, 2016

All states and Washington, D.C., on average, historically experienced more than 50 days a year where the maximum temperature exceeds 80°F, with Washington, D.C., and Maryland recording more than 100 days per year. The number of days per year above 80°F is projected to increase by 36–46 days at mid-century and 58–74 days at end-of-century. While the increase in the total number of days per year above 80°F is similar across all states, the projected percentage of days per year above 80°F increases for mid-century and end-of-century are highest for New York (65 percent and 105 percent, respectively), Connecticut (79 percent and 126 percent, respectively), Rhode Island (94 percent and 151 percent, respectively), and Massachusetts (82 percent and 131 percent, respectively).

The projected increase in the number of days per year above 95°F is most dramatic for the southern-most states (Maryland, Washington, D.C., Delaware, Pennsylvania, and New Jersey). These states historically experienced 3–6 days annually above 95°F and are projected to experience a total of 18–35 days at mid-century, and 47–73 days at the end-of century. Figure 7.15-8 illustrates the projected change in days over 95°F in each state by the mid-century.

Historically (1950–1999), on average, the temperature threshold of 110°F has not been exceeded along the Preferred Alternative route. For all states, this is not projected to change at mid-century, with minimal (i.e., <0.5 day) projected at the end-of-century.

7.15.7.2 Extreme Cold

In North America, climate change is projected to result in increases in hot days and extended warm spells (i.e., heat waves), reductions in cold days, cold nights and frosts, and more rapid increases in minimum temperature extremes than maximum temperature extremes.[5] However, the frequency and duration of extreme cold events in the Northeast may be affected by potential increases in "blocking" events, described by the National Climate Assessment (NCA) as large-scale weather patterns with little or no movement.[6] The NCA acknowledges that further research is required since conclusions about trends in "blocking" depend on the method of analysis. Because of the uncertainty of the climate change–related influence on this hazard, the FRA has made no quantitative projections. Table 7.15-2 in Volume 2, Chapter 7.15, provides a qualitative listing of the potential effects of extreme cold events (including effects of snow and ice) on rail assets.

7.15.8 Comparison to the Action Alternatives

In nearly every flooding scenario in current climate conditions, the Preferred Alternative has a slightly higher percentage of acreage at risk of inundation than the Tier 1 Draft EIS Action Alternatives. The only case where this differs is that the Preferred Alternative and Alternative 1 have the same percentage at risk of sea level rise flooding.

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[5] Intergovernmental Panel on Climate Change (IPCC). (2013). *Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* New York: Cambridge University Press.
[6] U.S. Global Change Research Program. (2014). *2014 National Climate Assessment.* Retrieved from *http://nca2014.globalchange.gov/*

Table 7.15-2 summarizes the three counties located along the Representative Routes of the Existing NEC +Hartford/Springfield Line, the Preferred Alternative, and the Action Alternatives that have, or are proposed to have, rail assets located where the highest total acreage at risk from each flood hazard occur under current climate conditions. Also included in the table is the percentage of the total acreage within the Representative Routes at risk of flooding accounted for by these three counties. It is notable that New London, CT, consistently represents one of the counties at highest risk of all types of flooding under the Existing NEC + Hartford/Springfield Line, the Preferred Alternative, and the Action Alternatives (with the exception of storm surge flooding under the Preferred Alternative and sea level rise flooding under Alternative 3).

Table 7.15-2: Current Climate Conditions: Counties with Largest Number of Acres at Risk of Inundation along the Representative Routes of the Existing NEC + Hartford/Springfield Line, Preferred Alternative, and Action Alternatives

Flooding Hazard	Existing NEC + H/S Line[1]	Preferred Alternative	Alt. 1	Alt. 2	Alt. 3
Sea level rise flooding	▪ New London, CT ▪ Hudson, NJ ▪ New Haven, CT 50% of the total number of acres at risk	▪ New London, CT ▪ Harford, MD ▪ Hudson, NJ 42% of total number of acres at risk	▪ New London, CT ▪ Hudson, NJ ▪ New York, NY 56% of the total number of acres at risk	▪ New London, CT ▪ Hudson, NJ ▪ Philadelphia, PA 38% of the total number of acres at risk	▪ Hudson, NJ ▪ New Castle, DE ▪ New York, NY 42-44% of the total number of acres at risk
Storm surge flooding	▪ New London, CT ▪ New Haven, CT ▪ New Castle, DE 55% of the total number of acres at risk	▪ New Haven, CT ▪ New York, NY ▪ New Castle, DE 42% of total number of of acres at risk	▪ New London, CT ▪ New Haven, CT ▪ Hudson, NJ 47% of the total number of acres at risk	▪ New London, CT ▪ Philadelphia, PA ▪ New Haven, CT 44% of the total number of acres at risk	▪ New London, CT ▪ Hudson, NJ ▪ New Castle, DE 40-42% of the total number of acres at risk
Riverine flooding	▪ New London, CT ▪ New Haven, CT ▪ Hartford, CT 40% of the total number of acres at risk	▪ New London, CT ▪ Harford, MD ▪ New Haven, CT 31% of total number of acres at risk	▪ New London, CT ▪ New Haven, CT ▪ Fairfield, CT 37% of the total number of acres at risk	▪ New London, CT ▪ New Haven, CT ▪ Philadelphia, PA 32% of the total number of acres at risk	▪ New London, CT ▪ New Castle, DE ▪ Hudson, NJ 21-24% of the total number of acres at risk

Source: NEC FUTURE team, 2016
[1] H/S Line = Hartford/Springfield Line

7.15.9 Conclusions

Under the Preferred Alternative, analysis indicates there would be a net total decrease in GHG emissions in the year 2040, when compared to the No Action Alternative.

Flood and extreme temperature-related impacts affect the Existing NEC + Hartford/Springfield Line (as a proxy for the No Action Alternative) and will also affect the Preferred Alternative. The risks and associated impacts are likely to increase under mid-century and end-of-century climate conditions. While a significant portion of the Existing NEC is along the coast, the Preferred Alternative provides a mix of inland and coastal routes, particularly in the northern half of the Study Area. Analyses showed that rail assets and infrastructure associated with inland routes are at much lower risk of coastal flooding than coastal routes. Rail assets located in counties along inland routes, however, are still subject to riverine flooding, as is the Existing NEC. The geographic area of those risks is likely to increase as a result of climate change. It is also important to note that this assessment did not consider vulnerability-reducing adaptation measures and design considerations that would be a part of the Preferred Alternative. As such, the risk of flooding to the Preferred Alternative is potentially lower than what is presented in this analysis.

The Preferred Alternative requires investment to improve the resiliency of the Existing NEC + Hartford/Springfield Line infrastructure. The resiliency and redundancy provided by the Preferred Alternative both north and south of New York City provide a benefit compared to the No Action Alternative. Investment in new infrastructure associated with the off-corridor sections of the Preferred Alternative provides an opportunity to locate and design the infrastructure in a way that minimizes its risk to flood and extreme heat related impacts. In some areas, upgrading the Existing NEC + Hartford/Springfield Line to be more resilient may not be enough and providing redundant track outside of the areas of risk supplies alternative routing when some segments are closed because of flooding. This redundancy allows some level-of-service to be maintained. The following section presents potential mitigation and adaptation strategies.

7.15.10 Potential Mitigation Strategies

Understanding that the effects of climate change will continue to worsen, it is important to consider ways in which to make improvements to the existing and new rail infrastructure that can better withstand the potential effects on inundation and extreme weather events. This section provides an overview of potential mitigation and adaptation strategies that could be considered during future stages of project development. Chapter 7.13, Air Quality, provides potential mitigation to reduce GHG emissions.

The earlier that adaptation approaches are considered in the infrastructure planning and design process, the lower the relative cost and potential disruption associated with implementing the changes. For example, the marginal cost of building an embankment to a higher elevation when it is first built is significantly cheaper, and less disruptive, than increasing the height of an existing embankment and the assets it supports.

Multiple approaches can be used to adapt rail service and infrastructure to future climate and therefore minimize the risk of flood or extreme temperature-related impacts. Typical categories of response include the following:

- Investigations – Specialist assessments and explorations of individual assets, specific issues, and solutions (e.g., flood modeling of specific locations to determine likely future risk related to riverine flooding).

- Policy – Changes to policies, standards and guidelines (e.g., design and maintenance specifications or adjust standards relating to rail neutral temperatures to ensure projected increases in temperature are considered over time).
- Behavioral – Adjustments to existing processes, operational systems and procedures (e.g., emergency management plans or refining the process for determining go-slow orders (e.g., the revised Amtrak approach to improved predictions).
- Physical – Physically engineered solutions (e.g., ensuring the design of assets consider the identified risks, particular flood risk – location, elevation, or protective barriers, use of concrete ballast and continuous tension catenary wires, or relocation of the tracks).

The FRA reviewed climate change–related policies and initiatives that have been published by various government agencies in Washington, D.C., and the eight states along the NEC. From these sources, the FRA identified the following common themes:

- Supporting coordination and cooperation of planning agencies and infrastructure owners and operators
- Increasing the understanding of the climate science and how hazards may alter over time (e.g., downscaled climate projections and higher-resolution inundation and coastal hazard modeling)
- Assessing the vulnerability of infrastructure assets and systems
- Integrating consideration of climate change and adaptation into existing decision-making processes including planning, emergency management, design and maintenance of assets

The FRA has taken action related to each of these themes by integrating consideration of climate change into the Tier 1 EIS process. The climate change analysis has engaged with planning agencies, considered climate change projections, and assessed the vulnerability of rail assets.

Table 7.15-3 provides a listing of potential adaptation actions relevant to each asset class and the risks they face from flood and extreme temperatures. The existence of an inland route may assist in reducing service disruptions should a coastal flooding event affect assets along the coast.

In developing adaptation options specific to the NEC, consideration should be given to regional or state-based adaptation actions to reduce the risk profile of the Preferred Alternative.

Table 7.15-3: Summary of Potential Climate Change Adaptation Actions for the NEC

Asset	Risk	Adaptation Actions
BUILT ASSETS		
Rail tracks (at-grade, embankment, trench, and tunnel construction)	▪ Inundation leading to restriction of service and damage to assets from destabilization (Scour) (Extreme rainfall) ▪ Buckling of tracks (Extreme heat) ▪ Damage from fire (Wildfire) ▪ Increase maintenance requirements and access issues (Snow storm)	▪ Flood mapping to identify current and projected 1 percent (100 year) and 0.2 percent (500 year) flood levels across planned route. ▪ Design to minimize flood risk. ▪ Include consideration of increased degradation of materials in asset management plans and inspection regimes (e.g., over time – more-frequent inspection periods or ensuring inspection following extreme events such as wind, heat, rain, and freezing). ▪ Emergency management plan to minimize risk to staff, passengers and assets (rolling stock) during flood and heat events. ▪ Emergency backup for pumping of flood waters. ▪ Review drainage plans to minimize likely flooding of tracks (e.g., overcapacity of drainage, or water flowing into cuttings/ stations). ▪ Alternate commuter route (e.g., bus replacement). ▪ Optimizing go-slow order process. ▪ Adjusting rail neutral temperatures in line with climate projections.
Station platforms	▪ Inundation leading to restriction of service and damage to assets from destabilization (scour) (extreme rainfall) ▪ Increase maintenance requirements and access issues (Snow storm)	▪ Ensure station level emergency management planning. ▪ Design to minimize flood risk. ▪ Maintenance asset inspection regime.
Station buildings	▪ Inundation leading to restriction of service and damage to assets stored in the facility and from destabilization (scour) (extreme rainfall) ▪ Increased cooling requirements (Extreme heat) ▪ Increase degradation of materials (Extreme heat) ▪ Damage from wind-blown debris (Extreme wind)	▪ Ensure station level emergency management planning. ▪ Design to minimize flood risk – both risk of flood waters entering building and damage if it does (e.g., appropriate positioning of electrical supply equipment and other utilities). ▪ Maintenance asset inspection regime. ▪ Internal storage of goods in a manner that minimizes damage if facility is flooded. ▪ Green design – energy efficiency and passive cooling. ▪ Incorporating renewable energy and storage to operate during power outages.

Table 7.15-3: Summary of Potential Climate Change Adaptation Actions for the NEC (continued)

Asset	Risk	Adaptation Actions
BUILT ASSETS (cont'd)		
Storage facilities for rail vehicles	■ Inundation leading to restriction of access / service, damage to assets stored in the facility, potential for environmental impacts from mobilization of contaminants (Extreme rainfall) ■ Increase maintenance requirements and access issues (Snow storm)	■ Emergency management planning to relocate vehicles (sensitive equipment). ■ Design to minimize flood risk – both risk of flood waters entering building and damage if it does (e.g., positioning of electricals, water sensitive urban design). ■ Storage of goods in a manner that minimizes damage if facility is flooded. ■ Green design – energy efficiency and passive cooling / shading of vehicles. ■ Incorporating renewable energy and storage to operate during power outages.
Storage facilities for maintenance equipment	■ Inundation leading to restriction of access / service, damage to assets stored in the facility, potential for environmental impacts from mobilization of contaminants (Extreme rainfall) ■ Increase maintenance requirements and access issues (Snow storm)	■ Emergency management planning to relocate vehicles (sensitive equipment). ■ Design to minimize flood risk – both risk of flood waters entering building and damage if it does (e.g., positioning of electrics). ■ Maintenance asset inspection regime. ■ Internal storage of goods in a manner that minimizes damage if facility is flooded. Consideration of environmental hazard if damage occurs (e.g., Storage and containment of hazardous goods and waste materials). ■ Green design – energy efficiency and passive cooling. ■ Incorporating renewable energy and storage to operate during power outages.
Electrical equipment (substations, overhead power / catenary wires), signaling, communications, security lighting, supporting retail / activity centers and emergency equipment (e.g., backup generators, firefighting / water pumps for flood treatment)	■ Inundation leading to damage to and failure of electrical equipment including substations, destabilization of supporting structures (e.g., poles) (Extreme rainfall) ■ Degradation of materials (Extreme heat and Extreme cold / ice) ■ Failure of overhead lines (e.g., sagging) (Extreme wind and heat) ■ Increased potential for loose electric currents resulting from increased salinity in the air and ground	■ Flood mapping to identify current and projected 1 percent (100 year) and 0.2 percent (500 year) flood levels across planned route. ■ Emergency management plan / back up power, communications and signaling. ■ Redundancy for power, signaling and communication. ■ Include consideration of increased degradation of materials in asset management plans and inspection regimes (e.g., over time – more-frequent inspection periods or ensuring inspection following extreme events such as wind, heat, rain, and freezing). ■ Expanded range of grounding around electrified tracks. ■ Incorporating renewable energy and storage to operate during power outages.

Table 7.15-3: Summary of Potential Climate Change Adaptation Actions for the NEC (continued)

Asset	Risk	Adaptation Actions
BUILT ASSETS (cont'd)		
Bridge structures (aerial and major bridge construction)	■ Inundation or ground movement leading to destabilization of bridge structures (Extreme rainfall, drought) ■ Degradation of materials including expansion of concrete joins, protective cladding, coatings and sealants) (Extreme heat)	■ Flood mapping to identify current and projected 1 percent (100 year) and 0.2 percent (500 year) flood levels across planned route. ■ Consider flows in design. ■ Include consideration of increased degradation of materials in asset management plans and inspection regimes (e.g., over time – more-frequent inspection periods or ensuring inspection following extreme events such as wind, heat, rain, and freezing).
Retaining walls (embankment and tunnel construction)	■ Inundation leading to destabilization (scour) (Extreme rainfall) ■ Damage from fire (Wildfire) ■ Degradation of materials including expansion of concrete joins, protective cladding, coatings and sealants) (Extreme heat)	■ Include consideration of increased degradation of materials in asset management plans and inspection regimes (e.g., over time – more-frequent inspection periods or ensuring inspection following extreme events such as wind, heat, rain, and freezing).
Vehicles	■ Inundation leading to degradation from exposure to water, damage to internal components (electrical and non-electrical) ■ Damage from fire (Wildfire) ■ Failure of air conditioning restricting use (Extreme heat) ■ Increased operational costs (Extreme heat)	■ Emergency management plan for where to put vehicles in time of storm. ■ Regenerative breaking to minimize power costs. ■ Ensure air conditioning installed in vehicles to operate up to specific extreme heats levels.
Noise walls	■ Inundation leading to destabilization (scour) (Extreme rainfall) ■ Damage from fire (Wildfire) ■ Degradation of materials including expansion of concrete joins, protective cladding, coatings and sealants) (Extreme heat)	■ Include consideration of increased degradation of materials in asset management plans and inspection regimes (e.g., over time – more-frequent inspection periods or ensuring inspection following extreme events such as wind, heat, rain, and freezing). ■ Use of solar panels to generate electricity. .

Table 7.15-3: Summary of Potential Climate Change Adaptation Actions for the NEC (continued)

Asset	Risk	Adaptation Actions
HUMAN ASSETS (access to / from, health and safety during use / operation)		
Operational staff	■ Restricted access (Extreme rainfall) ■ Potential injury while undertaking work from flood waters, heat stress, exposure to cold / ice an wind-blown debris (Extreme rainfall, Extreme heat, extreme wind)	■ Emergency management plan to minimize exposure to risk ■ Standard operating procedures to ensure safe operation during extreme heat, cold, storms, wind, etc.
Passengers / commuters	■ Restricted access (Extreme rainfall) ■ Potential injury while using service from flood waters, heat stress, exposure to cold / ice an wind-blown debris (Extreme rainfall, Extreme heat, extreme wind)	■ Design (operation and maintenance) of facilities to ensure safe environment during extreme events ■ Emergency management plan to minimize exposure to risk ■ Communication program to educate commuters of the shared responsibility for safety and suggested ways they can reduce their exposure to risks ■ Backup/alternative transport during extreme events and method of communicating with commuters during these times
SUPPORTING SERVICES		
Electricity supply	■ Inundation leading to damage to and failure of electrical equipment including substations, destabilization of supporting structures (e.g., poles) (Extreme rainfall)	■ Redundancy of supply / back up facilities ■ Emergency management planning to consider loss of power ■ Self-sufficiency, generate electricity on site ■ Energy efficiency to reduce demand
Emergency response	■ Inundation disrupting access by emergency services vehicles (Extreme rainfall)	■ Emergency management planning including participation of emergency services and tenants and community

Source: NEC FUTURE team, 2015

7.15.11 Subsequent Tier 2 Analysis

Volume 2, Appendix E.15, provides the limitations of this assessment. Key actions that could be undertaken as part of Tier 2 project analysis and design should include the following:

- Review the latest climate science trends for any applicable updates to the projections and/or trends.
- Undertake targeted, site-specific riverine and coastal flood modeling.
- Undertake joint probability riverine and coastal flood analysis.
- Consider additional interim sea level rise scenarios (e.g., between 1 foot and 6 feet) to better quantify the timing of the risk and prioritization of improvements.
- Consider increasing coastal storm surge intensity (as the science progresses), or larger coastal storm surge events (e.g., 500-year event).
- Incorporate adaptation considerations into design to minimize risk exposure and increase ability to recover from extreme events (e.g. track elevation strategies).[7]
- Incorporate consideration of adaptation costs (i.e., more resilient infrastructure) as well as increased maintenance costs and service disruptions associated with likely increased flooding and extreme heat impacts.

The above analysis may be guided by the Federal Highway Administration's Virtual Framework for Vulnerability Assessment.

Table 7.15-4 provides an overview of the modules contained in the framework and how they may be applied to Tier 2 analysis. In addition, consideration should be given to the *Revised Guidelines for Implementing Executive Order 11988, Floodplain Management*.[8]

Furthermore, on August 1, 2016, the Council on Environmental Quality issued final guidance on consideration of GHG emissions and the effects of climate change in National Environmental Policy Act documents.[9] This guidance states that "when addressing climate change agencies should consider: (1) The potential effects of a proposed action on climate change as indicated by assessing GHG emissions (e.g., to include, where applicable, carbon sequestration); and, (2) The effects of climate change on a proposed action and its environmental impacts." The FRA developed a methodology for the NEC FUTURE Tier 1 EIS, in coordination with federal and state agencies, which considered GHG emissions and the vulnerability of rail assets. This Tier 1 Final EIS identifies areas at

[7] National Climate Assessment. (Revised 2014). *Ch. 26: Decision Support.* *http://nca2014.globalchange.gov/report/response-strategies/decision-support*

[8] Federal Emergency Management. (Revised 2015). *Agency Guidelines for Implementing Executive Order 11988, Floodplain Management*. Retrieved from *http://www.fema.gov/media-library-data/1422653213069-9af488f43e1cf4a0a76ae870b2dcede9/DRAFT-FFRMS-Implementating-Guidelines-1-29-2015r2.pdf*

[9] Council on Environmental Quality, "Final Guidance for Federal Departments and Agencies on Consideration of Greenhouse Gas Emissions and the Effects of Climate Change in National Environmental Policy Act Reviews," 81 Fed. Reg. 51866 (August 5, 2016). Access at *http://energy.gov/sites/prod/files/2016/08/f33/nepa_final_ghg_guidance_FR.pdf*

risk that should be further evaluated during subsequent Tier 2 project studies. More in-depth analysis of GHG emissions may also be needed for Tier 2 project studies.

Table 7.15-4: Overview of the Federal Highway Administration's Virtual Framework for Vulnerability Assessments Modules and Their Application to Tier 2 Analysis

Framework Module	Relevance to Tier 2 Analysis
Module 1: Articulate Objectives Includes: ■ Defining the project scope, area of study, and level of detail required ■ Identifying stakeholders and engaging them in the planning process ■ Defining the vulnerability assessment objectives	Guidance related to this module could assist in setting the scope of Tier 2 analysis. The NEC FUTURE Tier 1 analysis can inform the articulation of objectives.
Module 2: Identify Key Climate Stressors Includes selecting climate stressors to analyze, based on the sensitivity of transportation assets	The Tier 1 assessment has selected climate stressors relating to flooding and extreme temperature as the focus. Tier 2 analyses may consider a broader set of climate stressors (refer to U.S. DOT's Sensitivity Matrix developed as a part of the U.S. DOT Gulf Coast study).
Module 3: Select and Characterize Relevant Assets Includes determining the following: ■ Which assets to evaluate, including the criticality of assets ■ The temporal scope of assets ■ Data availability	Guidance related to this module could be of use in developing the scope for Tier 2 analysis (refer to Guide to Assessing Criticality in Transportation Adaptation Planning developed as a part of the U.S. DOT Gulf Coast Study).
Module 4: Assess Vulnerabilities Includes assessing sensitivity, exposure and adaptive capacity of assets and the associated risks	Guidance related to this module could be of use in developing the scope for Tier 2 analysis (refer to the U.S. DOT Vulnerability Assessment Scoring Tool).
Module 5: Integrate Vulnerabilities into Decision-Making Includes identifying, analyzing, and prioritizing adaptation options	The work undertaken in the Tier 1 EIS is a demonstration of how vulnerabilities are being considered in the decision-making process. Guidance related to adaptation planning may be of benefit in Tier 2 analysis.
Module 6: Monitor and Revisit Includes developing and implementing a monitoring and evaluation plan, engaging stakeholders, evaluating outcomes, revisiting inputs into the assessment (e.g., climate data, information on assets or operations)	These elements should be considered in the development of adaptation options and ongoing planning for the NEC FUTURE.

Sources:
1. NEC FUTURE team, 2016
2. U.S. Department of Transportation – Federal Highway Administration. (2015, February 2). *Gulf Coast Study, Phase 2 Task 4*. Retrieved February 23, 2015, from Federal Highway Administration: *http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/gulf_coast_study/phase2_task4/index.cfm*
3. U.S. Department of Transportation – Federal Highway Administration. (2015, February 2). *Virtual Framework for Vulnerability Assessment*. Retrieved February 23, 2015, from Federal Highway Administration: *http://www.fhwa.dot.gov/environment/climate_change/adaptation/adaptation_framework/%*