Monterey County Regional Conservation Investment Strategy

Transportation Climate Change Vulnerability Assessment

September 2020

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Acronyms and Abbreviations

AR5	Fifth Assessment Report
CAL FIRE	California Department of Forestry and Fire Protection
IPCC	Intergovernmental Panel on Climate Change
MHHW	Mean Higher High Water
NOAA	National Oceanic and Atmospheric Administration
OPC	(California) Ocean Protection Council
RCIS	Regional Conservation Investment Strategy
RCIS area	Monterey County Regional Conservation Investment Strategy area
RCP	Representative Concentration Pathway

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1. EXECUTIVE SUMMARY

Climate change is projected to pose increasing risk for transportation infrastructure in the Monterey County Regional Conservation Investment Strategy (RCIS) area, primarily through more severe, frequent flooding due to increased storm events and sea level rise, an increase in the extent and frequency of wildfires, and infrastructure damage because of more extreme heat days. Although infrastructure was designed to be adaptive to a large range of climatic conditions, the increased exposure to climate hazards is projected to affect the reliability and capacity of these transportation networks. To assess the climate vulnerability of transportation assets in the RCIS area, a high-level exposure and consequence assessment of transportation assets was conducted for the hazards of sea level rise inundation, coastal storm flooding, extreme heat, and wildfires. Previously completed and ongoing climate vulnerability and adaptation studies for the region also were reviewed and incorporated into the findings. Transportation infrastructure in Elkhorn Slough and along the oceanfront areas of the city of Monterey were identified as highly vulnerable to rising sea levels because of coastal flood exposure.

2. PROJECTIONS OF CLIMATE CHANGE

This section reviews the best-available climate science for the RCIS area—including changes in temperature, precipitation, and sea level rise. It also discusses the physical impacts of these changes in the climate, including wildfires, flooding, coastal erosion, landslides, and drought.

2.1 Modeling Climate Change

To project future climate conditions, scientists rely on numerical models, known as general circulation models. These models incorporate the inter-related physical processes of the atmosphere, ocean, and land surface to simulate the response of climate systems to changing greenhouse gas and sulfate aerosol emissions. These models are based on well-established physical principles and have been demonstrated to reproduce observed changes of recent and past climates. Because the level of future emissions will be affected by population, economic development, environmental changes, technology, and policy decisions, the Intergovernmental Panel on Climate Change (IPCC) has developed a range of possible future emission scenarios, based on a combination of these driving factors.

For the most recent IPCC report, the Fifth Assessment Report (AR5), the IPCC updated its scenarios—now called representative concentration pathways (RCPs)—to reflect advances in modeling approaches and additional factors that could affect future climate conditions (IPCC 2013). For climate adaptation planning, RCP4.5 and RCP8.5 are the most commonly used scenarios. The higher of the two (RCP8.5) also is referred to as a business-as-usual scenario and represents rapid economic growth, with greenhouse gas concentrations exceeding 900 parts per million (ppm) by 2100. RCP4.5 represents a more moderate scenario, with greenhouse gas emissions rising until 2040 and reaching a concentration of 550ppm, followed by stabilization.

The different RCP scenarios are incorporated into the numeric general circulation models, creating combinations of selected future conditions that can be used as input for researchers to assess the influence of the variables on the projected climate. General circulation models provide estimates of climate change on a global level because the resolution typically is too coarse for detailed regional climate projections. Therefore, the models often are "downscaled" to allow more place-based projections on the local level. Using general circulation model results for input, downscaled models generate locally relevant data by connecting global-scale projections and regional dynamics.

2.2 State Climate Change Guidance and Resources

California has developed a series of guidance documents and studies, to enhance the understanding of climate change impacts on a regional scale and directly inform vulnerability assessments and adaptation strategies. Table 2-1 summarize State resources that are leveraged for assessment of climate stressors in the RCIS area. Table 2-2 summarizes projected changes in temperature, precipitation and sea level rise based on low and high emission conditions.

Table 2-1. State of California Climate Change Guidance and Resources

Study (Author/Date)	Summary
California's Fourth Climate Change Assessment–Central Coast Region Report (Langridge 2018)	• The assessment is composed academic and technical reports, discussing climate change projections for a suite of climate stressors, including temperature, sea levels, snowpack, annual precipitation, precipitation intensity, frequency of drought, frequency and intensity of Santa Ana winds, marine layer clouds, and wildfire. • Potential impacts also are described for a variety of sectors (e.g., land use and development, biodiversity and ecosystems, forest health, transportation, and public health). • The Central Coast Regional Report, which includes Monterey County, emphasizes potential effects on natural ecosystems, agriculture, and coastal and farm communities, and it lists potential adaptations for each sector.

Study (Author/Date)	Summary
Ocean Protection Council Sea Level Rise Guidance Update (California Ocean Protection Council 2018)	• This guidance update: • compiles, reviews, and summarizes the latest research on sea level rise • presents the latest peer-reviewed projections of sea level rise, describes an extreme scenario for sea level rise caused by rapid ice sheet loss from the West Antarctica ice sheet, and presents scenario selections using risk-based (probabilistic) planning capabilities, and • lays out preferred approaches to planning for vulnerable assets, natural habitats, and public access.
Cal-Adapt (Cal-Adapt 2017)	• To satisfy a key recommendation of the 2009 California Climate Adaptation Strategy, Cal-Adapt was developed to provide an interactive geospatial tool for localized climate projections in California. • The tool allows users to explore projected changes in temperature, extreme heat, precipitation, snowpack, wildfire, and sea level rise across the state, based on a variety of climate models and future emission scenarios. • The updated version of the tool, Cal-Adapt 2.0, also includes high-resolution, local climate projections, using downscaling methods and emission scenarios that align with the Intergovernmental Panel on Climate Change's Fifth Assessment Report.

2.3 Sea Level Rise Projections

Since installation of the Monterey tide station in 1973, sea levels have increased at a rate of 0.06 inch per year, which equates to 0.52 foot in 100 years (NOAA 2018). Numerous studies indicate a global acceleration of local sea level rise during the turn of the twenty-first century, with rates tripling earlier observations. Based on the latest climate science, Monterey County sea levels are likely to rise between 0.5 and 1.1 feet by mid-century, and between 0.9 and 3.3 feet by end of the century. The California Ocean Protection Council (OPC) recommends using the upper limit of the likely range for projects with a high tolerance to flooding (e.g., parks or natural areas) (California OPC 2018).

Because uncertainty exists regarding future greenhouse gas emissions, sea level rise projections with lower probabilities of occurring also have been considered. In the RCIS area, a 0.5 percent probability exists that sea level rise will reach or exceed 1.9 feet by mid-century and 6.9 feet by the end of the century (California OPC 2018). OPC recommends using these projections when planning for assets with lower tolerances to flooding, such as major transportation corridors (California OPC 2018). Table 2-2 summarizes projected sea level rise ranges, based on low and high emission conditions.

2.4 Temperature Projections

Temperatures are expected to increase significantly for the RCIS area over the next century. Based on the RCP8.5 scenario, annual average temperatures are expected to increase by 4.9°F by mid-century and 7.5°F by end-of-century relative to historical period observations (1976–2005) (Table 2-2). Changes in the number of extreme heat days, defined as days with temperatures above the 98th percentile of observed daily maximum temperatures, are projected to increase by 15 days by mid-century and 30 days by end-of-century (Langridge 2018).

2.5 Precipitation Projections

Projections of future precipitation are associated with considerable uncertainty. Precipitation is one of the least certain aspects of climate models at the regional level, because the models do not resolve many of the fine-scale and complex interactions that occur locally. In general, a projected increase of year-to-year variability exists along the Central Coast, with fewer days of precipitation but an increase in the amount of precipitation occurring during wet days. The largest changes are expected to occur in coastal areas, where the amount of precipitation recorded in a single day may increase by up to 30 percent in Monterey County by the end of the century. The average annual precipitation, based on the RCP8.5 scenario, shows an increase of 2.1 inches by mid-century and 5.1 inches by end-of-century, when compared to historical conditions (1976–2005) (Langridge 2018) (Table 2-2).

2.6 Projection Summary

In general, sea levels are projected to rise at an accelerated rate through the next century. Similarly, maximum temperatures are projected to continue to increase, with greater increases experienced in inland areas. Average precipitation also is expected to increase by a relatively small amount, but annual variability in total inches is expected to increase substantially by the end of the century, with less total precipitation overall but an increase in the amount of precipitation during storm events.

Table 2-2. Summary of Climate Stressors

	Historical (1961–1990)	Low Emissions		High Emissions	
		Mid-Century (2040–2069)	End-of-Century (2070–2099)	Mid-Century (2040–2069)	End-of-Century (2070–2099)
Sea Level Rise	N/A	N/A	2.3–5.5 feet	1.1–1.9 feet	3.3–6.9 feet
Temperature (annual average)	70°F	73.7°F	74.9°F	74.9°F	77.5°F
Temperature (# of extreme heat days)	4.3	14	19	19	34
Precipitation (annual average)	19.3 inches	21.1inches	21.2 inches	21.4 inches	24.4 inches

Notes:

1. For low emissions, all climate stressors are based on RCP4.5, except sea level rise, which is based on RCP2.6.
2. For high emissions, all climate stressors are based on RCP8.5.
3. Only sea level rise projections, based on RCP8.5, are provided in the Guidance prior to 2060, because emissions currently are on the RCP8.5 trajectory.

3. ANALYSIS METHODOLOGY

To assess climate change vulnerability, a literature review was conducted of regional adaptation plans and a high-level exposure assessment of transportation assets was conducted using inundation maps (NOAA 2015) and wildfire hazard severity maps (CAL FIRE 2007).

3.1 Literature Review

Monterey County and several of its communities have completed a suite of studies, to evaluate vulnerability and potential adaptation strategies in preparation for climate change impacts (Table 3-1). The studies range from reports to understanding potential climate impacts on public health, and to city-specific climate change adaptation plans, to protect built and natural public infrastructure.

Table 3-1. Previous and Ongoing Climate Change Vulnerability Assessments and Adaptation Plans for Monterey County/Monterey Cities

Study/Lead Agency (Date)	Summary
City of Monterey Transportation Adaptation Plan Monterey–Salinas Transit, Transportation Agency for Monterey County, Association of Monterey Bay Area Governments (2018)	• Identifies transportation infrastructure vulnerable to climate change and develops adaptation strategies to preserve the transportation network by building on the findings of the City's Sea Level Rise and Vulnerability Analyses, Existing Conditions, and Issues Report. • Focuses on benefits to regional disadvantaged communities, local businesses, homes, and schools relying on the network.
City of Monterey Sea Level Rise and Vulnerability Analyses, Existing Conditions and Issues Report City of Monterey (2016)	• Examines existing conditions and climate stressor projections for sea level rise, temperature, precipitation, and wildfire in a series of planning horizons through 2100. • Evaluates coastal flood hazards based on wave flooding, barrier beach flooding, tidal inundation, and short and long-term erosion.
Monterey County Multi-Jurisdictional Hazard Mitigation Plan The Monterey County Hazard Mitigation Planning Team (2015)	• Serves as a guide for State and local efforts to reduce disaster losses of life, property, and infrastructure, including transportation assets. • Identifies trends and vulnerabilities associated with county-wide hazards, including sea level rise flooding, precipitation flooding, wildfires, landslides, and coastal erosion. • Offers county-wide and jurisdiction-specific recommendations to reduce future risks.

Study/Lead Agency (Date)	Summary
City of Pacific Grove Climate Change Vulnerability Assessment City of Pacific Grove (2015)	• Discusses potential climate change impacts, including temperatures, sea level rise, ocean acidification, extreme storms, and wildfires. • Evaluates the adaptive capacity of existing city assets. • Provides recommendations to assist the City in addressing identified climate change impacts.
Monterey Bay Sea Level Rise Vulnerability Assessment The Monterey Bay Sanctuary Foundation (2014)	• Presents the methods used to map erosion and coastal flood hazards, based future climate scenarios for the Monterey Bay coastline. • Presents the results at the planning horizons of 2030, 2060, and 2100. • Creates hazard zones for the 100-year tide, wave run-up, overtopping, and seasonally closed lagoons.

3.2 Transportation Infrastructure Vulnerability Assessment

A high-level exposure assessment was conducted for Monterey County's transportation infrastructure, to provide insight on risk and timelines for intervention. Climate stressors that were assessed included flooding from rising sea levels, and wildfires, which are directly influenced by increases in temperature and changes in the precipitation cycle. A high-level evaluation of potential impacts from extreme heat exposure also was conducted, through a review of previously completed and ongoing climate studies for the region; the findings are discussed in Section 4. Evaluated infrastructure included existing and planned projects under the following three asset categories: highways, main roads, and rail lines.

3.2.1 Sea Level Rise Inundation Mapping

Inundation maps are a valuable tool for evaluating the potential exposure of habitats, infrastructure, and assets to future water-level conditions. The maps are used to evaluate the timing and extent of potential flooding, based on projections of sea level rise. Inundation maps also help planners to identify critical flooding thresholds, where an entire area may be compromised.

Three sea level rise amounts—1, 3, and 7 feet—were selected for flood exposure. The scenarios represent projections for 2050 and 2100, based on the State's latest sea level rise guidance (California OPC 2018). The maps show areas vulnerable to flooding, based on two future flood conditions: daily tidal inundation, and temporary storm flooding. Daily tidal inundation conditions are represented by mean higher high-water (MHHW) level, and temporary storm flooding is represented by the 100-year storm tide. The 100-year storm tide is a statistically-derived water elevation that has a 1 percent chance of occurring in any given year. It includes the effects of the astronomical tide and storm conditions (because of atmospheric pressure and meteorological effects, precipitation, and El Niño conditions).

Future inundation layers for sea level rise scenarios that are available from the National Oceanic and Atmospheric Administration (NOAA 2015) were downloaded and used to understand potential future flood exposure of the transportation infrastructure in the RCIS area. NOAA sea level rise inundation layers provide the geographical extent and depth of inundation using 1-foot increments up to 10 feet above the average high-tide conditions, represented by MHHW elevation. The inundation maps do not account for wave height, rainfall, or other potential variations in conditions that could affect the depth or extent of inundation at any given location.

The assessment of the exposure in sea level rise to the transportation infrastructure in the RCIS area involved conducting a spatial analysis to estimate the timing and extent of temporary storm flooding and daily tidal inundation. Sea level rise layers for 2050 and 2100 conditions were overlaid on the locations of transportation features to estimate exposure to future water-level conditions.

3.2.2 Wildfire Threat Mapping

The California Department of Forestry and Fire Protection (CAL FIRE) identifies present-day wildfire hazard severity zones for the RCIS area (CAL FIRE 2007). A suite of physical factors characterizing the local environment, including existing and potential vegetation sources, flame length, blowing embers, topography, likelihood an area will burn over a 30 to 50-year time period, and typical weather for the area, was used to develop zones that estimate fire frequency and potential fire behavior in the state responsibility area (CAL FIRE 2007). A science-based and field-tested computer model was used to assign hazard scores, based on each factor. The resulting zones were ranked Very High, High, or Moderate Fire Hazard Severity. Areas designated as being Very High or High Fire Severity zones are the most likely to experience wildfire, and transportation structures likely to be affected are identified in each zone.

Although an evolving climate was not accounted for in the CAL FIRE model, it is anticipated that climate change may exacerbate wildfire risk, in terms of intensity, frequency, and/or burn extent. Future wildfire projections of downscaled model output for annual acreage burned based on two climate scenarios (RCP4.5 and RCP8.5) were evaluated to understand the potential impacts of future climate conditions on wildfire risk (Cal-Adapt 2017). Table 3-2 summarizes the findings for a historical baseline period (1950-2005) to represent existing conditions, mid-century (2035-2064) conditions, and end-of-century

(2070-2099)[1] conditions. Although there is projected to be a small increase in average acreage burned between the historical period to the mi-century projections, there is not a clear increasing trend in the wildfire projections beyond mid-century conditions. These findings indicate that frequent and sometimes large wildfires will continue to be a major disturbance in forested regions of the RCIS area through the coming century, present-day wildfire hazard severity zones are a sufficient tool to represent at-risk areas (Langridge 2018). The assessment of wildfire threat involved conducting a spatial analysis to estimate the extent of transportation infrastructure that may be affected directly by wildfires. Layers of potential fire hazard severity were overlaid on the locations of transportation features to estimate exposure of infrastructure in fire-prone areas.

Table 3-2. Projected Changes in Average Area Burned by Wildfires in the RCIS Area

Emission Scenario	Historical (1950-2005) (mean hectares/year)	Mid-Century (2035-2064) (mean hectares/year)	End-of-Century (2070-2099) (mean hectares/year)
RCP4.5	8,867	10,522	10,455
RCP8.5	8,826	10,501	10,053

[1] Results assume the human population growth rate in the RCIS area will continue to increase until 2060, followed by stabilization.

4. RESULTS

This section describes the results of a high-level vulnerability assessment, focused on potential exposure and climate change impacts on the transportation infrastructure in the RCIS area. The results are the culmination of climate vulnerabilities that were identified in previous studies and the findings of a high-level mapping evaluation of infrastructure in areas vulnerable to sea level rise, from flooding and wildfire exposure.

4.1 Sea Level Rise

A high-level assessment of the exposure to sea level rise was performed using inundation maps to evaluate the potential vulnerability of transportation infrastructure to daily tidal inundation and temporary storm flooding (Figure 4-1, Figure 4-2, Figure 4-3, Figure 4-4, Figure 4-5). A "no action" scenario was assumed to examine the effect of not implementing strategies to protect existing assets.

Sea level rise inundation exposure of all transportation infrastructure would be limited to Elkhorn Slough (Figure 4-4) and the portion of the city of Monterey adjacent to Del Monte Beach (Figure 4-5). By mid-century, large portions of Elkhorn Slough's low-lying salt marshes are projected to be flooded, exposing numerous stretches of highways, primary arterials, main roads owned and maintained by the Transportation Agency for Monterey County, and rail lines. By end-of-century, flooded areas of Elkhorn Slough are projected to expand and cover a larger region, and to begin to expose waterfront roadways in the city of Monterey from overtopping along the low-lying shoreline of Del Monte beach. Table 4-1 summarizes the analysis of sea level inundation exposure by transportation asset type (i.e., highways, major roads, and rail lines), with approximate mileage of the exposed network.

Table 4-1. Summary of Transportation Infrastructure Exposure to Sea Level Rise Impacts

Transportation Assets in the RCIS area	Sea Level Rise Scenarios					
	2-feet Sea Level Rise (Mid-Century)		3-feet Sea Level Rise (End-of-Century)		7-feet Sea Level Rise (End-of-Century)	
	Daily Tidal Inundation	Temporary Storm Flooding	Daily Tidal Inundation	Temporary Storm Flooding	Daily Tidal Inundation	Temporary Storm Flooding
Highways						
State Route 156 (Elkhorn Slough area)	0.2 mile	0.9 mile	0.2 mile	1.6 miles	1.6 miles	2.6 miles
State Route 183 (Elkhorn Slough area)	0.1 mile	0.1 mile	0.1 mile	0.1 mile	0.1 mile	3.2 miles
State Route 1 (Elkhorn Slough area)	2.7 miles	7.2 miles	4.5 miles	8.1 miles	9.6 miles	12.4 miles
Main Roads						
Lighthouse Ave (City of Monterey)	N/A				0.2 mile	0.2 mile
Franklin St (City of Monterey)	N/A				0.4 mile	0.4 mile
Del Monte Ave (City of Monterey)	N/A				0.7 mile	0.7 mile
Fremont St (City of Monterey)	N/A				0.03 mile	0.03 mile
Rail Lines						
Union Pacific (Elkhorn Slough area)	8.7 miles	13.7 miles	11.3 miles	13.7 miles	13.7 miles	13.7 miles

Potential impacts on roadways (highways and main roads) include the following.

Temporary Storm Flooding:

- Increased emergency response times from road closureLimited access to neighborhoods or commercial areas during storm events;
- Extended travel time for passengers required to drive inland around the Elkhorn Slough area;
- Large-scale effects on commercial shipping dependent on corridors;

- Temporary road closure during large storm events;
- Scour of road banks from high velocity storm flows;
- Repeated flooding, which may decrease the useful life and increase the maintenance frequency/costs;
- Increased erosion of coastal bluffs, creating the potential for local road failure and transporation infrastructure damage; and
- Coastal storm events that may undercut coastal bluffs, creating landslides that can cause local roadways failure and transporation infrastructure damage.

Daily Tidal Inundation:

- Long-term inundation, interupting the roadway network, affecting access to housing, jobs, tourism, commercial areas, shipping, and emergency response;
- Erosion of roadway infrastructure, with prolonged inundation of the base of coastal bluffs that may increase erosion, creating the potential for local road failure and transporation infrastructure damage; and
- Higher water levels at the base of coastal bluffs that may increase the chance of landslides, creating the potential for local road failure and transporation infrastructure damage.

Potential impacts on rail lines include the following.

Temporary Storm Flooding:

- Delayed or caneled passenger and freight service during large storm events;
- Power switches, derails, and signals associated with railways may be damaged; and
- Scour of railway foundations from high velocity storm flows.

Daily Tidal Inundation:

- Long-term inundation, leaving the railway inoperable and affecting regional and statewide public transportation, freight service, the regional and state economy, and possible social consequences by loss of access to jobs in the region; and
- Erosion of railway foundations.

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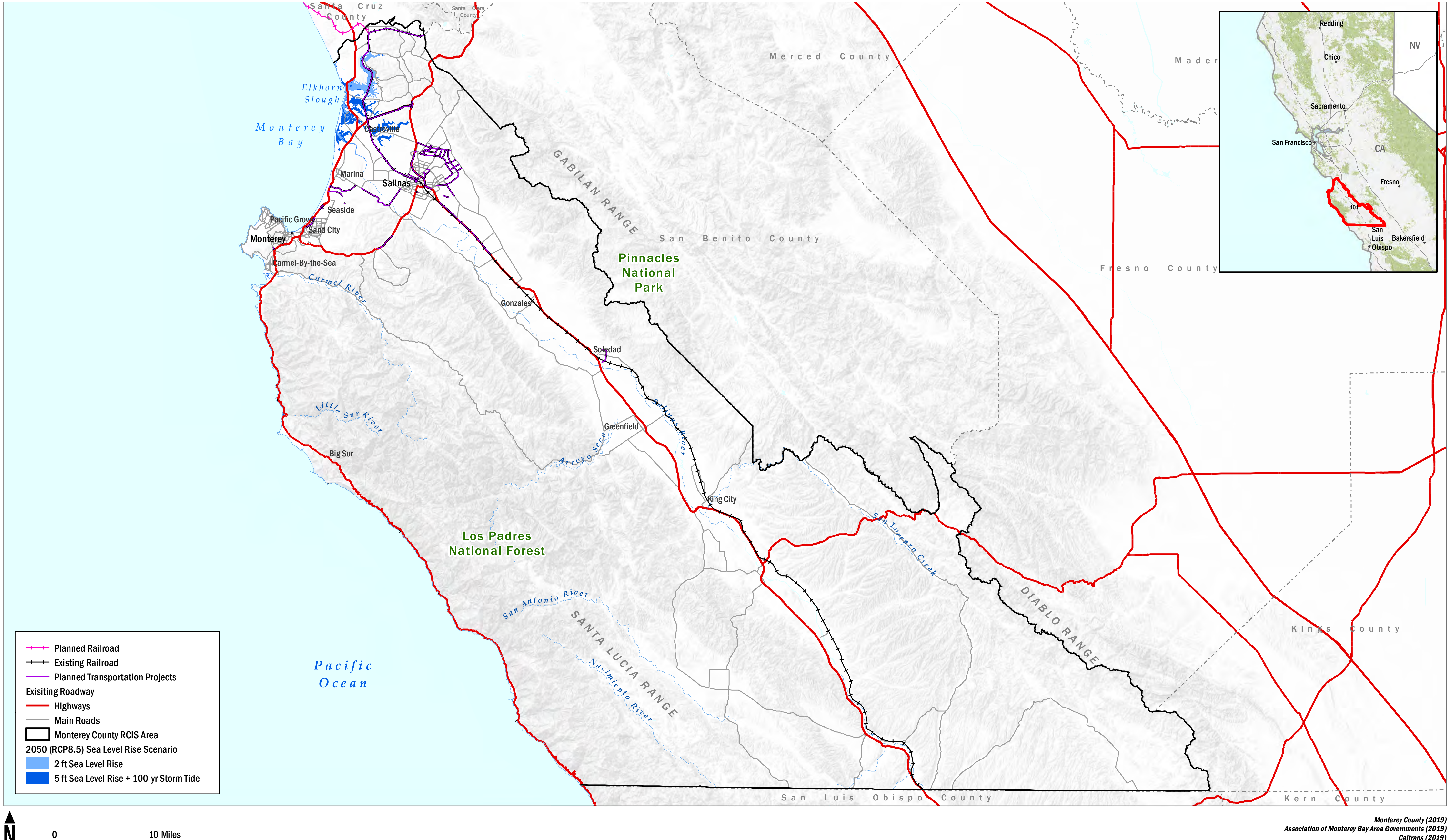

Monterey County (2019)
Association of Monterey Bay Area Governments (2019)
Caltrans (2019)
National Oceanic and Atmospheric Administration (2017)

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FIGURE 4-1
2050 (RCP8.5) Sea Level Rise Scenario

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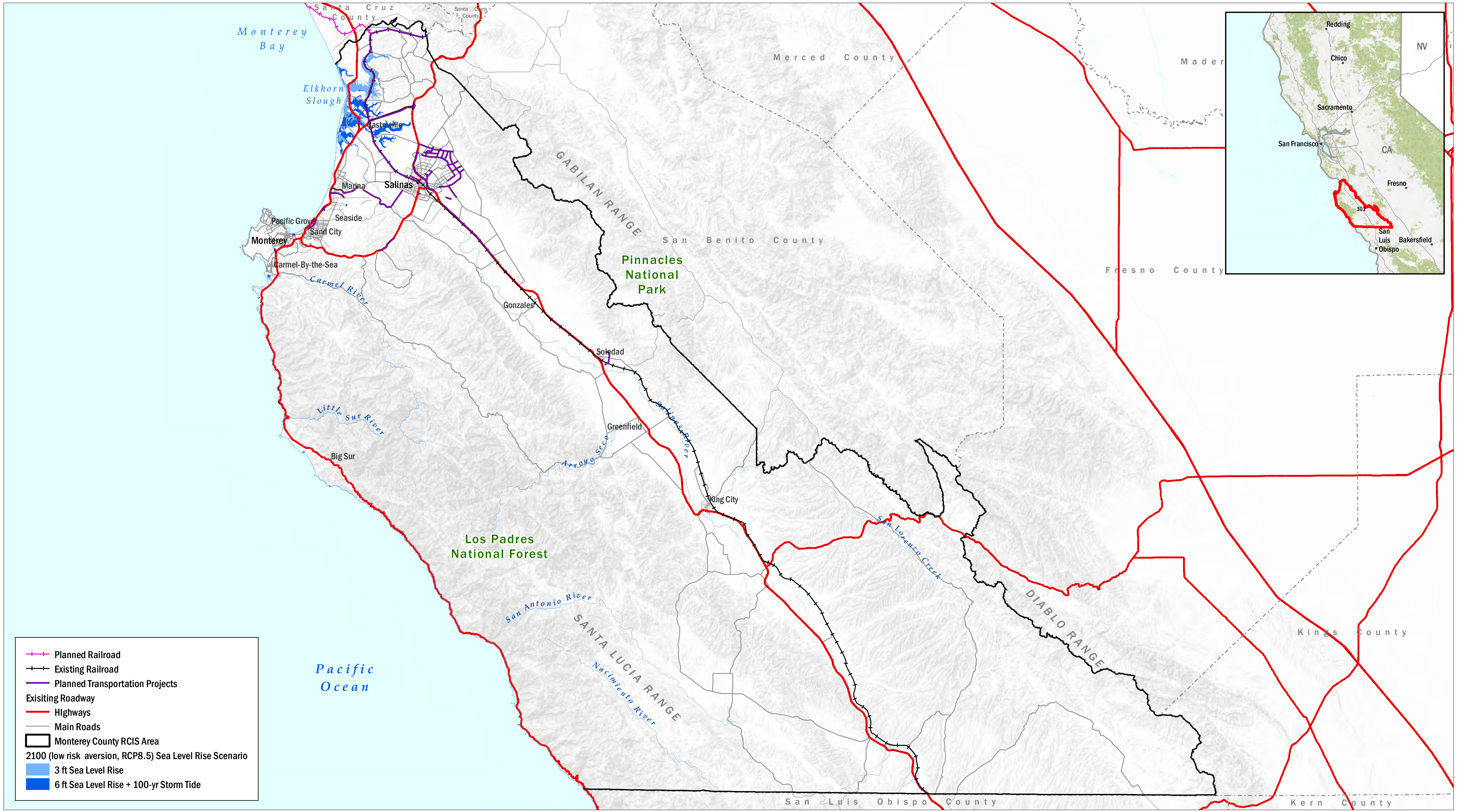

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0 10 Miles

Monterey County (2019)
Association of Monterey Bay Area Governments (2019)
Caltrans (2019)
National Oceanic and Atmospheric Administration (2017)

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FIGURE 4-2
2100 (low risk aversion, RCP8.5)
Sea Level Rise Scenario

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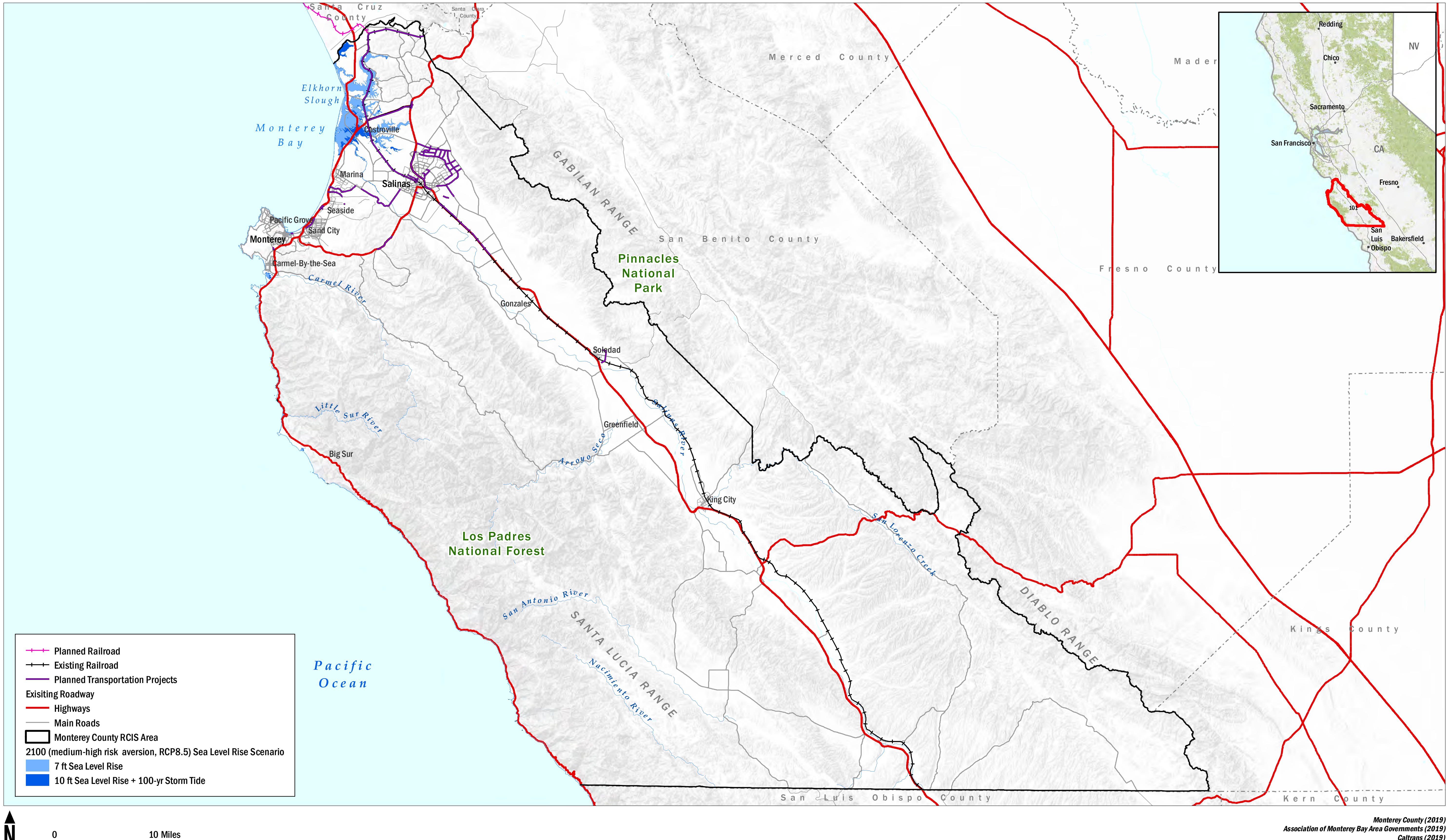

Monterey County (2019)
Association of Monterey Bay Area Governments (2019)
Caltrans (2019)
National Oceanic and Atmospheric Administration (2017)

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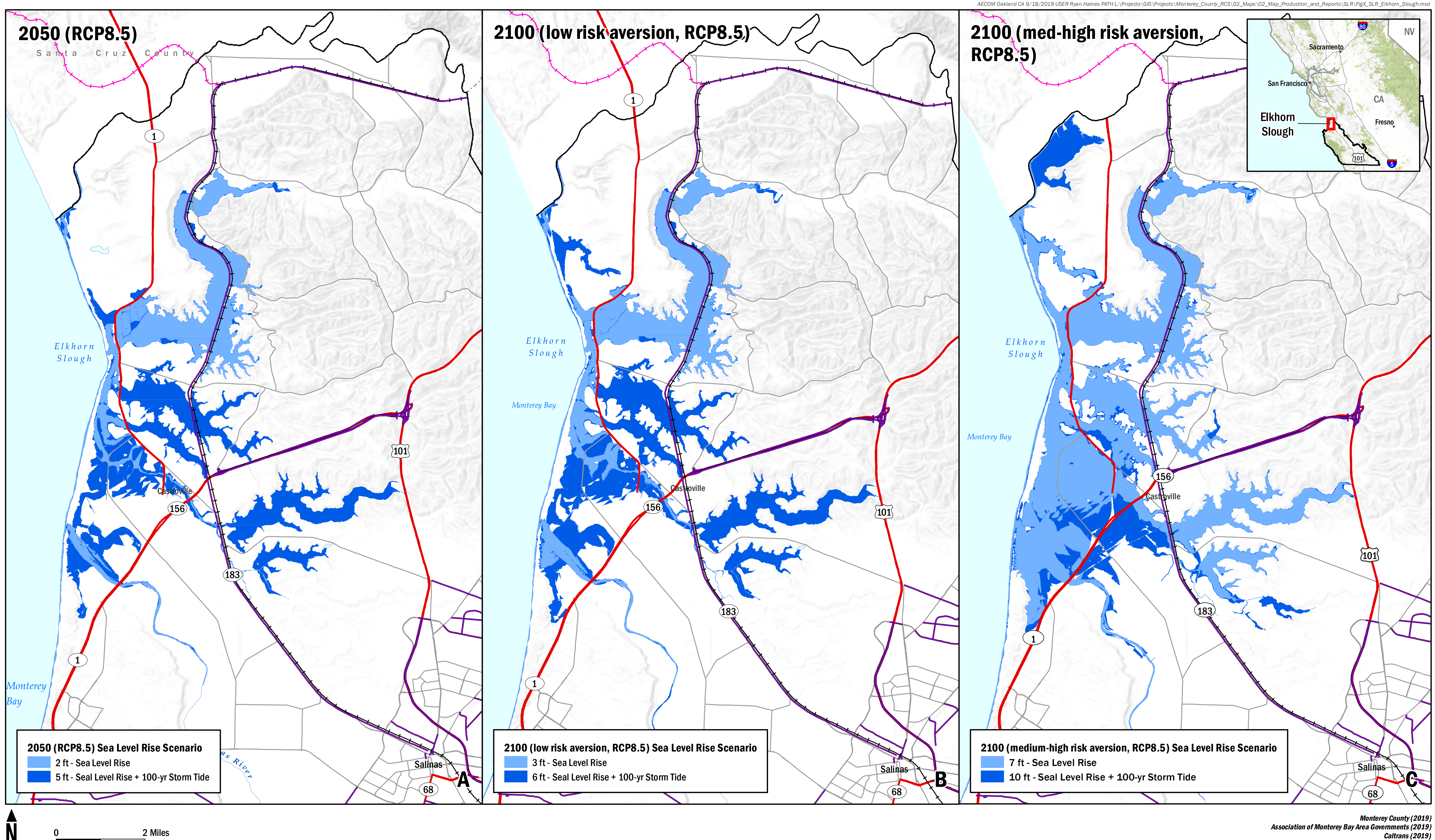
FIGURE 4-3
2100 (medium-high risk aversion, RCP8.5)
Sea Level Rise Scenario



Monterey County (2019)
Association of Monterey Bay Area Governments (2019)
Caltrans (2019)
National Oceanic and Atmospheric Administration (2017)

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Planned Railroad
Existing Railroad
Planned Transportation Projects
Exisiting Roadway
Highways
Main Roads
Monterey County RCIS Area

FIGURE 4-4
Elkhorn Slough Sea Level Rise Detail

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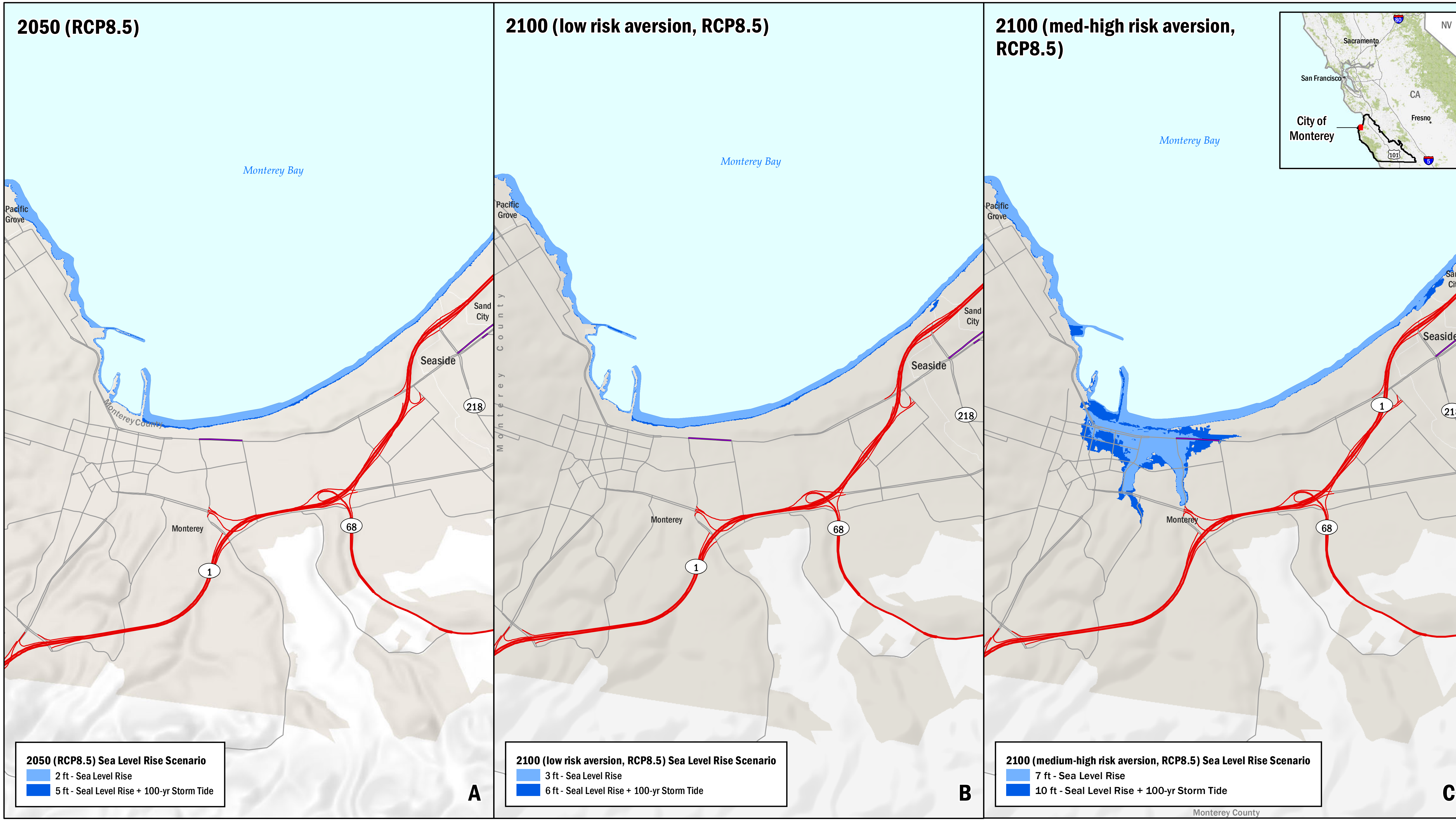

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0 3,000 Feet

Monterey County (2019)
Association of Monterey Bay Area Governments (2019)
Caltrans (2019)
National Oceanic and Atmospheric Administration (2017)

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Monterey County Regional Conservation Investment Strategy

Planned Railroad
Existing Railroad
Planned Transportation Projects
Exisiting Roadway
Highways
Main Roads
Monterey County RCIS Area

FIGURE 4-5
City of Monterey Sea Level Rise Detail

4.2 Wildfire

A high-level assessment of exposure to wildfires was conducted, using fire hazard severity zones developed by CAL FIRE (2007) to evaluate the potential vulnerability of transportation infrastructure to seasonal wildfire risk. The highest rated fire hazard severity zones are generally located along the north coast of Monterey County, between the Carmel Highlands and the Santa Lucia Range, and along the mountain crests west of the Salinas Valley in the Sierra de Salinas Range, and in chaparral communities in the northern portion of the Gabilan Range (

Figure 4-6). High and moderate fire hazard severity zones exist primarily along the southern inland areas of the RCIS area Table 4-2 summarizes highways, main roads, and rail ways that traverse areas that are within high fire hazard severity zones.

Table 4-2. Summary of Wildfire Risks for Transportation Assets

Monterey County Transportation Assets	Wildfire Hazard Severity Zones		
	Moderate	High	Very High
Highways			
State Route 68 near Corral De Tierra	0.5 miles	4.5 miles	5.2 miles
State Route 25 near Lonoak	8.8 miles	3.2 miles	
State Route 1 Big Sur area		10.0 miles	34.4 miles
U.S. Highway 101 Elkhorn Slough area	0.8 miles	10.8 miles	
U.S. Highway 101 near San Lucas, San Ardo, and Wunpost	38.4	13.4	
State Route 146 near Harlem	0.4 miles	5.0 miles	1.6 miles
State Route 198 near Priest Valley	22.4 miles	34.3 miles	
Main Roads			
East Carmel Valley Road (near Carmel Valley)		0.5 mile	0.7 mile
San Miguel Canyon Road (near Manzanita County Park)	0.3 mile	0.2 mile	
Vierra Canyon Road (near Prunedale)		0.2 mile	
Rail Lines			
Union Pacific (Elkhorn Slough area, east of Salinas River near Harlem, Metz, and San Ardo)	21.0 miles	16.4 miles	

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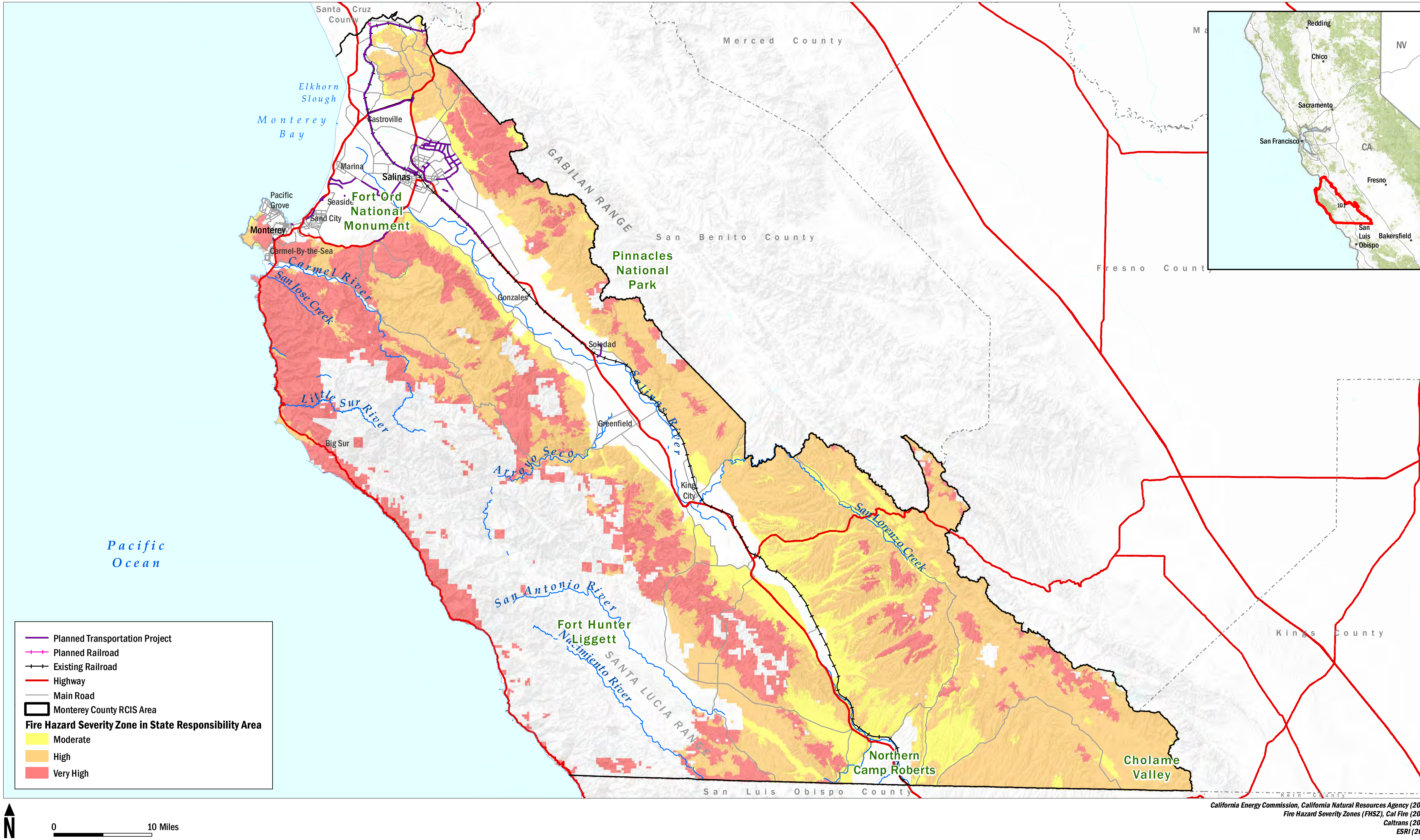

California Energy Commission, California Natural Resources Agency (2019), Fire Hazard Severity Zones (FHSZ), Cal Fire (2007), Caltrans (2019), ESRI (2016)

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FIGURE 4-6

Fire Hazard Severity Zones

Potential impacts on roadways (highways and major roads) include:

- Impassable roads because of wildfire and smoke;
- Increased emergency response times because of road closures;
- Limited access to neighborhoods or commercial areas during and after fires;
- Landslides that may follow fire events, damaging roadways;
- Extended travel time for passengers required to drive around areas affected by fires; and
- Large-scale effects on commercial shipping that are dependent on corridors.

Potential impacts for rail lines include:

- Delayed or canceled passenger or freight service during fires;
- Damage to wooden ties, power switches, derails, and signals associated with railways ;
- Landslides that may follow fire events, damaging railways; and
- Direct wildfire impacts leaving railway inoperable, affecting regional and statewide public transportation, freight and passenger service, the regional and state economy, and possible social consequences from loss of access to jobs in the region.

4.3 Extreme Heat

A review of previously completed and ongoing climate studies in the RCIS area was performed to understand the potential impacts that extreme heat poses on regional transportation infrastructure. Although all transportation assets are exposed to the same amount of incoming solar radiation as the surrounding environment, the dark surfaces of asphalt roadways and rail lines absorb more solar radiation, elevating their local surface temperature and thus exposure to extreme heat. Increasing temperatures can have considerable impacts on transportation infrastructure, particularly when temperatures exceed conditions for which the system has been designed. Transportation infrastructure traversing inland areas is particularly vulnerable to extreme heat, because inland areas have higher temperatures than coastal areas. Prolonged roadway exposure to extreme heat may include the following impacts:

- Early deformation or buckling of asphalt roadways, leading to safety issues, temporary road closures, or higher costs of infrastructure maintenance and repairs (Daniel et al. 2013);
- Increased travel time including emergency response times because of road closure during repairs; and

- An increase in the number of roadway accidents or, in an extreme scenario, hazardous waste spillage, due to maintenance issues.

Potential impacts on rail lines include:

- Railway buckling or kinking because of metal expansion;
- Possible derailment from railway deformation;
- Increased maintenance, repair, and inspection costs; and
- Delayed passenger or freight service during heat speed restrictions, which may become more frequent and occur for longer durations.

5. CONCLUSION

In the RCIS area, climate change is projected to pose an increasing risk for transportation infrastructure, primarily through more severe, frequent flooding, an increase in the intensity and extent of areas prone to wildfires, and infrastructure damage because of extreme heat days. Although the transportation infrastructure in the RCIS area has been designed to accommodate a large range of climatic conditions, it currently often disrupted by natural disasters that will be exacerbated by climate change. Projected exposure to climate hazards will affect the reliability and capacity of transportation networks, while also increasing the cost of the transportation system through more frequent maintenance and replacement of physical assets.

Transportation infrastructure in Elkhorn Slough and the along the oceanfront areas of the City of Monterey was identified as highly vulnerable to rising sea levels because of coastal flood exposure. Sections of roadways and rail lines running through Elkhorn Slough already are flooded routinely during spring tide conditions, causing traffic and operational disruptions. Sea level rise also will influence coastal erosion, which was not evaluated in this assessment, but will have large implications for the transportation assets in the RCIS area. Much of the coastline is characterized by a series of eroding coastal cliffs and is undeveloped, except the scenic and popular State Route 1, which traces much of the cliff's edge. Although considerable uncertainty exists in historic cliff erosion rates and their shoreline variability because of limited data availability, many studies agree that sea levels will exacerbate future erosion rates (City of Monterey 2016; USGS 2007). Landslides commonly affect State Route 1 access and recently have triggered landward relocation of a section of the roadway in neighboring San Luis Obispo County.

Fluctuations in the hydrological cycle resulting from increases in temperatures, changes in precipitation patterns, and increased durations and frequency of drought conditions also are projected to affect the potential for wildfires across the RCIS area. Monterey County is connected by a series of major highways, main roads serving as arterials to cities and towns, and a rail network that provides access to the region. All of these transportation assets pass through or are in close proximity to shrublands and woodlands that can burn in wildfires, particularly highways traversing remote mountain areas. Even if the physical infrastructure would not be directly affected by fire damage, secondary effects, such as severe flooding, debris flows, landslides, and downed trees also may disrupt use of roadways and rail throughout the RCIS area.

As temperatures continue to increase through this century, highway and rail infrastructure may be affected by extreme heat days during the summer. For highways, the primary impact of extreme heat exposure may be an accelerated degradation of asphalt roadway materials. For rail, extreme heat may cause kinking or buckling of the rail line, which will affect the safety of rail operations. The potential for extreme heat impacts is highest for highways and rail lines traversing the inland RCIS area, which has higher temperatures than the coastal region.

6. REFERENCES

Cal-Adapt. 2017. *Exploring California's Climate Change Research*. Website developed by University of California, Berkeley with funding from the California Energy Commission. Available: https://cal-adapt.org/. Accessed September 17, 2019.

California Department of Forestry and Fire Protection (CAL FIRE). 2007. *Fire Hazard Severity Zones*. Available: https://osfm.fire.ca.gov/divisions/wildfire-prevention-planning-engineering/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/. Accessed September 17, 2019.

California Ocean Protection Council (OPC). 2018 (March 14). *State of California Sea-Level Rise Guidance, 2018 Update*. Available: http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf. Accessed September 17, 2019.

City of Monterey. 2016. 2016 *City of Monterey Final Sea Level Rise and Vulnerability Analyses, Existing Conditions and Issues Report*. Prepared by City of Monterey, EMC Planning Group Inc., and Revell Coastal, LLC., Monterey, CA. Available: https://monterey.org/Portals/0/Policies-Procedures/Planning/WorkProgram/LCP/16_0316_FINAL_Monterey_ExistingConditions_wAppendixA_WEB.pdf. Accessed September 13, 2019.

Intergovernmental Panel on Climate Change (IPCC). 2013. *Climate Change 2013: The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK, and New York. doi:10.1017/CBO9781107415324. Accessed September 17, 2019.

Langridge, R. 2018. *Central Coast Summary Report*. *California's Fourth Climate Change Assessment*. Publication number SUM-CCCA4-2018-006. University of California, Santa Cruz.

National Oceanic and Atmospheric Administration (NOAA). 2015. *Sea Level Rise Viewer*. Available: https://coast.noaa.gov/digitalcoast/tools/slr.html. Accessed September 17, 2019.

———. 2018. *Sea Level Trends*. Available: https://tidesandcurrents.noaa.gov/sltrends. Accessed September 17, 2019.

U.S. Geological Survey (USGS). 2007. *National Assessment of Shoreline Change, Part 4: Historical Coastal Cliff Retreat along the California Coast*. Open File Report. DOI 10.3133/ofr20071133. Available: https://pubs.er.usgs.gov/publication/ofr20071133. Accessed September 17, 2019.