CHAPTER 4

Climate Change Vulnerability

4 CLIMATE CHANGE VULNERABILITY

Climate change is not a distant or abstract issue. Whether it's smoky air from a nearby wildfire, higher energy bills from air conditioning needs during a prolonged, unseasonal heat wave, or crops that do not grow like they used to, climate change is already affecting the daily lives of Napa County residents. As such, this chapter describes climate change vulnerability across Napa County, including all six local jurisdictions within the county (hereinafter referred to as "Napa County Jurisdictions" when describing the collective government entities of the County of Napa, the Cities of American Canyon, Calistoga, Napa, and St. Helena, and the Town of Yountville). Specifically, this chapter provides an overview of the adaptation planning process and summarizes the results of the Vulnerability Assessment (VA) prepared to inform this Napa County Regional Climate Action and Adaptation Plan (RCAAP), exploring how climate change affects Napa County communities. The entire VA can be found in **Appendix G**.

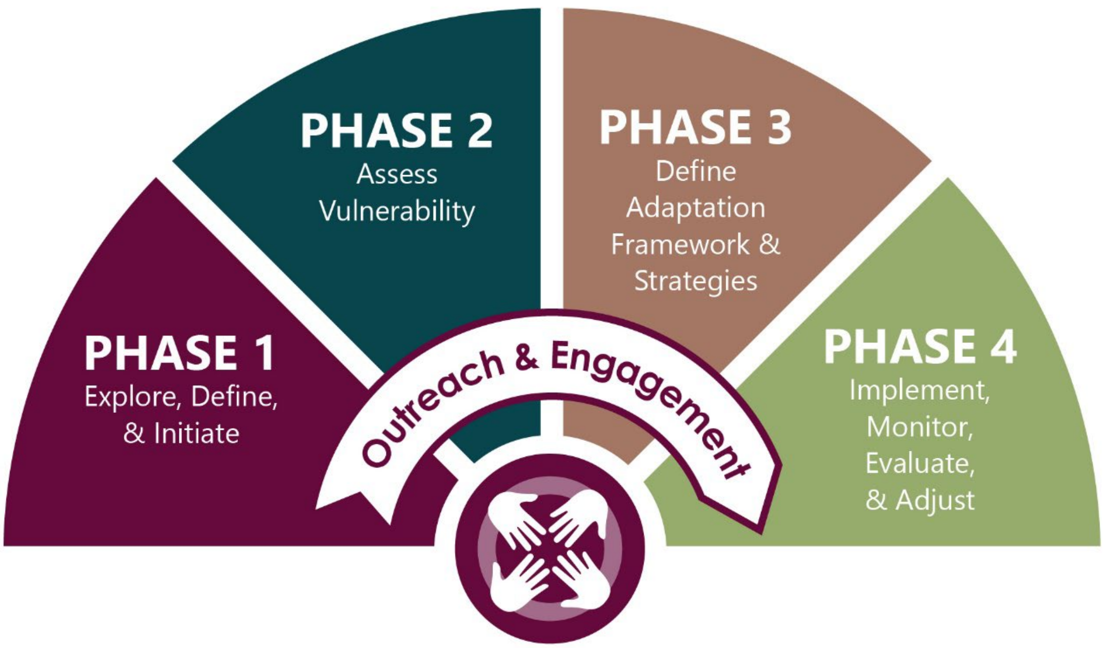
4.1 ADAPTATION PLANNING PROCESS

The adaptation planning process aims to improve community resilience in the context of climate change. A climate-resilient community is one: (1) that can effectively cope with, manage, and minimize the impacts of current and future climate hazards (and climate change more broadly); and (2) that can recover efficiently and equitably when adverse impacts are experienced. To assist local governments and other entities through the adaptation planning process and ultimately build more climate-resilient communities, the California Governor's Office of Emergency Services (Cal OES) prepared the *California Adaptation Planning Guide* (APG), which provides comprehensive vulnerability assessment and adaptation planning guidance (Cal OES 2020). Most recently updated in June 2020, the APG includes a step-by-step process (illustrated in **Figure 4.1**) that entities may use to help plan for and adapt to the impacts of climate change, and as such, all adaptation components of this RCAAP were prepared in accordance with the APG. The four phases of this process are described further below:

- **Phase 1 – Explore, Define, and Initiate**: Includes scoping and defining the adaptation planning effort. This involves identifying key stakeholders, potential climate change effects, and important physical, social, and natural assets in the community.

- **Phase 2 – Assess Vulnerability**: Includes an analysis of the potential impacts and adaptive capacity associated with climate change hazards to determine the vulnerability of populations and community assets and, ultimately, to identify how climate change could affect the community.
- **Phase 3 – Define Adaptation Framework and Strategies**: Focuses on creating an adaptation framework and developing adaptation strategies based on the results of the vulnerability assessment—that is, how the community will address the potential for harm identified in the vulnerability assessment, given the community's resources, goals, values, needs, and regional context.
- **Phase 4 – Implement, Monitor, Evaluate, and Adjust**: In this phase, the adaptation framework is implemented, consistently monitored and evaluated, and adjusted based on continual learning, feedback, and/or indicators.

Figure 4.1 Adaptation Planning Process



Source: **Cal OES 2020**; **modified by Ascent in 2025**.

4.2 VULNERABILITY ASSESSMENT OVERVIEW

The VA prepared in advance of this RCAAP, which can be found in its entirety in **Appendix G**, provides a comprehensive analysis of vulnerability to climate change across Napa County. The VA was conducted in accordance with Phase 2 of the Adaptation Planning Process (see **Figure 4.1**) and includes distinct analyses that determine exposure, sensitivity, potential impacts, adaptive capacity, and vulnerability in the context of climate change. Each of these terms, as defined by the APG, are presented below (Cal OES 2020):

- **Exposure**: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas subject to harm.
- **Sensitivity**: The degree to which a species, natural system, community, government, or other associated systems would be affected by changing climate conditions.
- **Potential Impacts**: A specific negative result of a climate change effect, generally on a particular population or asset. The combination of exposure and sensitivity often determines potential impacts.
- **Adaptive Capacity**: The combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.
- **Vulnerability**: The degree to which natural, built, and human systems are at risk from climate change impacts. Overall, vulnerability is considered a function of exposure, sensitivity, potential impacts, and adaptive capacity.

Several tools and resources were used to obtain relevant data and information to conduct these analyses, including Cal-Adapt, *California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report*, and several others. For more details on data and information used, or VA methodologies more broadly, please refer to **Appendix G**.

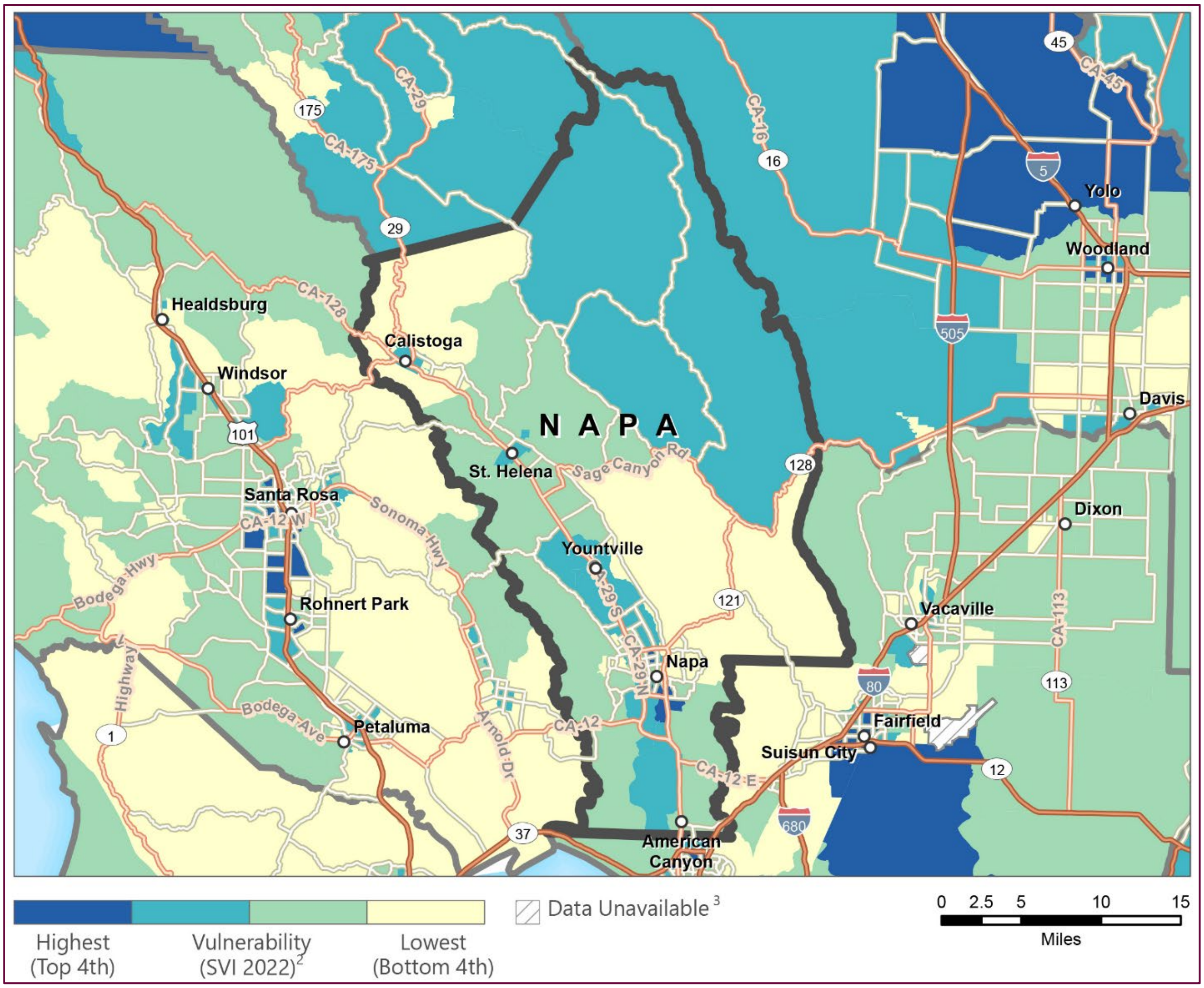
What Does the Vulnerability Assessment Consider?

While the VA is intended to comprehensively assess countywide vulnerability to climate change across multiple climate change effects, the VA includes specific discussions and considerations pertaining to three broad categories: (1) populations; (2) built environment; and (3) community functions. While not addressed as a separate category in the VA, natural resources will also be affected by climate change, and impacts on natural resources are discussed to some extent regarding effects on tourism, agriculture, and other community functions.

Photo Credit: County of Napa.

Populations refer to all people within Napa County, residents and visitors alike, with emphasis on vulnerable populations, or those who "experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts" (OPR 2018). These disproportionate realities that vulnerable populations face are often caused by physical, social, political, and economic factors (e.g., race, national origin, income inequality, sexual orientation), which are then exposed or worsened by climate impacts. While many tools exist to identify vulnerable populations within the county, one such tool used in the VA is the Social Vulnerability Index (SVI) tool developed by the U.S. Centers for Disease Control and Prevention (CDC). See **Figure 4.2** below for Napa County's SVI map, where populations in areas with a high social vulnerability may also be particularly vulnerable to climate impacts.

Figure 4.2 Napa County Social Vulnerability Index



Source: **CDC 2022**.

Napa County's built environment includes assets essential to the health and welfare of residents and visitors and are especially vital in the context of climate change. These assets range from residential and commercial buildings to an array of critical infrastructure, including essential facilities (e.g., fire stations, medical facilities, schools), transportation infrastructure (e.g., roadways, bridges, railroads), and utility infrastructure (e.g., energy, communications, water, and wastewater). And lastly, community functions are the resources, assets, operations, economic sectors, and services that are created or influenced between populations and the built environment, which include agriculture (including viticulture and viniculture), tourism and recreation, transportation and mobility, energy delivery, and housing, among others. Collectively, the county's populations, the built environment, and community functions are the primary categories accounted for when considering countywide vulnerability to climate change.

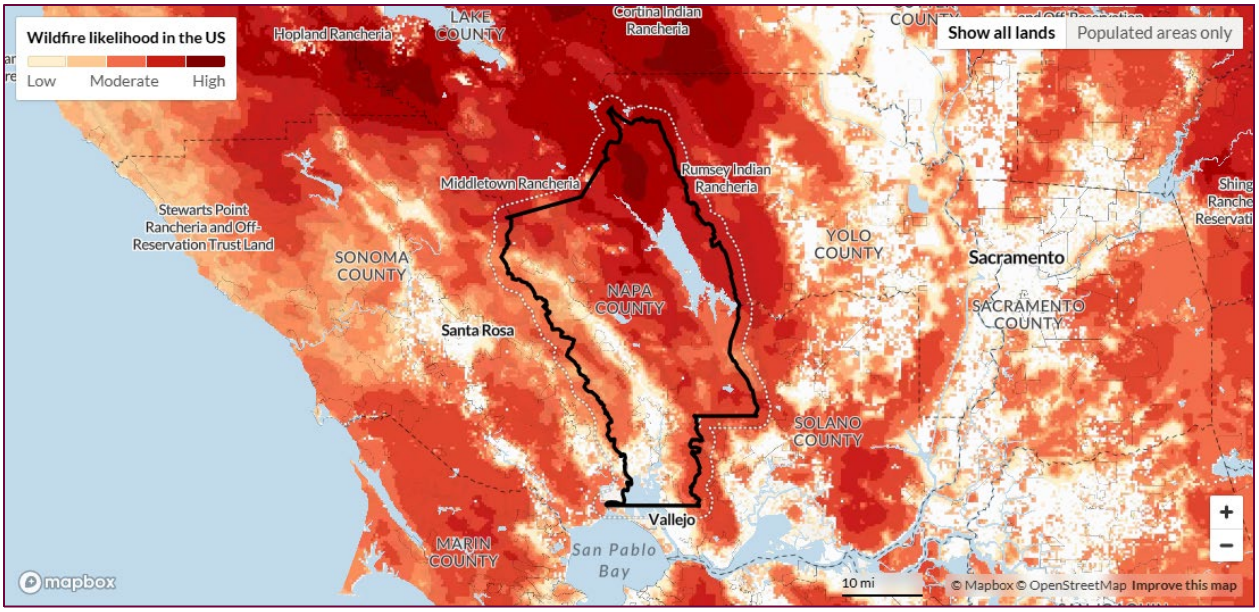
Climate Change Effects

The subsections below discuss some of the key findings for each of the five climate change effects evaluated in the VA: (1) wildfire; (2) increased temperatures and extreme heat; (3) extreme precipitation, sea level rise, and flooding; (4) drought; and (5) energy grid impacts. It should be noted that the first four climate change effects pertain to hazards that will be altered or worsened by climate change, while the last one (i.e., energy grid impacts) does not relate to a specific hazard, but rather an important topical area warranting discussion and analysis in the VA.

Wildfire

Historically, attention to wildfire in California has mostly focused on the Sierra Nevada region and Southern California, but recent large and destructive wildfires across the San Francisco Bay Area and in Napa County, such as the Tubbs, Nuns, and Atlas Fires in 2017 and the LNU Lighting Complex Fires in 2020, have rapidly shifted attention to ongoing risks in the region. In fact, Napa County has greater wildfire likelihood (i.e., the probability of wildfire burning in any given year) than 95 percent of counties in the United States, on average, which is illustrated in **Figure 4.3** below (USFS 2024).

Figure 4.3 Wildfire Likelihood in Napa County



Note: Wildfire likelihood refers to the probability of wildfire burning in any given year based on fire behavior modeling across thousands of simulations of possible fire seasons. It does not consider fire intensity, is not predictive, and does not reflect any currently forecasted weather or fire danger conditions.

Source: **USFS 2024**.

While many factors play into wildfire likelihood, and wildfire risk more broadly, including development patterns and historical fire suppression regimes, among others, climate change is one of the contributing factors. Wildfire activity has always been intricately connected to climate and continues to be an endemic part of natural systems across the state (CAL FIRE 2018). As climate change presses on, it has led to more favorable conditions for wildfire ignition and spread by contributing to a fire season that starts earlier, runs longer, and features conditions that could result in extreme fire behavior (MacDonald et al. 2023). **Table 4.1** demonstrates this notion. Specifically, it displays historical data and future projections for the average number of days per year in Napa County, where the Keetch-Byram Drought Index (KBDI) exceeds 600, representing a severe drought. Generally, while not a predictor of wildfire, the KBDI represents a simplified proxy for favorability of occurrence and spread of wildfire.

Table 4.1 Historical and Future Projected Number of Days Where the Keetch-Byram Drought Index Exceeds 600 in Napa County

Annual Averages	Historical (1961-1990)	Near-Term[1] (Present-2050)	Mid-Term[1] (2035-2064)	Long-Term (2070-2099) RCP 4.5[2]	Long-Term (2070-2099) RCP 8.5[3]
Number of Days where KBDI Exceeds 600	102.1	113.0	120.1	121.8	140.3
Number of Days where KBDI Exceeds 600 Change from Historical (±)	N/A	+10.9	+18	+19.7	+38.2

Notes: KBDI = Keetch-Byram Drought Index; RCP = Representative Concentration Pathway.

1 Projections for the “Near-Term” and “Mid-Term” timescales are based on RCP 8.5.

2 RCP 4.5 represents a lower greenhouse gas emissions scenario.

3 RCP 8.5 represents a high greenhouse gas emissions scenario.

4 KBDI, while not a predictor of wildfire, represents a simplified proxy for favorability of occurrence and spread of wildfire.

Source: **CEC 2024a**.

The potential impacts of wildfire on Napa County’s people, built environment, and community functions are wide-ranging. First, the risk of direct exposure of people and the built environment to wildfire is especially worrisome for those located in the wildland-urban interface (WUI). Direct exposure can result in severe injuries to people and can cause significant damage to residential and non-residential buildings, critical facilities, roadways, and bridges. Additionally, smoke and air pollution linked to wildfire can be a severe human health hazard, potentially leading to cognitive impairment, premature births, respiratory illnesses, and the worsening of pre-existing conditions. Wildfires can also create hazardous conditions even after they are suppressed, notably through destructive debris flows triggered by extreme post-fire precipitation, lost vegetation, and exposed soil. Further, a Public Safety Power Shutoff (PSPS) event may be activated during high wildfire risk conditions. While PSPS events are meant to prevent the ignition of potentially widespread, devastating wildfires, vulnerable populations without alternate power options may be adversely affected by the PSPS event itself, for example, if they lose air conditioning or refrigeration during extreme heat conditions. More potential impacts of wildfire are discussed in **Appendix G**.

Photo Credit: Adobe Stock.

Increased Temperatures and Extreme Heat

Napa County has experienced, and is projected to continue experiencing, increases in temperature and extreme heat because of climate change. According to Cal-Adapt, the average annual maximum and minimum temperatures across the county are projected to rise between 5- and 8-degrees Fahrenheit (°F) from their historical averages by the end of the century, depending on current and future global GHG emissions levels (CEC 2024b). Similarly, there will be notable increases in extreme heat events. **Table 4.2** displays historical data and future projections for increased temperatures and extreme heat in Napa County across multiple timescales through 2099. Acknowledging that the data in the table represents Napa County as a whole, it should be noted that both temperature and extreme heat can vary slightly depending on location within the county due to various geographic, topographic, and climatological factors. However, the general increasing trends hold true regardless of location.

Extreme heat thresholds are unique to any location. Napa County's threshold is 98.6 °F, which means that 98 percent of daily maximum temperatures in the county between the months of April and October from 1961 to 1990 were below this temperature.

Table 4.2 Historical and Future Projected Temperatures and Extreme Heat in Napa County

Annual Averages	Historical (1961-1990)	Near-Term[1] (Present-2050)	Mid-Term[1] (2035-2064)	Long-Term (2070-2099) RCP 4.5[2]	Long-Term (2070-2099) RCP 8.5[3]
Temperature					
Maximum Temperature (°F)	71.1	74.7	76.0	76.4	79.2
Maximum Temperature Change from Historical (±°F)	N/A	+3.6	+4.9	+5.3	+8.1
Minimum Temperature (°F)	43.6	47.2	48.3	48.7	51.9
Minimum Temperature Change from Historical (±°F)	N/A	+3.6	+4.7	+5.1	+8.3
Extreme Heat					
Number of Extreme Heat Days[4]	4.3	15.9	22.1	24.0	40.0
Number of Heat Waves[5]	0.2	1.5	2.5	2.6	5.4
Number of Days in Longest Stretch of Consecutive Extreme Heat Days	2.1	5.0	6.2	6.2	10.1

Notes: °F = degrees Fahrenheit; N/A = not applicable; RCP = Representative Concentration Pathway.

[1] Projections for the "Near-Term" and "Mid-Term" timescales are based on RCP 8.5.

[2] RCP 4.5 represents a lower greenhouse gas emissions scenario.

[3] RCP 8.5 represents a high greenhouse gas emissions scenario.

[4] The threshold for an extreme heat day in Napa County is 98.6 °F.

[5] Heat waves are defined by Cal-Adapt as four or more consecutive extreme heat days.

Source: **CEC 2024b**, **2024c**.

People across Napa County are at significant risk of being harmed by increased temperatures and extreme heat. Extreme heat can be harmful to public health, both directly and indirectly. Extreme heat itself can cause heat stroke and other heat-related illnesses, increase the risk of cardiovascular disease, respiratory disease, kidney failure, and preterm births, and exacerbate other pre-existing conditions in specific vulnerable populations, such as the medically fragile or chronically ill (LAO 2022). Additionally, extreme heat and rising temperatures can heighten allergies and intensify the photochemical reactions that produce smog, ground-level ozone, and fine particulate matter measuring 2.5 micrometers or smaller ($PM_{2.5}$), which can be detrimental to human health. Further, increased temperatures and extreme heat may lead to a substantial increase in air conditioning demand across the county, placing more stress on the electrical grid, leading to higher electricity bills for residents who have air conditioning and causing disproportionate impacts on individuals or families residing in units that do not have air conditioning. Further, the county's transportation systems risk being adversely affected by increased temperatures and extreme heat. During prolonged periods of increased temperatures or extreme heat, pavement may deteriorate, rail lines may buckle, the structural integrity of bridges may be compromised, air conditioning in buses could fail, and overall transportation maintenance costs may increase (Caltrans 2018; Cambridge Systematics 2015). Further details on the potential impacts of increased temperatures and extreme heat can be found in the VA, located in **Appendix G**.

Extreme Precipitation, Sea Level Rise, and Flooding

Similar to increased temperatures and extreme heat, Napa County is projected to experience a steady increase in average annual precipitation through the end of the century, with much of that precipitation likely to occur in the form of extreme precipitation events. According to Cal-Adapt, the historical average annual precipitation in Napa County is 31.3 inches, and the historical average annual number of extreme precipitation events is 3.3. As shown in **Table 4.3**, the average annual precipitation across the county may rise to 41 inches, with the number of extreme precipitation events potentially exceeding 5 per year by the end of the century, depending on the level of current and future GHG emissions (CEC 2024b, 2024d).

Like extreme heat thresholds, extreme precipitation thresholds are unique to any location. Napa county's threshold is 1.47 inches of precipitation over a two-day period.

Table 4.3 Historical and Future Projected Precipitation and Extreme Precipitation in Napa County

Annual Averages	Historical (1961-1990)	Near-Term[1] (Present-2050)	Mid-Term[1] (2035-2064)	Long-Term (2070-2099) RCP 4.5[2]	Long-Term (2070-2099) RCP 8.5[3]
Precipitation					
Precipitation	31.3	36.2	36.9	34.0	41.0
Precipitation Change from Historical (±)	N/A	+4.9	+5.6	+2.7	+9.7
Extreme Precipitation					
Number of Extreme Precipitation Events[4]	3.3	3.9	4.3	4.2	5.4
Number of Extreme Precipitation Events[4] Change from Historical (±)	N/A	+0.6	+1.0	+0.9	+2.1

Notes: N/A = not applicable; RCP = Representative Concentration Pathway.

1 Projections for the "Near-Term" and "Mid-Term" timescales are based on RCP 8.5.

2 RCP 4.5 represents a lower greenhouse gas emissions scenario.

3 RCP 8.5 represents a high greenhouse gas emissions scenario.

4 The threshold for an extreme precipitation event in Napa County is 1.47 inches over a two-day period.

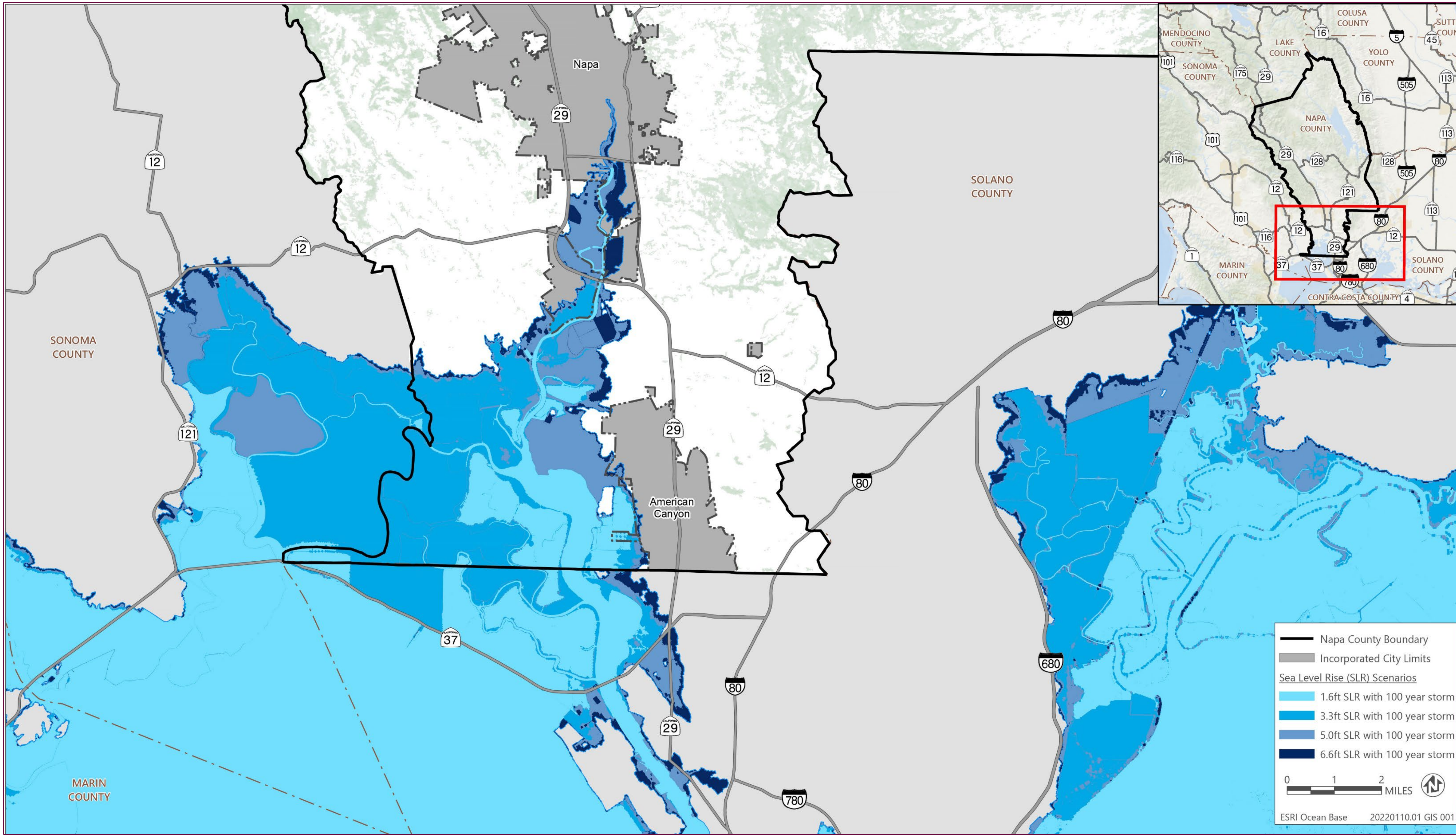
Source: **CEC 2024b**, **2024d**.

Photo Credit: Adobe Stock.

In general, the San Francisco Bay Area exhibits “booms and busts,” which refers to the existence of both very wet years and very dry years. The amount of precipitation that falls in any particular year is largely influenced by occurrences of large, discrete winter storms, also known as atmospheric rivers, which often provide a substantial fraction of the region’s annual precipitation, inclusive of Napa County (OPR, CEC, and CNRA 2018). Extreme precipitation from these atmospheric rivers may prove to be more variable, volatile, and potentially more severe. In addition to extreme precipitation, a portion of the county is exposed to sea level rise, namely the southwestern portion of the county that includes areas of American Canyon, Napa, and the unincorporated county. While most of these areas are undeveloped, some developed areas are at risk. **Figure 4.4** displays various sea level rise scenarios coupled with the presence of a 100-year storm, showing where inundation would occur (Our Coast Our Future 2024).

Increased annual precipitation, extreme precipitation events, and sea level rise can all expose the county to various coastal and inland flood impacts through temporary flooding and permanent inundation. While thousands of residents and almost $2 billion worth of residential property are located within the county’s 100- and 500-year floodplains, putting them at direct risk and exposure to flood impacts, the range of potential impacts associated with flooding in the county is much broader. These potential impacts range from public health concerns (e.g., overflow of sewage systems which can promote water- and food-borne illnesses), transportation network disruptions, and adverse impacts on local businesses, to recreation and tourism challenges, disproportionate impacts on vulnerable populations, and compromising critical infrastructure integrity—among many others. Further details on potential impacts can be found in **Appendix G**.

Figure 4.4 Napa County Sea Level Rise Scenarios



Source: **Data downloaded from Our Coast Our Future in 2024; adapted by Ascent in 2024**.

Drought

California, inclusive of Napa County, has a highly variable climate that is susceptible to prolonged periods of droughts, and recent research suggests that extended drought occurrences (or "mega-droughts") could become more common in future decades (CEC 2024a). As discussed previously, wet years in the state are likely to become wetter, while dry years will likely become drier, but dry years are likely to be followed by additional dry years. According to Cal-Adapt, the maximum length of a dry spell in Napa County, which is defined as the maximum number of consecutive days with precipitation less than 1 millimeter, is projected to increase through the end of the century if current GHG emissions trends continue (see **Table 4.4**). While the actual precipitation amounts will change year-to-year, this supports the general notion that drought may become more pervasive in the county.

Table 4.4 Historical and Future Projected Length of Dry Spells in Napa County

Annual Averages	Historical (1961-1990)	Near-Term[1] (Present-2050)	Mid-Term[1] (2035-2064)	Long-Term (2070-2099) RCP 4.5[2]	Long-Term (2070-2099) RCP 8.5[3]
Maximum Length of Dry Spell[4] (days)	110.8	111.2	111.2	110.3	116.4
Maximum Length of Dry Spell[4] Change from Historical (± days)	N/A	+0.4	+0.4	-0.5	+5.6

Notes: °F = degrees Fahrenheit; N/A = not applicable; RCP = Representative Concentration Pathway.

1 Projections for the "Near-Term" and "Mid-Term" timescales are based on RCP 8.5.

2 RCP 4.5 represents a lower greenhouse gas emissions scenario.

3 RCP 8.5 represents a high greenhouse gas emissions scenario.

4 A dry spell refers to the maximum number of consecutive days with precipitation less than 1 millimeter.

Source: **CEC 2024a**.

When it comes to the potential impacts of drought, one of the most notable impacts is on the county's water supply. While local drought trends are important to consider for the county's water supply, it should be noted that most of the municipal water supply in the county is sourced from the State Water Project and local reservoirs, which can be affected by broader statewide drought trends. Much of the agriculture industry and many residents in the unincorporated portions of the county rely on groundwater as their only water source. The Napa Valley Subbasin is highly responsive to wet and dry conditions, and successive years of drought could have a major impact on residents and the economy. Limited water supplies, and drought more broadly, can result in an array of cascading impacts throughout the county, including (but not limited to) potential water restrictions, higher water and food prices, reduced air and water quality, increased tree mortality, and wine industry impacts. Each potential impact is discussed further in **Appendix G**.

Photo Credit: Adobe Stock.

Energy Grid Impacts

Unlike the previous four subsections, which discuss climate change effects that each pertain to a specific climate hazard, this subsection pertains to an important topical area warranting discussion and analysis in the VA. In general, all climate hazards, namely extreme heat, flooding, and wildfire, can have significant potential impacts on the energy grid. Some of these potential impacts include increased energy demand (e.g., during periods of extreme heat), damage to energy grid infrastructure (e.g., power plants, substations, transmission lines), decreased grid reliability, and grid failure, which can all result in a spectrum of cascading impacts throughout the county. More details of the potential impacts to the energy grid are discussed in **Appendix G**.

Scoring for Potential Impacts, Adaptive Capacity, and Vulnerability

Based on guidance from the APG, potential impacts and adaptive capacity for each climate change effect are scored on a qualitative scale of Low to High. Descriptions of each qualitative score for potential impacts and adaptive capacity are provided in **Table 4.5**.

Table 4.5 Potential Impact and Adaptive Capacity Scoring Descriptions

Score	Potential Impact Scoring Description	Adaptive Capacity Scoring Description
Low	Impact is unlikely based on projected exposure; would result in minor consequences to public health, safety, and/or other metrics of concern.	Napa County Jurisdictions lack capacity to manage climate change effect; major changes would be required.
Medium	Impact is somewhat likely based on projected exposure; would result in some consequences to public health, safety, and/or other metrics of concern.	Napa County Jurisdictions have some capacity to manage climate change effect; some changes would be required.
High	Impact is highly likely based on projected exposure; would result in substantial consequences to public health, safety, and/or other metrics of concern.	Napa County Jurisdictions have high capacity to manage climate change effect; minimal to no changes are required.

Note: Napa County Jurisdictions = the collective government entities of the County of Napa, the Cities of American Canyon, Calistoga, Napa, and St. Helena, and the Town of Yountville.

Source: **Cal OES 2020**.

After scores are determined for potential impacts and adaptive capacity, vulnerability to each climate change effect can be characterized with a score from 1 to 5. **Table 4.6** presents the rubric used to determine overall vulnerability scores based on the magnitude of potential impacts on populations, the built environment, and community functions while considering the current adaptive capacity in place to mitigate potential impacts.

Table 4.6 Vulnerability Scoring Rubric

		Potential Impacts		
		Low	Medium	High
Adaptive Capacity	Low	3	4	5
	Medium	2	3	4
	High	1	2	3

Source: **Cal OES 2020.**

Potential impact scores, adaptive capacity scores, and overall vulnerability scores for each climate change effect—wildfire; increased temperatures and extreme heat; extreme precipitation, sea level rise, and flooding; drought; and energy grid resiliency—are included in **Table 4.7** below. The VA, located in **Appendix G**, provides a detailed account of how each score was determined. The table shows that increased temperatures, extreme heat, and drought had the highest vulnerability scores at 4, meaning that these climate change effects should be highly prioritized within Napa County. However, all the climate change effects that were evaluated ranked Medium to High in potential impacts, meaning that despite any current adaptive capacity already in place to manage those climate change effects, there is some level of risk for experiencing negative potential impacts, especially if current adaptive measures fail. Noting that, the adaptation strategies presented in **Chapter 5** of this RCAAP are directly informed by the results of the VA and aim to further bolster adaptive capacity and resilience across the county to all climate change effects.

Table 4.7 Potential Impact, Adaptive Capacity, and Vulnerability Scoring Summary for Napa County

Climate Change Effect	Potential Impact Score	Adaptive Capacity Score	Vulnerability Score
Wildfire	High	High	**3**
Increased Temperatures and Extreme Heat	High	Medium	**4**
Extreme Precipitation, Sea Level Rise, and Flooding	Medium	Medium/High	**2-3**
Drought	High	Medium	**4**
Energy Grid Impacts	Medium	Medium	**3**

Source: **Evaluated by Ascent in 2024**.