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CLIMATE CHANGE VULNERABILITY ASSESSMENT REPORT

City of Santa Rosa

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INTRODUCTION

The City of Santa Rosa (City) prepared this Climate Change Vulnerability Assessment Report in conformance with State of California requirements, as established in California Government Code Section 65302(g)(4), to assess climate change vulnerability and address climate change adaptation and resilience as part of Santa Rosa Forward, the City's General Plan Update. The goal of the State's requirement is to enable the community to prepare for, respond to, withstand, and recover from disruptions exacerbated or caused by climate change. This report discusses the regulatory framework and method for integrating adaptation and resilience into City policies, the climate change hazards affecting the resilience of Santa Rosa, specific populations and assets included in the assessment, and a summary of the climate change vulnerability assessment results. The Climate Change Vulnerability Assessment Report builds off the workshop series conducted by EcoAdapt in January 2021 and uses the *Climate Vulnerability and Adaptation Report for Santa Rosa* for climate change hazard projections, populations and assets, potential impacts, and adaptive capacity. A more detailed description of climate change hazard projections can be found in the EcoAdapt report. Appendix A provides a list of abbreviations and key terms used throughout the Climate Change Vulnerability Assessment Report.

Community Profile

The City of Santa Rosa is in the central portion of Sonoma County, about 45 miles north of San Francisco. The Northern California Coast Ranges rise to a maximum height of 8,098 feet above sea level and the city sits in the southern portion of this mountain range at 164 feet above sea level. Santa Rosa has a Mediterranean climate, with rain in the winters and hot, dry summers. According to the General Plan Update's Existing Conditions Report, Santa Rosa is home to approximately 181,000 residents.

Santa Rosa covers approximately 41.1 square miles and was originally home to the Graton Rancheria, Southern Pomo, and Wappo Tribal Nations. Approximately 90 percent of the city is developed; 64 percent is residential; 17 percent is commercial, industrial, public/institutional; and 9 percent is parks. The remaining land is agriculture, open space, or vacant land. Santa Rosa is also the regional hub of Sonoma County, offering a variety of services, job opportunities, and entertainment options for residents in nearby communities in Sonoma County.

State agencies divide California into several distinct climate zones, and Santa Rosa is part of Climate Zone 2. This climate zone covers the hilly Northern Coastal range and expands east to the Northern Central Valley and south to the San Francisco Bay Area.[1] In Santa Rosa, annual average high temperatures range from 55 degrees Fahrenheit in January to 84 degrees Fahrenheit in July. Low temperatures range from 37 degrees Fahrenheit in January to 52 degrees Fahrenheit in July and August. The city receives an average of approximately 38 inches of precipitation. Most precipitation falls between October and May, with rare occurrences of summer storms. The Mediterranean climate and cold, rainy winters make Santa Rosa a prime location for agricultural production and outdoor recreation activities.

Santa Rosa's primary transportation access is from Highway 101, the primary highway in central Sonoma County, and State Route 12 (SR-12). SR-12 runs perpendicular to Highway 101, connecting Sebastopol to the City of Sonoma. Other major roadways include Fountaingrove Parkway, Montgomery Drive, Santa Rosa Avenue, and College Avenue. The Santa Rosa Transit Mall is the busiest transit hub north of the Bay Area. Local transit is provided by CityBus, while Sonoma County Transit, Golden Gate Transit, Mendocino Transit, and Greyhound provide regional bus services. Sonoma-Marin Area Rail Transit (SMART) provides commuter rail services to Santa Rosa and other communities in the region.

Regulatory Framework

In 2015, the State of California adopted Senate Bill (SB) 379, establishing Section 65302(g)(4) of the California Government Code to require the Safety Element of the General Plan to include more information about wildfire hazards, flooding risks, and other short-term and long-term threats posed by climate change. SB 379 is the foundation for climate adaptation and resiliency in General Plan Safety Elements, as it requires local governments to conduct vulnerability assessments as part of their long-range public safety planning efforts and to prepare policies that will protect against harm caused by climate change.

Other important updates to Section 65302(g) of the California Government Code related to Safety Elements, climate change, and resiliency include SB 1035, SB 99, and Assembly Bill (AB) 747. SB 1035 amended Section 65302(g)(3) of the California Government Code to require local governments to review, and update as needed, their Safety Element during an update to their Housing Element or Local Hazard Mitigation Plan (LHMP) (or no less than every eight years). Any revisions to the Safety Element should include updated information related to flood hazards, fire hazards, and climate adaptation and resilience. SB 99 amended Section 65302(g) of the California Government Code and requires jurisdictions to review and update the Safety Element to include information identifying residential developments in hazard areas that do not have at least two emergency evacuation routes. AB 747 added Section 65302.15 to the California Government Code, which will go into effect in January 2022, and will require local governments to identify the capacity, safety, and viability of evacuation routes in the Safety Element or LHMP. The City's climate change vulnerability assessment, along with the update to the Safety Element, will help the City meet the State's requirements and support consistency with and integration of the General Plan and LHMP.

The State of California prepared a guidance document, the *California Adaptation Planning Guide* (APG), to assist communities in addressing climate adaptation and resilience, and complying with Section 65302(g)(4) of the California Government Code. This guide presents a step-by-step process for gathering the best available climate change science and projections of future conditions, completing a climate change vulnerability assessment, creating adaptation strategies, and integrating those strategies into General Plans and other policy documents. The City's climate change vulnerability assessment is consistent with the guidance and recommended methods provided in the APG.

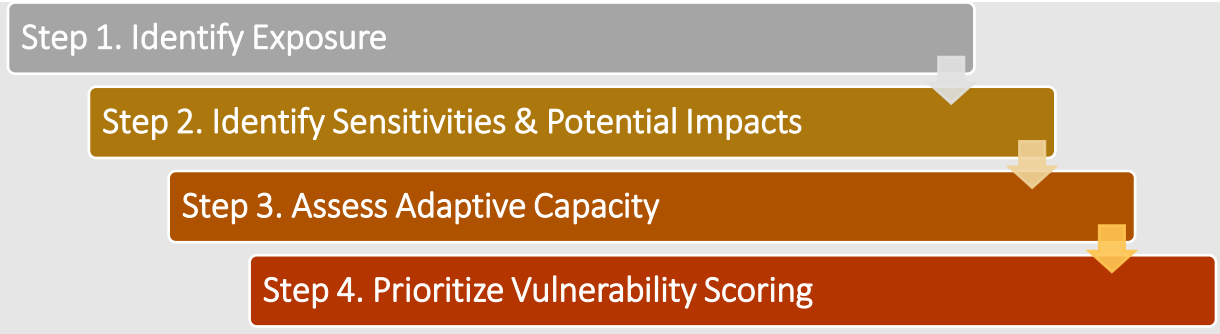
Climate Science Overview

Climate change is a long-term change in the average meteorological conditions in an area. Currently, the global climate is changing due to an increase in greenhouse gas (GHG) emissions that trap heat near the Earth's surface. While some levels of these gases are necessary to maintain a comfortable temperature on Earth, an increased concentration of these gases due to human activity traps additional heat, changing Earth's climate system in several ways. These effects can lead to an increase in frequency and intensity of climate change hazards, which according to the APG, have the potential to cause fatalities, injuries, property and infrastructure damage, interruption of business, and other types of harm or loss. These hazards can include extreme heat, severe storms, wildfires, landslides, and drought conditions, among others. This Climate Change Vulnerability Assessment Report evaluates the impacts created by these hazards in and around Santa Rosa and the ability of Santa Rosa's populations and community to resist and recover from these hazards, to assess which aspects of the community are most vulnerable to climate change.

Method

The Climate Change Vulnerability Assessment analyzes how a changing climate may harm the City of Santa Rosa, and which aspects of the community – including people, buildings and infrastructure, ecosystems and natural resources, services, and economic drivers – are most vulnerable to its effects. The vulnerability assessment primarily follows the recommended process published in the APG in 2020 by the California Governor's Office of Emergency Services (Cal OES) and recommended by the Governor's Office of Planning and Research. This includes a four-step process: (1) characterizing the community's exposure to current and projected climate hazards; (2) identifying potential sensitivities and potential impacts to community populations and assets; (3) evaluating the current ability of the City, populations, and assets to cope with climate impacts, also referred to as its adaptive capacity; and (4) identifying priority vulnerabilities based on systematic scoring. These steps are shown in **Figure 1** and further described in this section.

Figure 1. California Adaptation Planning Guide Vulnerability Assessment Method



Step 1: Identify Exposure. The goal of this step is to characterize the community's exposure to current and projected climate change hazards. Many projections of climate change hazards rely on multiple scenarios that reflect different levels of how global GHG emissions and atmospheric GHG concentrations may change over time. The Intergovernmental Panel on Climate Change (IPCC), an organization that represents the global scientific consensus about climate change, has identified four climate scenarios, also called Representative Concentration Pathways (RCPs), that can be used to project future conditions. RCPs are labeled with different numbers (e.g., RCP 2.6, RCP 6) that refer to the increase in the amount of energy that reaches each square meter of Earth's surface under that scenario. The four RCPs are:

- **RCP 2.6:** Under this scenario, global GHG emissions peak around 2020 and then decline quickly.
- **RCP 4.5:** Under this scenario, global GHG emissions peak around 2040 and then decline.
- **RCP 6:** Global emissions continue to rise until the middle of the century.
- **RCP 8.5:** Global emissions continue to increase at least until the end of the century.

The Cal-Adapt database, which provides California-specific climate change hazard projections, uses RCP 4.5 for a low emissions scenario and RCP 8.5 for a high emissions scenario. The Governor's Office of Planning and Research *Planning and Investing for a Resilient California* document and the APG recommend using RCP 8.5 for analyses considering impacts through 2050, as there are minimal differences between emission scenarios for the first half of the century. The APG also recommends using RCP 8.5 for late-century projections, for a more conservative and risk-adverse approach. The City used the RCP 8.5 GHG emission scenario results provided by the Cal-Adapt database and other resources for this assessment.

The first step of this Climate Change Vulnerability Assessment was to confirm hazards expected to occur in the City of Santa Rosa. The City identified eight climate change hazards for this assessment, listed here and discussed in more detail in the Climate Change Hazards of Concern section and EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa*.[i]

Sensitivity: The level to which a species, natural system, or community, government, etc., would be affected by changing climate conditions.

Source: California Adaptation Planning Guide

1. Agricultural and Ecosystem Pests and Diseases
2. Drought
3. Extreme Heat
4. Human Health Hazards
5. Landslides
6. Severe Wind
7. Severe Storms
8. Wildfire

The City derived the climate change hazard data from up-to-date information, including the Cal-Adapt database, the APG, the *California 4th Climate Change Assessment,* the California Geological Survey, the Federal Emergency Management Agency (FEMA), the California Department of Forestry and Fire Protection (CAL FIRE), the Santa Rosa 2016 LHMP and EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa*.

Step 2. Identify Sensitivities and Potential Impacts. This step included evaluating past and potential future climate change impacts to community populations and assets. The City first identified a list of populations and assets to include in the assessment with the following five categories:

1. Populations: People that experience a heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to adapt to or recover from climate impacts.
2. Buildings and Infrastructure: Structures that provide various services to Santa Rosa community members and visitors.
3. Economic Drivers: Economic sectors and activities that make significant contributions to the Santa Rosa economy.
4. Ecosystems and Natural Resources: Types of wild and natural lands within the city boundary.
5. Key Services: Important functions to community members provided by government agencies and private companies.

This list included 20 populations, 23 infrastructure and building types, 8 economic drivers, 6 ecosystems and natural resources, and 8 key services. (The Populations and Assets section presented later in this report describes these populations and assets.) The populations and assets for the Climate Change Vulnerability Assessment were derived from the results of the EcoAdapt Climate Change Adaptation Workshop series held in January 2021, which included participants from various City departments, Sonoma County, and community-based organizations. After confirmation of this list, the City looked at which hazards are likely to affect which populations and assets, because not all hazards will affect all populations or assets. For example, human health hazards are likely to impact most populations but are

[i] Please refer to EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa* report when reading through the Climate Change Hazards of Concern section and Critical Vulnerabilities section of this report.

not likely to physically affect parks and open space or school buildings. The outcome of this step was an applicability matrix that identified whether a population or asset is likely to be exposed to a hazard. If a population or asset has the potential to be affected directly or indirectly by a hazard, a "yes" was indicated in the appropriate box. Direct impacts affect buildings and infrastructure, health or populations, or immediate operations of economic drivers or community services, and they can lead to indirect impacts on the broader system or community, including populations or asset types in a different category. For example, severe wind can *directly* damage electrical transmission lines causing power outages, which can *indirectly* impact persons with chronic illnesses who depend on the electricity for life support systems. Therefore, both electrical transmission lines and persons with chronic illnesses were marked as "yes" for being affected by severe wind and would be evaluated in the assessment.

> **Exposure:** The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm.
>
> **Impact:** The effects (especially the negative effects) of a hazard or other conditions associated with climate change.
>
> *Source: California Adaptation Planning Guide*

After the applicability review, the City evaluated potential impacts to the applicable populations and community assets. To identify how great the impacts of each relevant hazard are on the populations and community assets, the City considered a number of different questions that helped ensure the assessment broadly covered a range of potential harm. Examples of these questions include:

- Could the hazard(s) cause injury or damage?
- Is there a risk of behavioral or mental harm, loss of economic activity, or other nonphysical effects?
- How many people or community assets could be harmed both directly and indirectly?
- How long would the impacts persist?
- Is there a substantial chance of death or widespread destruction?

Based on the results of the impact assessment, the City ranked each population and asset low, medium, or high for each relevant hazard. Impact is considered a negative quality, and therefore a higher impact score means that there is a higher potential for harm to a population or asset. A lower impact score means that there is a lower potential for harm to a population or asset. Table 1 provides more detail about what each score means.

Table 1. Rubric for Impact Scoring

Impact Score	Meaning (People and Ecosystems)	Meaning (Buildings and Infrastructure, Services, and Economic Drivers)
Low Impact	Community members may not notice any change. If noticed, effect would be minor with only occasional disruptions.	Damage, interruption in service, or impacts on the local economy is small or intermittent enough to mostly go unnoticed. If noticed, effects are only minor.
Medium Impact	There is a marked impact to the community. Quality of life may decline. Impacts may be chronic, and at times substantial.	Damage, service interruptions, and other impacts are clearly evident. Impacts may be chronic and occasionally substantial.
High Impact	The well-being of the community declines significantly. The community's current lifestyle and behavior may no longer be possible. There is a severe risk of widespread injury or death to people, or of significant or total ecosystem loss.	Buildings, infrastructure, and services often or always cannot function as intended or needed to meet community demand. Large sections of the economy experience major hardships or are not feasible.

Step 3. Assess Adaptive Capacity. Adaptive capacity is the ability of populations and community assets to prepare for, respond to, and recover from the impacts of climate change. Each population and asset was evaluated for adaptive capacity by considering the following questions:

1. Are there existing programs, policies, or funding to provide assistance?
2. Are there barriers that limit response or recovery? Are these barriers created by financial limitations, political challenges, lack of access to technology or other resources, or other factors?
3. Do alternatives exist in or near Santa Rosa that community members can use?

> **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."
>
> *Source: California Adaptation Planning Guide*

Based on the results of the adaptive capacity assessment, the City ranked the adaptive capacity of each population or asset as low, medium, or high. Adaptive capacity is considered a positive attribute, so a higher adaptive capacity score will mean that a population or asset may be more adaptable to the hazard. A lower adaptive capacity score means that a population or asset may have a harder time adjusting to the changing conditions. **Table 2** provides more detail about what each score means.

Table 2. Rubric for Adaptive Capacity Scoring

Adaptive Capacity Score	Meaning
High Adaptive Capacity	Adaptation solutions are feasible for most or all sensitivities. There may be occasional or small-scale challenges to implementing adaptation methods, but populations and assets can adapt with little or no effort. Many alternatives exist in the area that can provide similar services.
Medium Adaptive Capacity	Some adaptation methods are available, but not always feasible. Adapting may create significant challenges for some sensitivities. Some alternatives exist within the jurisdiction area that can provide similar services.
Low Adaptive Capacity	Adaptive solutions are available, but they are not used due to cost, technological or other resource constraints, and/or not supported by decision-makers or the community. Alternatives may not exist that can provide similar services. Some assets may not have feasible means to adapt.

Step 4. Prioritize Vulnerability Scoring. The City used the impact and adaptive capacity scores for each population and asset for each relevant hazard to determine the vulnerability score. The vulnerability score reflects how susceptible a population or asset is to harm from a particular hazard. Vulnerability is assessed on a scale of low, medium, and high. Low vulnerability does not mean that the population or asset will be unaffected by climate change, but that the effects are likely to be less substantial. The matrix in **Table 3** shows how impact and adaptive capacity scores combine and translate into a vulnerability score. For example, extreme heat would create a high impact on energy delivery services as mechanical failures, heat damage, and high demand for electricity from cooling equipment can disrupt this service. Adaptive capacity is low because many community members need to use more electricity on extreme heat days to keep cool and retrofitting electrical equipment can be expensive. Therefore, energy delivery services have a high vulnerability to extreme heat.

> **Vulnerability:** The degree to which natural, built, and human systems are susceptible "…to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt."
>
> *Source: California Adaptation Planning Guide*

Table 3. Vulnerability Scoring Matrix

Adaptive Capacity Score	Low Impact	Medium Impact	High Impact
Low Adaptive Capacity	Medium	High	High
Medium Adaptive Capacity	Low	Medium	High
High Adaptive Capacity	Low	Low	Medium

CLIMATE CHANGE HAZARDS OF CONCERN

As described in the APG, hazards are events or physical conditions that have the potential to cause fatalities, injuries, property and infrastructure damage, interruption of business, and other types of harm or loss. Some natural hazards are not climate change related, such as earthquakes, which do not have a known connection with climate change. Climate change hazards are natural hazards that can change in frequency and intensity due to climate change. The Climate Change Vulnerability Assessment assessed the climate change hazards that are most relevant to the City of Santa Rosa. The following list generally describes the climate change hazards included in the Climate Change Vulnerability Assessment:

- **Agricultural and Ecosystem Pests and Diseases:** Pests and diseases that may affect crops, plants, vineyards, and wildlife.
- **Drought:** A drought is a period of drier than normal conditions that result in water-related problems for people, agriculture, and ecosystems.
- **Extreme Heat and Warm Nights:** Extreme heat conditions are defined as conditions that are much hotter than average for Santa Rosa. Extreme heat days in Santa Rosa are considered days with temperatures above 98.1 °F and warm nights in Santa Rosa are considered nights with temperatures above 56.3 °F.
- **Human Health Hazards:** Human health hazards are bacteria, viruses, parasites, and other organisms that can cause diseases in people. Climate-related human health hazards are usually diseases carried by animals that are considered pests, such as mice and rats, mosquitos, and ticks.
- **Landslides and Debris Flows:** A landslide happens when a slope, like the side of a hill or mountain, becomes unstable during heavy rainfall events, causing soil and rocks to slide down slope.
- **Severe Storms:** Severe storms result in heavy rainfall, hail, lightning, and flooding.
- **Severe Wind:** Severe wind occurs when sustained wind speeds exceed 40 miles per hour and last for 1 hour or longer, or winds of 58 miles per hour for any duration.
- **Wildfire:** Wildfires are defined as any unplanned fire in a wildland area or in the wildland-urban interface. Wildfire can spread into developed areas by crossing the wildland-urban interface (the zone where undeveloped wildland meets developed areas) and cause significant damage to people and property.

The climate change hazards data is based on projections provided by Cal-Adapt, the *California Fourth Climate Change Assessment*, the California Geological Survey, FEMA, and scholarly research. A more detailed description of specific climate projections for the City of Santa Rosa can be found in EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa* (http://ecoadapt.org/workshops/santa-rosa-adaptation-workshop). The Critical Vulnerabilities section presents how these hazards are expected to affect the populations and assets included in the Climate Change Vulnerability Assessment.

POPULATIONS AND ASSETS

Populations and assets are the people, infrastructure, services, economic drivers, and other community features in the City of Santa Rosa that can be affected by climate change. The Climate Change Vulnerability Assessment looks at how each population and community asset may be affected by each of the climate change hazards discussed above. The APG provides a general list of populations and assets, which the City refined and used to develop a list of 65 populations and assets that fall into five distinct asset categories: (1) populations, (2) buildings and infrastructure, (3) economic drivers, (4) ecosystems

and natural resources, and (5) key services. The following sections describe the populations and assets included in each of the five categories.

Populations

The Climate Change Vulnerability Assessment evaluated 20 populations. These populations have age, financial, health, mobility, or other characteristics that make them more likely to be directly affected by hazardous events. The City gathered data for many populations listed from the 2020 *Santa Rosa Forward Existing Conditions Report*, the Healthy Places Index,[2] EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa,* and the 2020 *Sonoma County Homeless Census Comprehensive Report.*[3] The Climate Change Vulnerability Assessment included the following populations:

1. Children (under 18)
2. Cost-burdened households
3. Households in poverty
4. Immigrant communities
5. Linguistically isolated persons
6. Low-income households
7. Low-resourced people of color
8. Outdoor workers
9. Overcrowded households
10. Persons experiencing homelessness
11. Persons living in mobile homes
12. Persons living on single-access roads
13. Persons with chronic illnesses and/or disabilities
14. Persons without a high school degree
15. Persons without access to lifelines
16. Renters
17. Seniors (65+)
18. Seniors living alone
19. Students
20. Unemployed persons

Buildings and Infrastructure

The Climate Change Vulnerability Assessment assessed the vulnerability of 23 different types of buildings and infrastructure systems in Santa Rosa. These infrastructure categories help daily activities, economic drivers, community services, and emergency response events. Several of these assets support the transportation network, energy delivery, water and wastewater services, and recreation and tourism activities. The infrastructure section of the Climate Change Vulnerability Assessment focuses on the physical effects of climate change hazards on infrastructure itself instead of the services or economic activity they provide. The City derived information on buildings and infrastructure from the 2020 *Santa Rosa Forward Existing Conditions Report;* EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa;* and other local, State, and federal sources. The Climate Change Vulnerability Assessment included the following building and infrastructure assets:

1. Biking and pedestrian trails
2. Bridges
3. Communication facilities
4. Community centers
5. Dams
6. Electrical transmission infrastructure (substations and power lines)
7. Emergency operation buildings
8. Evacuation and cooling centers
9. Flood-control infrastructure and storm drains
10. Government administration facilities
11. Hazardous materials sites
12. Homes and residential structures
13. Libraries
14. Major roads and highways
15. Natural gas pipelines: Pacific Gas and Electric Company (PG&E)
16. Parks and open space
17. Public safety buildings
18. Railway
19. Schools

20. Single-access roads
21. Solid waste facilities
22. Transit facilities
23. Water and wastewater infrastructure

Economic Drivers

The Climate Change Vulnerability Assessment evaluated the vulnerability of nine distinct economic drivers in the City of Santa Rosa. These economic assets include agriculture-related assets, major employment industries, and recreation and tourism within the city and on surrounding regional and state lands. The City obtained information on economic drivers from the 2020 *Comprehensive Annual Financial Report* and the 2020 *Santa Rosa Forward Existing Conditions Report*. The Climate Change Vulnerability Assessment included the following economic driver assets:

1. Agribusiness
2. Education
3. Healthcare
4. Major employers, including Public Administration
5. Outdoor recreation and tourism
6. Retail trade
7. Research, development, and manufacturing
8. State and regional parks

Ecosystems and Natural Resources

There are six primary ecosystems in Santa Rosa, although many can be subdivided into specific habitats. The ecosystems and natural resources section of the vulnerability assessment focuses on how the plants and wildlife in ecosystems are likely to be affected by climate change hazards and the current ability of these systems to adapt to changing conditions. The primary resource for this analysis is the City of Santa Rosa General Plan 2035 Draft Environmental Impact Report, Biological Resources chapter. The Climate Change Vulnerability Assessment included the following ecosystems and natural resources:

1. Aquatic/Riverine
2. Douglas-Fir Forest
3. Grassland
4. Oak Woodland
5. Riparian Woodland
6. Wetlands

Key Services

The Climate Change Vulnerability Assessment evaluated the vulnerability of eight different types of services in Santa Rosa. These key service categories provide essential goods, utilities, and services to residents and visitors in the city. These services are provided by public and private agencies, as well as volunteer organizations. The key services section of the vulnerability assessment focuses on the actions and services provided in these categories instead of the physical buildings and infrastructure that support the services. The Climate Change Vulnerability Assessment included the following key services:

1. Communication services
2. Emergency medical response
3. Energy delivery
4. Government administration & community services
5. Public safety services
6. Public transit services
7. Solid waste removal
8. Water and wastewater

CRITICAL VULNERABILITIES

The vulnerability assessment evaluates the impact and adaptive capacity of each population and asset for each relevant hazard. Vulnerability scores were assigned on a scale of low, medium, and high (as shown in Table 3) to reflect how susceptible the population or asset is to harm posed by the hazard. In total, the Climate Change Vulnerability Assessment considered 360 different pairings for vulnerability. This section provides a summary of the key vulnerabilities within Santa Rosa. For a complete list of vulnerability scores for all populations and assets, refer to Appendix B.

Populations

The Climate Change Vulnerability Assessment evaluated 20 populations that may be disproportionately harmed by climate change hazards. Of the 20 populations evaluated in the vulnerability assessment, 16 scored as having high vulnerability for at least one hazard type. Populations are generally most vulnerable to wildfire, extreme heat, and human health hazards. The most vulnerable populations include households in poverty, outdoor workers, low-resourced people of color, seniors living alone, and immigrant communities. The critical vulnerability descriptions below group populations together that may face similar vulnerabilities. Table 4 shows how the 16 populations were grouped into 8 populations for these descriptions.

Table 4. Population Groups for Critical Vulnerabilities

Population Group	Populations Included
Households with limited financial resources	Households in poverty
	Cost-burdened households
	Low-income households
	Unemployed persons
Persons that spend a significant amount of time outdoors	Children
	Outdoor workers
Persons with health conditions or limited mobility	Persons with chronic illnesses and/or disabilities
	Persons without access to lifelines
	Seniors
	Seniors living alone
Low-resourced and immigrant communities	Immigrant communities
	Low-resourced people of color
Persons experiencing homelessness	Persons experiencing homelessness
Persons living in mobile homes	Persons living in mobile homes
Persons living on single-access roads	Persons living on single-access roads
Overcrowded households	Overcrowded households[1]

1. Based on the Santa Rosa General Plan 2035 Housing Element and U.S. Census, overcrowded households are defined as households with more than one person per room (including all rooms except bathrooms). Persons living in households with more than 1.5 persons per room are considered severely overcrowded.

Households with limited financial resources are highly vulnerable to nearly all hazards that will impact Santa Rosa, with the exception of agriculture and ecosystem pests and diseases. These persons, especially households in poverty, are more likely to live in homes with less insulation, less structural stability, or lack of air conditioning, increasing exposure to unsafe living conditions due to mold and mildew damage from severe storms, high indoor air temperatures from extreme heat, and poor indoor air quality from wildfire smoke. Households in poverty may lack the financial means to recover from property damage, increases in water and electricity bills, or illness caused by climate change hazards. Financial assistance programs and incentives, such as the Sonoma County Energy Independence Program's property assessed clean energy (PACE) financing, rebates, and tax credits are available to assist with upgrades to some homes. However, households with financial instability may be unaware or unable to participate in these services.

Persons that spend a significant amount of time outdoors, such as children and outdoor workers, are highly vulnerable to extreme heat and wildfire. Outdoor workers are also highly vulnerable to agricultural pests and diseases, drought, human health hazards, severe wind, and severe storms.

Children tend to spend more time outdoors than many adults and may not be aware of the onset of heat-related illnesses, such as heat exhaustion or heat stroke. Reduced air quality from wildfire smoke can also decrease the ability of young children to adapt to warmer temperatures over time.

Outdoor workers are directly exposed to extreme heat, human health hazards, and the smokey air quality conditions due to the outdoor nature of their occupations. Outdoor work often involves physically intense work, which can increase the risk of medical complications. Outdoor work can be halted during hazardous conditions, such as severe storms, severe wind, and wildfire, creating economic hardships for outdoor workers. Drought, extreme heat, and agriculture pests and diseases may also harm the crops, vineyards, and livestock that outdoor workers in the agriculture industry rely on causing additional economic hardship for outdoor workers. This may limit the ability of outdoor workers to seek medical attention for heat or air quality-related illnesses. Some outdoor workers may be able to transfer industries through educational programs within the Sonoma County Adult Education Program; however, this may not be feasible for all individuals.

Persons with existing health conditions or limited mobility, such as persons with chronic health conditions and/or disabilities, persons without access to lifelines, seniors, and seniors living alone are highly vulnerable to nearly all hazards. These individuals may have compromised immune systems that make it more difficult for health professionals to treat heat, human health, or smoke-related illnesses. Seniors in particular are usually more susceptible to heat-related illnesses, pathogens, and smoke conditions because they are more likely to have medical conditions that can worsen with extreme heat, and often take medicine that makes it harder for them to stay cool. These individuals may not be able to maintain their homes or properties in defense of wildfire and severe wind, as well as have difficulty evacuating during emergencies cause by severe storms, wildfire, or landslides. Power outages from Public Safety Power Shutoff (PSPS) events due to extreme heat or severe wind can also isolate these persons and potentially cause life-support systems to fail.

Low-resourced and immigrant communities, such as immigrant communities, linguistically isolated persons, and low-resourced people of color, are highly vulnerable to drought, extreme heat, human health hazards, severe wind, severe storms, and wildfire. These populations may be hesitant or unable to seek help due to language barriers, citizenship or immigration concerns, and racially based discrimination or profiling.[4] These individuals may live in low-lying areas or less resilient structures that can be damaged by severe storms, severe wind, and wildfires. Immigrant communities and low-resourced people of color may not have the financial means to pay for increased utility costs for water and electricity due to extreme heat and drought, or increased medical costs because of human health hazards, wildfire smoke, and extreme heat. Financial assistance programs, such as PACE, are available to assist with upgrades to some homes and FEMA assistance is available post-disaster; however, they may not be accessible for those with language barriers or for immigrant communities.

Persons experiencing homelessness lack permanent and often temporary shelter, which can leave them directly exposed to high temperatures, smoke from wildfires, severe wind, flooding from severe storms, and human health hazards. These persons may not have access to cool locations, water, sunscreen, or protective equipment to increase resiliency to extreme heat, human health hazards, and smoke conditions. High winds and heavy rainfall can damage or destroy temporary shelters and personal property of persons experiencing homelessness, and recovery can be difficult for these populations.

Persons living in mobile homes are highly vulnerable to extreme heat, landslides, severe wind, and wildfire. Mobile homes are generally less resilient than other housing types, making them more susceptible to damage from landslides, severe storms, and wildfire. People who live in mobile homes are more likely to suffer harm during a hazard event due to the methods and materials used for mobile home construction. Mobile homes may also lack sufficient insulation or air conditioning, which can increase indoor air temperatures for persons living in mobile homes during extreme heat conditions and exposure to wildfire smoke. Mobile home residents may be able to receive some financial relief from the California Department of Housing and Community Development if their home is damaged in a disaster; however, not all mobile homes may qualify for this assistance.

Persons living on single-access roads can become isolated from the community if their access routes or roadways become blocked or impassable due to landslides, wildfire, downed trees and debris from severe winds, severe storms that cause flooding, and other forms of severe weather. Blocked access routes can prevent evacuation during an emergency and access by emergency personnel and first responders. Residents and business owners who live on single-access roads may be unable to obtain medical care or vital goods such as food and medicine if their access routes or roadways become blocked or impassible.

Overcrowded households are highly vulnerable to human health hazards as overcrowding conditions facilitate the spread of contagious diseases, such as respiratory diseases including influenza, COVID-19, and pneumonia. Crowded housing conditions can increase interior moisture, providing a habitat for respiratory viruses, mites, roaches, and molds. While some households may be able to install improved air filtration and ventilation systems to reduce the spread of respiratory diseases, others may lack the financial means to make these retrofits.

Buildings and Infrastructure

Buildings and infrastructure vulnerability include the structures that support the economic drivers and services in the City of Santa Rosa. These assets are most vulnerable to severe storms, landslides, and wildfire. Of the 23 different types of buildings and infrastructure, 10 scored as having a high vulnerability to at least one hazard. Transportation infrastructure, including major roads and highways, railways, and single-access roads have similar vulnerabilities, and are therefore combined herein.

Electrical transmission infrastructure is highly vulnerable to extreme heat, landslides, severe wind, severe storms, and wildfire. Electric transmission infrastructure is dependent on overhead power lines owned and operated by PG&E. Extreme heat can cause mechanical failure of electrical equipment, heat damage to the aboveground infrastructure, and a high demand for electricity due to air conditioning units. Increased electricity usage for air conditioning during heat waves can overtax electrical transmission lines and transformers, which may malfunction or fail, causing power outages. Severe winds can cause transmission lines to sway near each other, potentially leading to arcing. This can generate sparks, excessive heat, and line damage. Landslides can damage electrical transmission lines if their foundations are undermined or fail. Wildfires can also damage power lines and substations. PG&E is currently conducting a climate vulnerability assessment to assess the risk and vulnerability of the infrastructure they operate to climate change hazards, which includes identifying any necessary improvement. However, some measures can both be expensive and require yearly or seasonal management activities.

Homes and residential structures are highly vulnerable to landslides, severe wind, severe storms, and wildfire. Homes in northeastern, eastern, and southern Santa Rosa are located Santa Rosa's Wildland-Urban Interface Fire Area and contain some areas identified as CAL FIRE's Very High Fire Hazard Severity Zones and California Geological Survey's landslide potential areas. These hazards can damage or destroy homes. Homes in western Santa Rosa and along the creeks are in the 100-year or 500-year floodplains and can be damaged by heavy rainfall that causes flooding. If flooding does not destroy a home, it can lead to mold and mildew, making the structure uninhabitable. Homes, especially older homes, can also be damaged by downed trees and debris from severe winds and other forms of severe storms. Funding sources such as PACE programs and rebates for energy-efficiency upgrades can help homeowners, including low-income residents, retrofit their homes. Homes can also be hardened against severe wind, severe storms, and landslides, and defensible space can be created to minimize damage from wildfires. However, these adaptive options can be expensive and are not always feasible for residents.

Transportation infrastructure, including major roads and highways, railway, and single-access roads are highly vulnerable to extreme heat, landslides, severe wind, severe storms, and wildfire. Major roads, which are frequently used as evacuation routes, can be blocked or closed due to catastrophic events and natural disasters such as wildfires, landslides, or flooding from severe storms, disrupting commute patterns and preventing effective evacuations during emergencies. Railways, which provide both freight and passenger services, can deform and buckle under extreme heat conditions or be flooded by heavy rainfall during a severe storm. If one section of a railway is damaged and becomes unusable, there are no alternative railway routes that can be used until the railway is repaired. However, roadways can serve as alternative transportation routes if railways become unusable. Single-access roads are the most vulnerable transportation asset, as alternative routes may not be available if these roadways are damaged or become impassable due to landslides, heavy rainfall that causes flooding, downed trees from severe wind, and wildfire. This could trap or isolate residents and business owners who live and work on

single-access roads, preventing them from evacuating, seeking medical care, or from obtaining vital goods such as food and medicine.

Dams are highly vulnerable to landslides and severe storms. Four dams in and surrounding the city are located within a landslide susceptibility area, which can cause instability of a dam or seepage within dam structures.[5] Heavy rainfall from severe storms may cause reservoirs to fill too quickly for the capacity of the spillway and dam structure. This can cause water to spill over the dam, damage spillways, and ultimately cause dam failure, resulting in major flooding downstream. The California Division of Dam Safety regulates dams in California. Upgrades or repairs to dams can be expensive and take many years to complete.

Parks and open spaces in the city are highly vulnerable to drought and landslides. Drought can cause unirrigated open spaces to lose plants and wildlife, reducing the available ecosystem services and quality of the open space.[6] Some parks and open space may function as intended during drought conditions, especially those managed with native and/or drought-tolerant landscaping and water and soil conservation and moisture retention techniques. Some public and private parks and green spaces, such as Nagasawa Community Park, Fountain Grove Golf Course, Howarth Memorial Park, Spring Lake Park, East Skyhawk Park, and others are in landslide susceptibility areas. Landslides can undermine walking and biking paths or damage park facilities in the city. Park facilities, trails, and paths can be retrofitted to prevent damage from landslides or rebuilt after landslides; however, this can become expensive for facilities that are repeatedly lost or damaged due to hazards.

Communication facilities are highly vulnerable to severe wind. Communication facilities can be damaged by debris carried by severe winds, causing them to malfunction and become unable to meet the demands of the community. In some cases, communication systems can be overloaded during a hazard event or a power outage, preventing the system from functioning as needed. Communication facilities can be retrofitted to prevent damage from severe wind or repaired after severe wind events to ensure reliable communication services. However, this can be expensive for facilities that are repeatedly lost or damaged due to hazards.

Flood-control infrastructure, such as flood-control channels, basins, and storm drain infrastructure, are highly vulnerable to severe storms that increase the risk of floodwaters overflowing banks during periods of heavy rainfall, as well as blockage of storm drain systems from landslides and wildfires. This can lead to the failure of flood-control systems or damage to infrastructure that drains stormwater away from both rural and urban areas, resulting in increased risks of flooding, damage to creek ecosystems, and degradation of water quality. Upgrades to flood-control infrastructure can be expensive and require coordination with multiple regional and state agencies, delaying the upgrade process.

Water and wastewater infrastructure are highly vulnerable to severe storms that cause flooding due to heavy rainfall. Although water infrastructure is likely to experience only minor effects, the Santa Rosa Laguna Treatment Plant is within the 100-year flood hazard zone.[7] During heavy rainfall, the wastewater infrastructure plant could be flooded and damaged, causing raw sewage to backup and flow into the water and soil surrounding the plant. The wastewater treatment plant currently has a temporary floodwall, but a permanent solution is needed. Furthermore, various aspects of the plant can be upgraded and retrofitted to prevent damage from flooding associated with severe storms. However, this can be expensive and take several years to complete once funding is available.

Economic Drivers

Economic driver vulnerability includes the economic assets and activities that support the Santa Rosa economy. These assets are most vulnerable to extreme heat and wildfire. Of the eight different types of economic drivers evaluated, three scored high for at least one hazard. Due to similar impacts and adaptive capacity, outdoor recreation and state and regional parks have been combined into one critical vulnerability discussion.

Agribusiness is highly vulnerable to agriculture and ecosystem pests and diseases, drought, extreme heat, severe wind, severe storms, and wildfire. Agribusiness including agricultural services and processing is highly dependent on the region's thriving agricultural production, which is highly vulnerable to these hazards. Drought can reduce water supplies, making less water available for crop irrigation and reducing yields or forcing farmers to change crop patterns or even the crops themselves. Extreme heat can damage vineyards and crops that depend on long, cold winters which may become less frequent. For example, cold-hardy crops, such as lettuce and apples, may become less suitable as temperatures increase, and melons and sweet potatoes may become more common because they can withstand high temperatures. Severe storms can harm or kill crops and agricultural infrastructure, reducing yields and causing costly repairs. Smoke from wildfires can not only damage crops such as vineyards, but can also harm farmworkers, which can impact the ability to effectively manage and harvest the products that are processed in Santa Rosa. In some cases, farmers may be able to find crop varietals that are more resilient to these changes; however, the processing of these crops may be different due to growing constraints. Agriculture pests and diseases may become more common as temperatures rise and droughts become more frequent, and some farmers may not be able to adjust to an increase in pests, reducing the amount of agricultural goods being processed in the city. Improved drainage and other infrastructure, changes to pest management activities, and increased personal protective equipment at farming operations may help reduce damage from hazards and help maintain the agribusiness industry in Santa Rosa. However, many of these actions can be expensive and may not be appropriate for all types of farming operations.

Outdoor recreation and tourism within the city and in surrounding state and regional parks is highly vulnerable to agriculture and ecosystem pests and diseases, drought, extreme heat, landslides, and wildfire. Drought and ecosystem pests and diseases can harm the plants and wildlife in state and regional parks, reservoirs, or creeks within and surrounding the city. Outdoor recreation facilities may close or reduce hours during extreme heat, smoke, or wildfire conditions, and after landslides. People may be less willing to travel to the city for outdoor recreation activities. Smoke created by wildfires can also curtail outdoor recreation activities as poor air quality can be harmful to people participating in outdoor activities. Defensible space and slope stabilization can be created around some sites, and outdoor recreation activities can be relocated to areas with accessible roadways and away from poor air quality or high temperatures, but these areas may not be in the city or attract as much economic activity.

Education is highly vulnerable to wildfires as students, faculty, and staff may relocate after a wildfire has occurred in the city. In the aftermath of the Tubbs Fire in 2017, school enrollment dropped significantly, preventing the education system from fully recovering. This pattern may decrease the number of education sector employment opportunities within the city. Education as an economic driver is highly dependent on the number students in a school district or at a college, and therefore the industry may have a difficult time recovering.

Ecosystems and Natural Resources

Ecosystem and natural resources, such as plants, trees, wildlife, and ecosystems in Santa Rosa, are most vulnerable to drought and extreme heat. Of the six different types of ecosystems and natural resources, four scored as having a high vulnerability to at least one hazard.

Aquatic and riverine ecosystems are highly vulnerable to drought, extreme heat, landslides, severe storms, and wildfire. Drought can lower water levels and water quality of aquatic and riverine ecosystems, contributing to algal blooms that lower the concentrations of dissolved oxygen, causing harm to fish and other aquatic species. Extreme heat can raise water temperatures in aquatic systems, also increasing dissolved oxygen content and decreasing overall water quality.[8] Landslides, heavy rainfall associated with severe storms, and fire retardants used to fight wildfires, can alter water courses and increase sediment, contaminants, and harmful nutrients in these systems. Sufficient precipitation, cooler temperatures, and improved water quality are necessary for recovery of fish and plant populations.

Douglas-fir forests are highly vulnerable to ecosystem pests and diseases, drought, extreme heat, and wildfire. Higher temperatures and drought can stress Douglas-fir trees and make them more susceptible to damage from pest infestation, such as the bark beetle, which prevents the flow of nutrients the forests need to survive. Bark beetle eggs typically will not survive a hard freeze[2] so warming temperatures have allowed the insects to flourish. Diseased or dying forests are more susceptible to wildfire and provide fuel for a fire to progress. Many Douglas-fir forests have reduced capacity to effectively recover from extreme heat events, prolonged drought, or pests and diseases. Seed longevity is projected to decrease, and fertility can decline slightly, making it harder for forests to reestablish themselves. This can create barriers to continuity (interconnected patches of a particular ecosystem) and dispersal (when seeds move from one site to a growing site) due to the rural and remote nature of the county.[9] These forests can also be managed to prevent or lessen the severity of wildfires; however, land management faces regulatory, financial, and personnel restrictions that limit the ability to effectively manage forests.[10]

Oak woodlands are highly vulnerable to ecosystem pests and diseases and severe wind. Sudden oak death and other pests and diseases can devastate oak woodlands, which may worsen with extreme heat and drought. Severe wind can cause sudden oak death to spread more rapidly within the ecosystem, harming oak trees and the wildlife that depend on these woodlands. Oak woodlands can typically recover from natural disturbance regimes, including pests and diseases. However, the spread of sudden oak death may not be manageable with increased drought conditions.[11]

Wetlands are highly vulnerable to drought and extreme heat. These ecosystems are largely dependent on precipitation for their water sources, and drought can reduce precipitation and soil moisture, leading to tree and shrub ecosystem encroachment.[12] Extreme heat can reduce the quantity and quality of water available for wetland habitats. Due to low connectivity and fragmented distribution of wetlands, these ecosystems may face difficulty adapting to extreme heat and drought conditions. This ecosystem is also highly dependent on water availability and may not be able to recover without an influx of water.[13] Ecosystem managers can restore wetland functions and create new wetlands; however, this can require coordination with land managers and can be expensive to complete.

[2] A hard freeze occurs when air temperatures fall to 28 degrees Fahrenheit or lower and then stay below 32 degrees Fahrenheit for several hours or days.

Key Services

Key services vulnerability includes the essential goods, utilities, and services to residents and visitors in the city. These assets are most vulnerable to wildfire. Of the eight different types of key services, four scored as highly vulnerable to at least one hazard.

Energy delivery services are highly vulnerable to extreme heat, landslides, severe wind, and wildfire. These services are dependent on overhead power lines and underground natural gas pipelines owned and operated by PG&E, which are susceptible to extreme heat, fallen trees from severe winds, landslides, and wildfire. Extreme heat can cause power outages due to mechanical failure of electrical equipment, heat damage to the aboveground infrastructure, and a high demand for electricity due to air conditioning units. Solar and hydroelectric energy production could decrease due to extreme heat. Solar photovoltaic panels experience a decrease in efficiency due to excessive heat of converting solar energy to electric energy by 10 to 25 percent as temperatures rise. Solar panels can also experience a decrease in energy output by as much as 20 percent due to smoke and ash conditions.[14] The reservoirs that produce hydroelectric energy may experience higher rates of evaporation, which reduces the amount of water available to generate electricity. Electrical lines that are close to forested areas could be damaged by falling trees that result from severe wind. These impacts could become chronic as forest ecosystems weaken due to extreme heat and drought. Landslides can damage electrical transmission lines if their foundations are undermined or fail. High winds can also cause PG&E to turn off electricity to prevent sparks, as part of a PSPS event, which disrupts energy delivery to Santa Rosa. Wildfires can also damage power lines, natural gas lines, and substations. PG&E is currently conducting a climate vulnerability assessment to assess the risk and vulnerability of the infrastructure they operate to climate change hazards, which includes identifying any necessary improvements. However, some of these measures can both be expensive and require yearly or seasonal management activities.

Water and wastewater services are highly vulnerable to drought, landslides, severe storms, and wildfire. Drought can reduce water available from the Russian River, which is the primary source of wholesale water supply provided by Sonoma Water. This can lead the City to use more groundwater to meet the demand of residents, government and other institutions, industries, and businesses and/or to declare a water shortage emergency and implement its Water Shortage Contingency Plan. Landslides can damage the pipelines carrying water to residents and wastewater to the wastewater treatment plant, and services could be suspended until repairs are made. Heavy rainfall caused by severe storms can cause flooding that can overwhelm the Santa Rosa Laguna Treatment Plan and untreated effluent could leak into the surrounding water and soil. Wildfires could degrade the surface water quality that Santa Rosa relies on due to ash content or fire retardants that contaminate surface water supplies. Increased water conservation measures, use of more recycled water, and more extensive treatment equipment can protect water services throughout the city. Wastewater services may have a more difficult time adapting due to the expensive nature of moving and retrofitting wastewater infrastructure.

Public transit services are highly vulnerable to severe wind, severe storms, and wildfire. These hazards can cause delays or rerouting of bus transit and may delay or block railway transit services. Transit services could be delayed for hours or days, depending on the severity of the event. Transit users may also be deterred from using transit if roadways and bus stops are flooded or during smoke conditions from wildfires. In some cases, buses can be rerouted if roads become impassable due to flooding or wildfire. However, this is not possible for rail-based transit services.

Emergency medical services are highly vulnerable to human health hazards as an increase in vector-borne and other illnesses may cause the demand to outweigh the capacity of emergency medical response services. There may be shortages of healthcare facilities, equipment, pharmaceuticals, and personnel if healthcare workers become sick or if supply chains are disrupted. Local and regional medical centers and providers can strengthen medical supply chains and prepare emergency contingency plans for if or when human health hazards increase in frequency and intensity. However, this may take time and require extensive coordination.

CONCLUSION

Out of the 65 populations and assets Santa Rosa analyzed, 40 are highly vulnerable to one or more hazard condition. Wildfire is responsible for the largest number of high vulnerability scores, followed by extreme heat and severe storms. The resilience of these populations and assets can increase through the implementation of adaptation and hazard mitigation goals, policies, implementation programs, and projects, such as those discussed in the 2016 *Santa Rosa Local Hazard Mitigation Plan* or EcoAdapt's *Climate Vulnerability and Adaptation Report for Santa Rosa.* Adaptation is the adjustment to natural and human systems in response to actual or expected changes in climate conditions to reduce the harmful effects of actual or expected changes.[15] The results of the Climate Change Vulnerability Assessment and the reports discussed above can be used to develop General Plan goals, policies, and actions to reduce the critical vulnerabilities and increase resilience throughout the City of Santa Rosa.

APPENDIX A: ABBREVIATIONS AND GLOSSARY

Abbreviations

AB: Assembly Bill

APG: Adaptation Planning Guide

Cal OES: California Governor's Office of Emergency Services

CAL FIRE: California Department of Forestry and Fire Protection

FEMA: Federal Emergency Management Agency

GHG: greenhouse gas emissions

IPCC: Intergovernmental Panel on Climate Change

LHMP: local hazard mitigation plan

PACE: Property Assessed Clean Energy

PG&E: Pacific Gas and Electric Company

PSPS: Public Safety Power Shutoff

RCP: Representative Concentration Pathway

SB: Senate Bill

Glossary

The Climate Change Vulnerability Assessment uses some terms specific to adaptation planning. The following identifies and defines key terms used throughout the vulnerability assessment. For a more comprehensive list of terms commonly used in adaptation planning, consult the California Adaptation Planning Guide (https://www.caloes.ca.gov/climate).

List of Terms[16]

Adaptation: Making changes in response to current or future conditions (such as the increased frequency and intensity of climate-related hazards), usually to reduce harm and to take advantage of new opportunities.[17, 18]

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."[19]

Climate Change: A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.

Community Asset: A valued feature of a community that may be harmed by climate change. Community assets may include buildings, infrastructure, community services, ecosystems, and economic drivers. See also "*Populations and Assets*."

Drought: A drought is a period of drier than normal conditions that results in water-related problems including, but not limited to, water supply shortages that impact people, agriculture, and ecosystems.

Economic Driver: Economic assets in Santa Rosa, including three agricultural-based sectors, major employment industries, and recreation and tourism on regional, State, and federal lands.

Exposure: The presence of people, infrastructure, natural systems, and economic, cultural, and social resources in areas that are subject to harm.[20]

Extreme Event: When a weather or climate variable exceeds the upper or lower thresholds of its observed range.[21, 22]

Extreme Heat: When temperatures rise significantly above normal levels and is measured by the number of extreme heat events per year and heat wave duration. An extreme heat day in Santa Rosa is where temperatures reach at least 98.1 degrees Fahrenheit.

Frontline Population: Those disproportionately affected by climate change. See "*Vulnerable Populations.*"

Hazard: An event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural losses, damage to the environment, interruption of business, or other types of harm or loss.[23]

Hazard Mitigation: Sustained action taken to reduce or eliminate the long-term risk to human life and property through actions that reduce hazard, exposure, and vulnerability.[24]

Impact: The effects (especially the negative effects) of a hazard or other conditions associated with climate change.

Populations and Assets: Populations and assets are the people, infrastructure, services, and economic drivers in the City of Santa Rosa that can be affected by climate change.

Resilience: The capacity of any entity—an individual, a community, an organization, or a natural system—to prepare for disruptions, to recover from shocks and stresses, and to adapt and grow from a disruptive experience. Community resilience is the ability of communities to withstand, recover, and to learn from past disasters to strengthen future response and recovery efforts.

Risk: The potential for damage or loss created by the interaction of hazards with assets such as buildings, infrastructure, or natural and cultural resources.

Sensitivity: The level to which a species, natural system, or community, government, etc., would be affected by changing climate conditions.[25]

Susceptibility: A person or population's potential for vulnerability due to demographic, socioeconomic, and geolocation characteristics.

Vulnerability: Climate vulnerability describes the degree to which natural, built, and human systems are susceptible "…to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt."[26]

Vulnerability Assessment: An analysis of how a changing climate may harm a community and which elements—people, buildings and structures, resources, and other assets—are most vulnerable to its effects based on an assessment of exposure, sensitivity, the potential impact(s), and the community's adaptive capacity.

Vulnerable Populations: Vulnerable populations include, but are not limited to, elderly, children, agricultural and outdoor workers, and those suffering from pre-existing cardiovascular or respiratory conditions.[27, 28]

APPENDIX B: CLIMATE CHANGE VULNERABILITY ASSESSMENT RESULTS MATRIX

POPULATIONS AND ASSETS	AGRICULTURE & ECOSYSTEM PESTS & DISEASES	DROUGHT	EXTREME HEAT	HUMAN HEALTH HAZARDS	LANDSLIDES	SEVERE WIND	SEVERE STORMS	WILDFIRE
Populations								
Children (under 18)	-	-	High	Medium	Low	Medium	Medium	High
Cost-burdened households	-	Low	Medium	Medium	Medium	Low	Low	Medium
Households in poverty	-	High	High	High	High	High	High	High
Immigrant communities	Medium	Medium	High	High	Medium	High	High	High
Linguistically isolated persons	-	-	Medium	Medium	Medium	Medium	Medium	High
Low-income households	-	Low	Medium	Medium	Medium	Medium	Medium	High
Low-resourced ethnic minorities	Medium	High	High	High	Medium	High	High	High
Outdoor workers	High	High	High	High	Medium	High	High	High
Overcrowded households	-	-	Medium	High	Low	Low	Low	Medium
Persons experiencing homelessness	-	-	High	High	-	High	High	High
Persons living in mobile homes	-	-	High	Low	High	High	Medium	High
Persons living on single-access roads	Low	-	-	Low	High	Medium	Medium	High
Persons with chronic illnesses and/or disabilities	-	-	High	High	Medium	High	Medium	High

POPULATIONS AND ASSETS	AGRICULTURE & ECOSYSTEM PESTS & DISEASES	DROUGHT	EXTREME HEAT	HUMAN HEALTH HAZARDS	LANDSLIDES	SEVERE WIND	SEVERE STORMS	WILDFIRE
Persons without a high school degree	-	-	Low	Low	Low	Low	Low	Medium
Persons without access to lifelines	-	-	Medium	Medium	Medium	Medium	Medium	High
Renters	-	-	Low	Low	Medium	Low	Medium	Medium
Seniors (65+)	-	-	High	High	High	Medium	High	High
Seniors living alone	-	-	High	High	High	High	High	High
Students	-	-	Low	Medium	Low	Low	Low	Low
Unemployed persons	-	Medium	Medium	Medium	Medium	Medium	Medium	High
Buildings and Infrastructure								
Biking and pedestrian trails	Medium	-	-	-	Low	Low	Low	Medium
Bridges	-	-	-	-	Medium	Medium	Medium	Medium
Communication facilities	-	-	Medium	-	Low	High	Low	Medium
Community centers	-	-	Low	-	-	Medium	Low	-
Dams	-	-	-	-	High	Low	High	Low
Electrical transmission infrastructure	-	-	High	-	High	High	High	High
Emergency operation buildings	-	-	Low	-	-	Low	Low	-

POPULATIONS AND ASSETS	AGRICULTURE & ECOSYSTEM PESTS & DISEASES	DROUGHT	EXTREME HEAT	HUMAN HEALTH HAZARDS	LANDSLIDES	SEVERE WIND	SEVERE STORMS	WILDFIRE
Evacuation and cooling centers	-	-	Low	-	-	Medium	Low	-
Flood-control infrastructure	-	-	-	-	-	-	High	-
Government administration facilities	-	-	Low	-	-	Low	Low	Medium
Hazardous materials sites	-	-	-	-	Medium	-	Medium	Medium
Homes and residential structures	-	-	Medium	-	High	High	High	High
Libraries	-	-	Low	-	-	Medium	Low	-
Major roads and highways	-	-	Medium	-	Low	Low	Medium	High
Natural gas pipelines: PG&E	-	-	-	-	Medium	-	Low	Low
Parks and open space	Low	High	Medium	-	High	Low	Low	Medium
Public safety buildings	-	-	Low	-	-	Medium	Low	High
Railway	-	-	High	-	-	-	High	Low
Schools	-	-	Medium	-	Low	Medium	Medium	Medium
Single-access roads	Medium	-	Low	-	High	High	High	High
Solid waste facilities	-	-	-	-	-	Low	Medium	-
Transit facilities	-	-	-	-	Medium	Low	Medium	Medium

POPULATIONS AND ASSETS	AGRICULTURE & ECOSYSTEM PESTS & DISEASES	DROUGHT	EXTREME HEAT	HUMAN HEALTH HAZARDS	LANDSLIDES	SEVERE WIND	SEVERE STORMS	WILDFIRE
Water and wastewater infrastructure	-	Low	-	-	Medium	-	High	Medium
Economic Drivers								
Agribusiness	High	High	High	Medium	Medium	High	High	High
Education	-	-	-	Medium	Low	-	Low	High
Healthcare	-	-	Low	Medium	Low	-	Low	Medium
Major employers, including Public Administration	-	-	-	Low	Medium	-	Low	Medium
Outdoor recreation and tourism	Medium	Medium	High	Medium	Low	Medium	Medium	High
Retail trade	-	-	Medium	Low	Low	-	Medium	Medium
Research, development, and manufacturing	-	-	-	Low	Low	-	Low	Low
State and regional parks	High	High	High	Medium	High	Medium	Medium	High
Ecosystems and Natural Resources								
Aquatic/Riverine	Low	High	High	-	High	Low	High	High
Douglas-Fir Forest	High	High	High	-	Low	Low	Low	High
Grassland	Medium	Medium	Low	-	Low	Low	Low	Medium
Oak Woodland	High	Low	Low	-	Medium	High	Low	Low

POPULATIONS AND ASSETS	AGRICULTURE & ECOSYSTEM PESTS & DISEASES	DROUGHT	EXTREME HEAT	HUMAN HEALTH HAZARDS	LANDSLIDES	SEVERE WIND	SEVERE STORMS	WILDFIRE
Riparian Woodland	Medium	Medium	Medium	-	Medium	Medium	Medium	Medium
Wetlands	Low	High	High	-	-	Medium	Medium	Medium
Key Services								
Communication services	Low	-	Low	-	Low	Medium	Low	Medium
Emergency medical response	Low	-	Medium	High	Medium	Low	Medium	High
Energy delivery	Medium	Low	High	-	High	High	Medium	High
Government administration and community services	-	-	Low	Low	Low	Low	Low	Low
Public safety response	Medium	-	Low	Medium	Medium	Medium	Medium	High
Public transit access	Low	-	Medium	Low	Medium	High	High	High
Solid waste removal	Medium	-	Medium	Low	Medium	Medium	Low	Medium
Water and wastewater	-	High	Low	-	High	Low	High	High

ENDNOTES

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