

# CLIMATE CHANGE VULNERABILITY ASSESSMENT CITY OF CHICO

---

Prepared for:

City of Chico

Prepared by:

Molly Marcussen

CivicSpark Fellow

2018

Table of Contents

Executive Summary..... 4

1 Introduction ..... 5

    1.1 City of Chico..... 6

    1.2 Cal-Adapt ..... 8

2 Exposure ..... 9

    2.1 Increased Temperature ..... 9

    2.2 Extreme Heat ..... 11

    2.3 Changes in Precipitation Patterns ..... 12

    2.4 Increased Storm and Flooding Events ..... 15

    2.5 Snowpack..... 18

**Surface Water** ..... 20

**Groundwater**..... 22

    2.6 Increased Wildfire Risk ..... 22

3 Sensitivity and Potential Impacts..... 27

    3.1 Increase in Temperature..... 27

**Population**..... 28

**Function and Structures**..... 30

    3.2 Changes in Precipitation, Increase in Flooding and Decrease in Snowpack..... 31

**Population**..... 32

**Functions and Structures** ..... 32

    3.3 Increase in Wildfire..... 33

**Population**..... 34

**Functions and Structures** ..... 34

4 Adaptive Capacity ..... 35

    4.1 Adaptive Efforts Related to Increased Temperature..... 36

    4.2 Adaptive Efforts Related to Changes in Precipitation Patterns ..... 38

    4.3 Adaptive Efforts Related to Increased Flooding ..... 39

    4.4 Adaptive Efforts Related to Increased Wildfires..... 40

Risk and Onset ..... 42

References: ..... 43

Appendix A.....46

## Executive Summary

In 2015, Governor Schwarzenegger signed Senate Bill (SB) 379, which states that local governments need to address climate adaptation and resiliency's in their general plan's safety element by 2022. The first step in meeting this requirement is to conduct a Climate Change Vulnerability Assessment to identify the risks that climate change poses to the local jurisdiction and the geographic regions most at risk from climate change. Consistent with the City's adopted Climate Action Plan, the City's Sustainability Task Force identified compliance with SB 379 and preparation of a Vulnerability Assessment as a high priority to promote climate change adaptation and resiliency for the community.

The Vulnerability Assessment provides both a quantitative and qualitative analysis of how climate change may impact the City of Chico through 2100. Direct impacts of climate change to the City include an increase in average temperature and changes in annual precipitation. Secondary impacts include increased frequency, intensity, and duration of extreme heat days and heat waves/events; increased flooding; increased wildfire; and, loss of snowpack and decreased water supplies. Over the long term, these changes create the potential for a wide variety of secondary consequences, including human health and safety risks, economic disruptions, shifts in ecosystem function and habitat qualities, and difficulties with provision of public services. **Appendix A** provides a simplified summary of future climate projections for the City of Chico using the State's Cal-Adapt modelling tool.

The biggest climate change threats to Chico are an increase in extreme heat events and increased flooding events. The City's roadways, infrastructure in flood zones, disadvantaged communities, and sensitive species habitat are among the most vulnerable to climate change impacts. Disaster recovery efforts require extreme measures and commitment to the development of healthy, organized responses to chaotic situations. Every region has a unique need. If a jurisdiction is not in synch with current regulation it may not only miss opportunities for State and federal funding, but it may leave a jurisdiction more vulnerable to the threats of climate change induced natural disasters. City staff intends to use this assessment as a guide bolstering the City's adaptive capacity to respond to these impacts. This Vulnerability Assessment provides an initial analysis of how climate change might impact the City of Chico and where the greatest risks lie.

# 1 Introduction

Climate change is a global phenomenon that, over the long term, will cause a wide variety of impacts on human health and safety, economic vitality, water supply, ecosystem function, and the provision of basic services (California Natural Resources Agency [CNRA] 2012:3). Locally in the Butte County region, as well as throughout California, climate change is already affecting and will continue to affect the physical environment.

This vulnerability assessment provides an overview of the primary and secondary threats associated with climate change and identifies threats most likely to affect the City of Chico (Chico). The findings of the vulnerability assessment will be used to develop climate adaptation strategies to address the threats, which will be included in Chico's planning documents to meet Senate Bill (SB) 379 requirements.

The California Adaptation Planning Guide (APG), developed by California Office of Emergency Services (CalOES) and CNRA, helps California communities plan for and adapt to the impacts of climate change. The APG identifies a nine-step process for communities to assess their specific climate vulnerabilities and provides strategies for communities to reduce climate-related risks and prepare for current and future impacts of climate change.

The first five steps (see **Figure 1**)

result in the preparation of a Vulnerability Assessment, which is an evaluation of a community's level of

exposure to climate-related impacts and an analysis of how these impacts will affect a community's populations, functions, and structures. The last four steps of the process use the information gathered in the Vulnerability Assessment to develop adaptation strategies and measures to help the community prepare for, respond to, and adapt to local climate change impacts.

The first five steps seek to answer the following questions:

- **Exposure:** what climate change effects will a community experience?
- **Sensitivity:** what aspects of a community (i.e., function, structures, and populations) will be affected?
- **Potential Impacts:** how will climate change affect the points of sensitivity?
- **Adaptive Capacity:** what is currently being done to address the impacts?

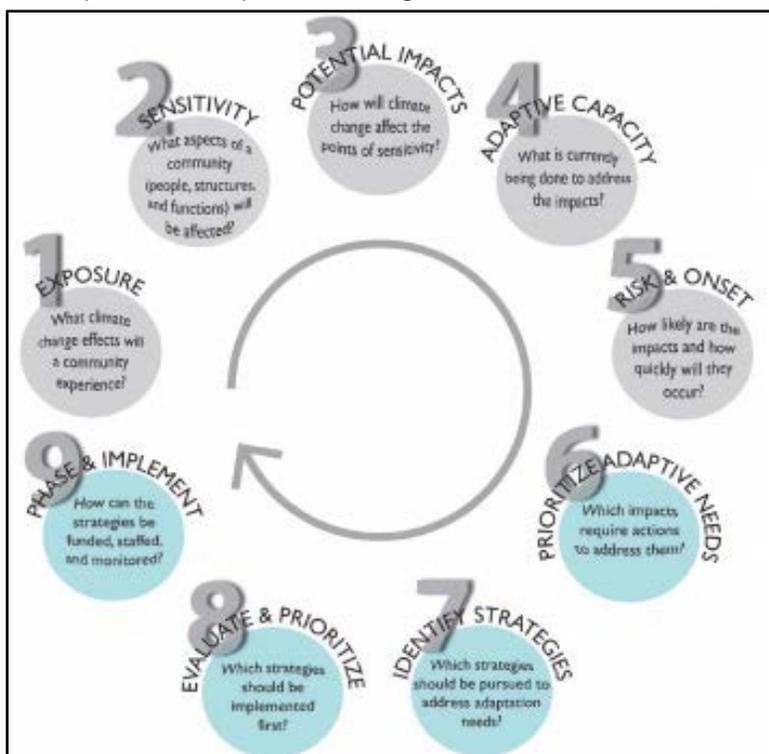


Figure 1: Adaptive Planning Guide (APG) Vulnerability Assessment Steps

- **Risk and Onset:** how likely are the impacts and how quickly will they occur?

Completion of the final four steps helps a community develop effective climate adaptation strategies to increase resilience to climate change:

- **Prioritize Adaptive Needs:** setting priorities for adaptation needs.
- **Identify Strategies:** identifying strategies to address adaptation needs.
- **Evaluate and prioritize:** evaluating and setting priorities for implementation of strategies.
- **Phase and Implementation:** establishing a phasing and implementation plan.

Based on data provided by IPCC and research conducted by the State of California and its partner agencies and organizations, the effects of climate change are already occurring and, to some degree or another, will continue to occur in Chico. These effects are identified and analyzed further below.

## 1.1 City of Chico

Chico is located at the northeastern edge of the Sacramento Valley, one of the richest agricultural areas in the world (see **Figure 2**). According to the United States Census Bureau, the city covers a total area of 27.8 square miles. The Sierra Nevada Mountains lie to the east, with Chico's city limits venturing several miles into the foothills via Bidwell Park. The Sacramento River lies five miles to the west of the city limits. Chico is the most populous city in Butte County, with an estimated population of 89,180 at the 2015 census estimate. The City's service area is 33 square miles and is characterized by an urban and suburban community mix. The city is a cultural and commercial center for a three-county regional market area. Chico supports a diverse range of industries including agriculture, recreation, tourism, healthcare manufacturing, and education. California State University, Chico is the second oldest institution in the California State University system, enrolling more than 16,000 students. Bidwell Park, the Country's 26th largest municipal park and the 13th largest municipally-owned park makes up over 17% of the City's area. Enloe Medical Center is located in Chico and serves as the regional medical hospital and Level II Trauma Center.

Chico's terrain is mostly flat with increasingly hilly terrain beginning at the eastern city limits. The city is bisected by Bidwell Park, which runs five miles from the city center to the foothills of the Sierra Nevadas. The city is also traversed by a number of creeks and flood channels flowing westward to the Sacramento River, including Big Chico Creek, Little Chico Creek, Lindo Channel (also known as Sandy Gulch), Mud Creek, Sycamore Creek, Comanche Creek, Dead Horse Slough, and Butte Creek.

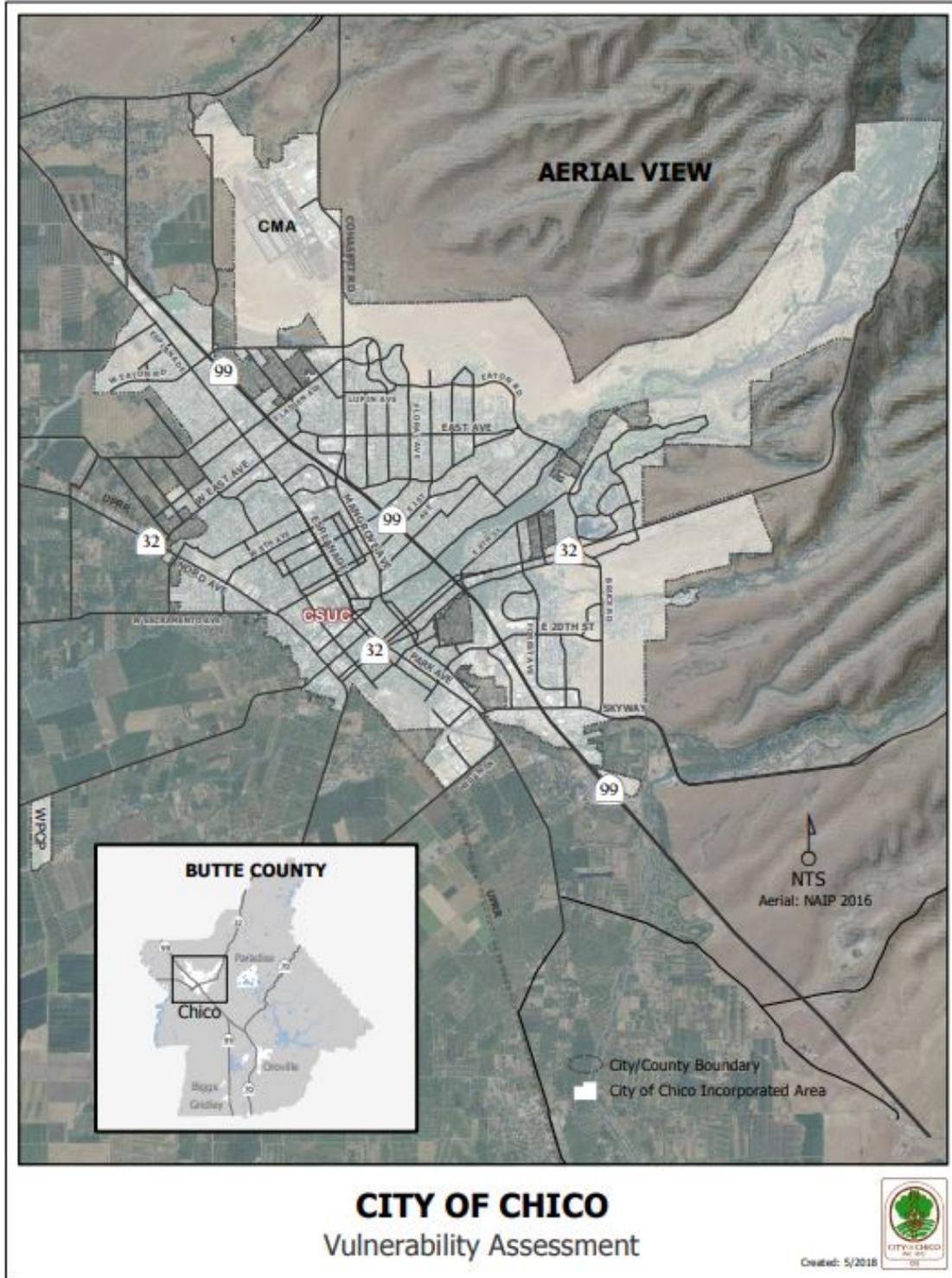


Figure 2: City of Chico Aerial View. Map by Brad Pierce, City of Chico. May 2018.

## 1.2 Cal-Adapt

As directed by the State's Adaptive Planning Guide (APG), the first step in adaptation planning is conducting a climate change vulnerability assessment utilizing Cal-Adapt. Cal-Adapt is a climate change scenario planning tool developed by the California Energy Commission (CEC) and the University of California, Berkeley Geospatial Innovation Facility. The data available on this site offers a view of how climate change might affect California at the local level. Here, you can use visualization tools, access data, and participate in community sharing to contribute your own knowledge. Cal-Adapt's development is a key recommendation of the 2009 California Climate Adaptation Strategy (Cal-Adapt, 2017). The state of California, as well as the California Adaptive Planning Guide, recommend using Cal-Adapt to conduct these assessments.

In order to accurately represent the variability of weather patterns, Cal-Adapt includes four different Global Climate Models (GCM's); Warm/Dry, Cool/ Wet, Average, and Complement Models. These climate projections have been downscaled from global climate models from the Program for Climate Model Diagnosis and Intercomparing (CMIP5) archive, using the Localized Constructed Analogs (LOCA) statistical technique developed by Scripps Institution of Oceanography. LOCA is a statistical downscaling technique that uses historical data to add improved fine-scale detail to global climate models (Cal-Adapt, 2017). Section 3: Sensitivity and Potential Impacts, contains Cal-Adapt charts which include four colored lines corresponding to the different models. The red line represents the Warm/Dry model, which shows the average future climate projection during a warm/ dry year. The blue line represents the Cool/Wet Model, which shows the average future projection during a cool/wet year. The yellow line represents the Average Model, which shows the average future climate projection for our typical California Mediterranean climate. The purple line represents the Complement Model, which shows the projection that is most unlike the first 3 for the best coverage of different possibilities.

For the purposes of this assessment, where predictive data exists, climate change effects are characterized for two milestone years: mid-century (2050) and end of century (2090). Historical data is used to set the baseline for describing the degree of change **which will occur** by these two future dates. Cal-Adapt downscales global climate simulation model data to local and regional resolutions under two emissions scenarios: a higher future global greenhouse gas (GHG) emissions scenario (RCP 8.5), and a lower future GHG emissions scenario (RCP 4.5). For the lower emissions scenario, emissions peak around 2040, then decline. In the higher emissions scenario, emissions continue to rise strongly through 2050 and plateau around 2100.

Which scenario most closely resembles actual future conditions depends on the effectiveness of international, federal, state, and local programs that are implemented or will be implemented to reduce GHG emissions. While there has been progress on GHG emissions reduction and significant national, sub-national, regional and local efforts, overall anthropogenic CO<sub>2</sub> emissions have continued to rise at a rate that is anticipated to have major consequences worldwide (IPCC 2014). Because the degree of effectiveness of implemented programs is not yet known, results from both emissions scenarios are considered in this vulnerability assessment to provide a reasonable range of potential outcomes of climate change.

## 2 Exposure

The first step of the vulnerability assessment is to identify the climate change impacts predicted for Chico. Using the California Adaptive Planning Guide, the climate change impacts projected for Chico are:

### Direct Impacts:

1. Increase in average temperature
2. Changes in annual precipitation

### Secondary Impacts:

1. Increased frequency, intensity, and duration of extreme heat days and heat waves/events
2. Increased flooding
3. Increased wildfire
4. Loss of snowpack and decreased water supplies

Over the long term, these changes create the potential for a wide variety of secondary consequences, including human health and safety risks, economic disruptions, diminished water supply, shifts in ecosystem function and habitat qualities, and difficulties with provision of public services (California Natural Resources Agency [CNRA] 2012). Locally, climate change is already affecting and will continue to alter the physical environment throughout Butte County and the City of Chico; however, specific implications of climate change vary with differing physical, social, and economic characteristics within the City. For this reason, it is important to identify the projected severity of climate change impacts on Chico, and the methods by which the City can reduce its vulnerability. Communities which begin planning now will have the best options for adapting to climate change and increasing resilience (CNRA 2012).

Cal-Adapt data describing future climate conditions for the City of Chico and surrounding area is summarized in the sections below.

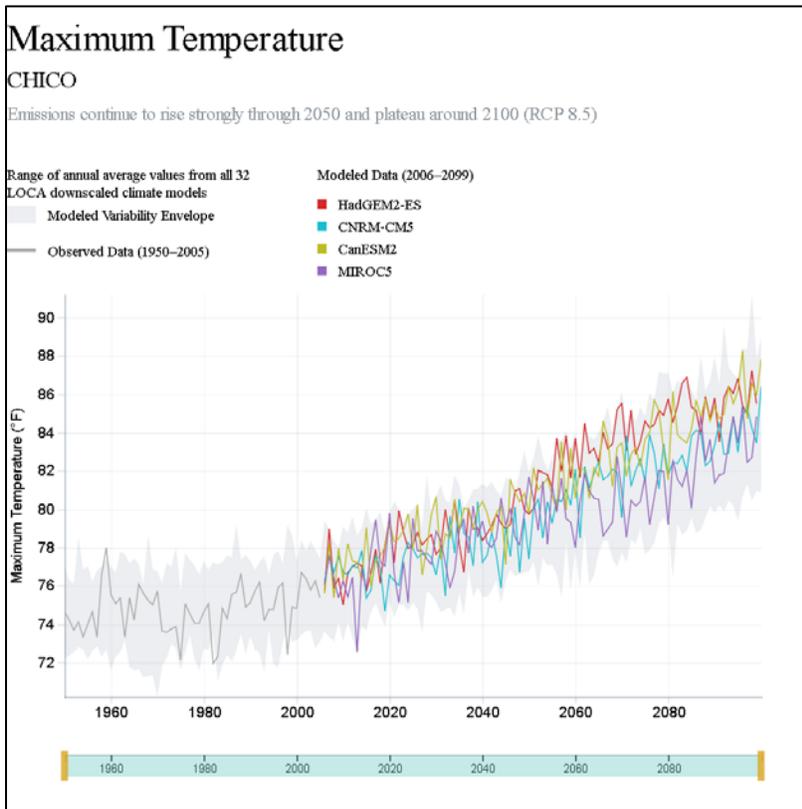
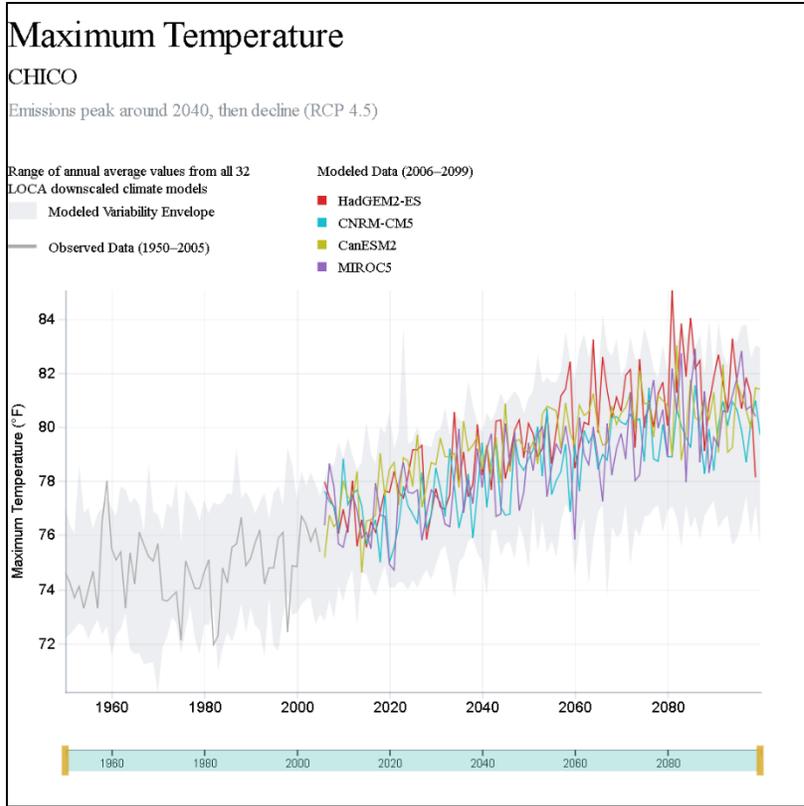
### 2.1 Increased Temperature

According to IPCC, global average temperatures are expected to increase relative to the 1986-2005 period by 0.5-8.6 degrees Fahrenheit (°F) by the end of the 21st century (2081-2100), depending on future GHG emissions scenarios (IPCC 2014: SPM). According to CNRA, average temperatures in California are projected to increase 2.7 °F above 2000 averages by 2050 and, depending on emissions levels, somewhere between 4.1-8.6°F by 2100 (CNRA 2012b:2).

Chico's historic (1960-1990) annual average maximum temperature is 74.7°F. Utilizing Cal-Adapt, under the Low-Emissions Scenario, the annual average maximum temperature is projected to be 79.1 °F by 2050 and 80.7 °F by 2090, for a potential total increase of 6 degrees (see **Figure 3**). The annual average maximum temperature under the High-Emissions Scenario is projected to be 80.0 °F by 2050 and 84.2°F by 2090, for a potential total increase of 7.5 degrees (see **Figure 4**).

The City's historical average annual low temperature is 47.8 °F. Under the Low-Emissions Scenario, the annual average low temperature is projected to be 52.0 °F by 2050 and 53.2°F by 2090 (Cal-Adapt, 2017). The annual average low temperature under the High-Emissions Scenario is projected to be 52.9 °F by 2050 and 57.1 °F by 2090, an increase of approximately 9.3 degrees (Cal-Adapt, 2017). These projected increases in annual average temperatures represent a significant increase over a short period of time.

**Figure 3:** This chart shows annual averages of observed and projected Maximum Temperature values for the selected area on graph under the RCP 4.5 scenario. The gray line (1950 – 2005) is observed data. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. (Cal-Adapt, 2018) The gray line (1950–2005) is observed data. The colored lines (2006–2100) are projections from 10 LOCA downscaled climate models selected for California.



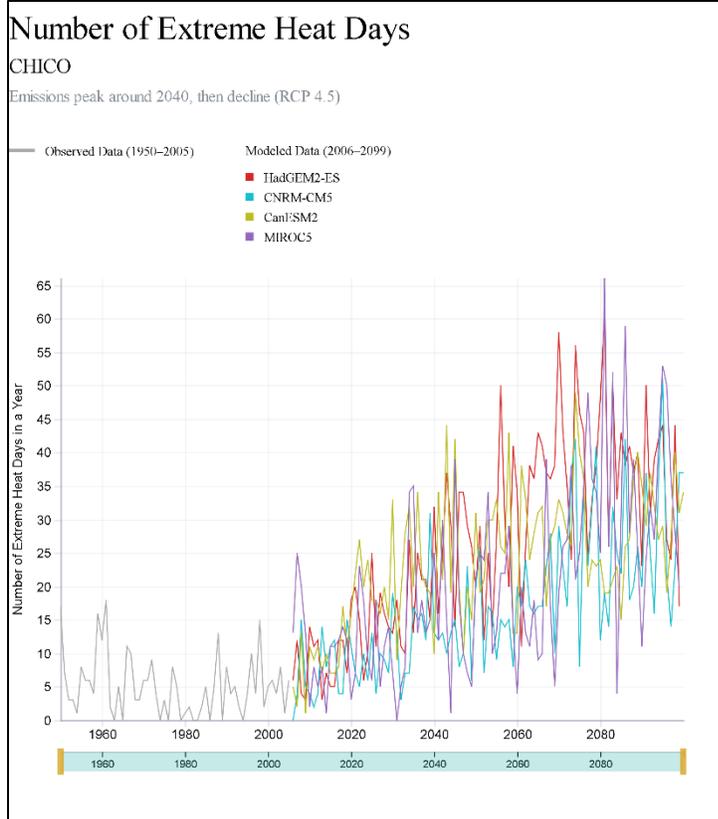
**Figure 4:** This chart shows annual averages of observed and projected Maximum Temperature values for the selected area on graph under the RCP 8.5 scenario. The gray line (1950 – 2005) is observed data. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. (Cal-Adapt, 2018) The gray line (1950–2005) is observed data. The colored lines (2006–2100) are projections from 10 LOCA downscaled climate models selected for California.

## 2.2 Extreme Heat

Increased temperatures are expected to cause secondary climate change impacts, including increases in the frequency, intensity, and duration of extreme heat days and multi-day heat waves/events in California. Using Cal-Adapt's Extreme Heat tool, projections were made for the change in frequency of extreme heat days, warm nights, and heat waves for the Low- and High-Emissions Scenarios in 2050 and the end of the century (2090).

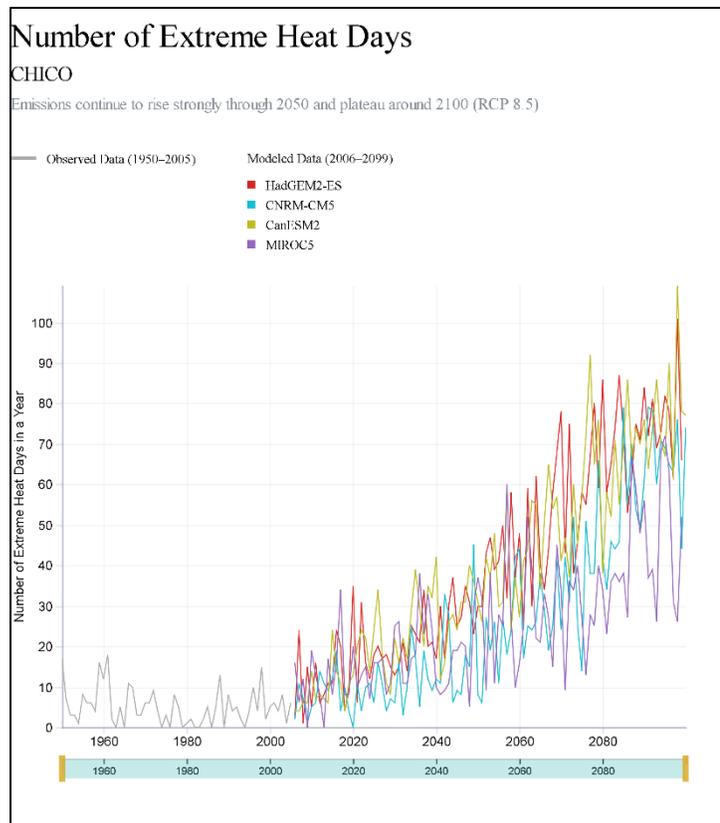
When extreme temperatures are experienced over a period of several or more days, they are known as either heat waves or heat events. The U.S. Environmental Protection Agency and Centers for Disease Control define extreme heat events as "periods of summertime weather that are substantially hotter and/or more humid than typical for a given location at that time of year." Scientists expect climate change to lead to longer, more severe, and more frequent extreme heat events.

Cal-Adapt defines an "extreme heat" day threshold for the City of Chico as 104.3 °F or higher (Cal-Adapt, 2017). Historically, the City has experienced an average of four extreme heat days annually. Under the Low-Emissions Scenario, the City is projected to experience an average of 18 extreme heat days by 2050 and 23 extreme heat days by 2100 (Cal-Adapt, 2017) (see **Figure 5**). Under the High-Emissions Scenario, the City is projected to experience an average 21 extreme heats by 2050 and 44 by 2090. (Cal-Adapt, 2017) (see **Figure 6**). Cal-Adapt also shows that extreme heat days are expected to occur earlier in the spring and later in the fall.



**Figure 5:** This chart shows number of Extreme Heat days in a year for the selected location on map under the RCP 4.5 scenario. An Extreme Heat day is defined as a day in April through October when the Maximum Temperature exceeds the location's Extreme Heat Threshold, which is calculated as the 98th percentile of historical maximum temperatures between April 1 and October 31 based on observed daily temperature data from 1961–1990). The gray line (1950–2005) is observed data. The colored lines (2006–2100) are projections from 10 LOCA downscaled climate models selected for California. (Cal-Adapt, 2018)

**Figure 6:** This chart shows number of Extreme Heat days in a year for the selected location on map under the RCP 8.5 scenario. An Extreme Heat day is defined as a day in April through October when the Maximum Temperature exceeds the location's Extreme Heat Threshold, which is calculated as the 98th percentile of historical maximum temperatures between April 1 and October 31 based on observed daily temperature data from 1961–1990). The gray line (1950–2005) is observed data. The colored lines (2006–2100) are projections from 10 LOCA downscaled climate models selected for California. (Cal-Adapt, 2018)



## 2.3 Changes in Precipitation Patterns

Global climate change will also affect physical processes and weather conditions beyond average temperatures. As a result of climate change, historic precipitation patterns are anticipated to be altered. Depending on location, precipitation events may increase or decrease in intensity and frequency and are notoriously difficult to predict.

While Cal-Adapt's projections show minimal changes in total annual precipitation in California, even slight changes could have a dramatic effect on California's ecosystems, which are conditioned to historic precipitation levels (CNRA 2012). Climate change is not only anticipated to result in an increase in the frequency and intensity of storms — meaning more water falling in the form of rain and flash floods — but is also anticipated to result in more prolonged periods of drought. This dichotomy makes analyzing the impacts of precipitation difficult, as there will be an even greater variability between extreme wet years and periods of drought than already exists in California's mostly Mediterranean climate.

Using Cal-Adapt's Annual Averages tool, historical annual average precipitation in the City of Chico is estimated to be 29.6 inches (Cal-Adapt, 2017). Under the Low-Emissions Scenario, the annual precipitation in the City is projected to increase to 32.8" by 2050 and 32.5" by 2090 (Cal-Adapt, 2017) (See Figure 7). Under the High-Emissions Scenario, annual precipitation in the City is projected to increase to 33.4" by 2050 and 35.8" by 2090. (Cal-Adapt, 2017) (See Figure 8).

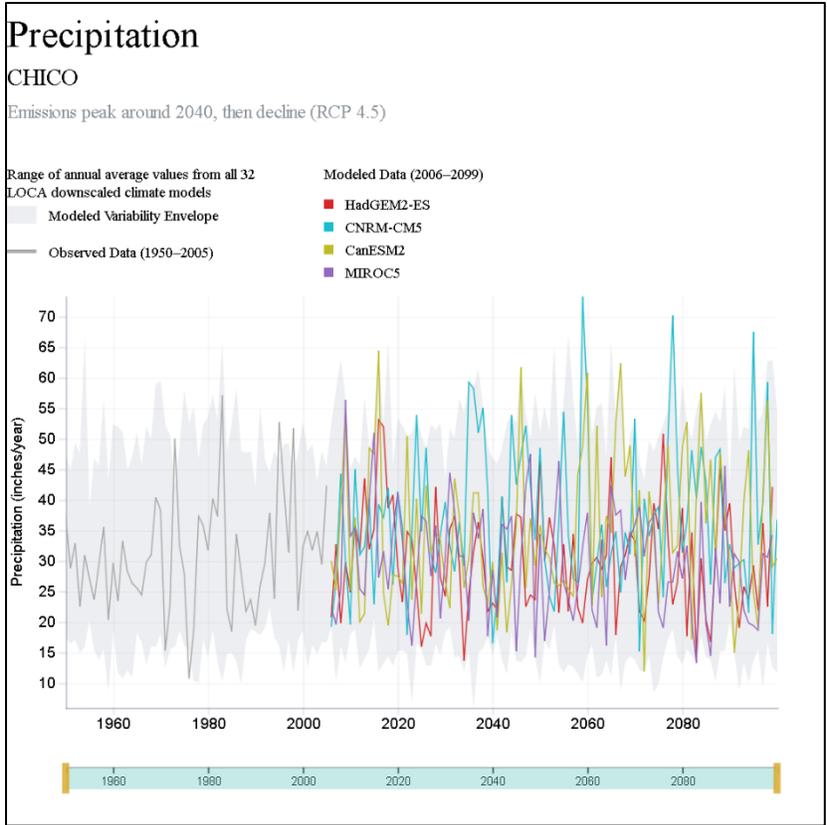
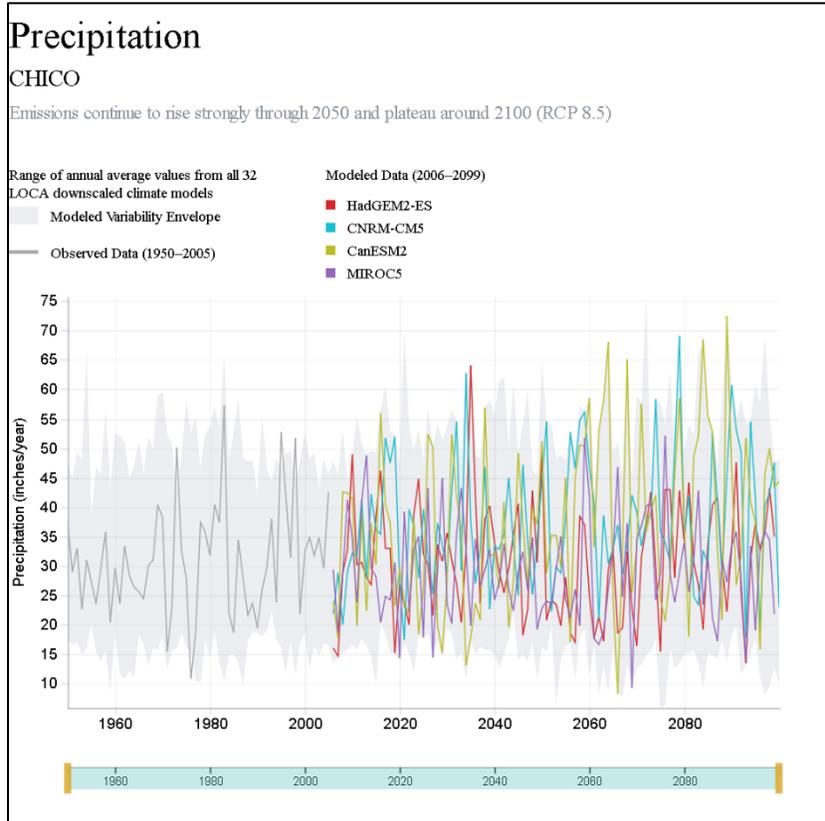


Figure 7: This chart shows annual averages of observed and projected Precipitation values for the selected area on map under the RCP 4.5 scenario. The gray line (1950 – 2005) is observed data. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. The light gray band in the background shows the least and highest annual average values from all 32 LOCA downscaled climate models. (Cal-Adapt, 2018)

Figure 8: This chart shows annual averages of observed and projected Precipitation values for the selected area on map under the RCP 8.5 scenario. The gray line (1950 – 2005) is observed data. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. The light gray band in the background shows the least and highest annual average values from all 32 LOCA downscaled climate models. (Cal-Adapt, 2018)



## 2.4 Increased Storm and Flooding Events

Climate change is predicted to modify the frequency, intensity, and duration of extreme storm events, with sustained periods of heavy precipitation and increased rainfall. The precipitation that will fall is expected to have more intense characteristics, such as high volume of rain falling over a shorter period of time with stronger and more destructive wind patterns. These storms may produce higher volumes of runoff and contribute to an increased risk of flooding. These projected changes could lead to increased flood magnitude and flooding frequency (IPCC, 2001).

When the Sacramento River, Big Chico Creek, and other tributaries that flow into these river systems can't discharge at a normal rate, these conditions result in backflows, which can cause tributaries to overflow and flood local areas. To combat these natural tendencies for flooding in the City, flood control systems have been established with dams, levees, and channels to control high flows and potential inundations. Lindo Channel diverts extra water volume from Big Chico Creek during high-flow events to prevent flooding in the City of Chico. Water is diverted through streams and channels around the city where, eventually flowing into the Sacramento River. See **Figure 9**, a map of Chico's watersheds, levees, and water infrastructure.

Flooding can occur anytime from November through April. Flooding generally occurs as result of prolonged rainfall, or rainfall combined with Sierra snowmelt and/or already saturated soils from previous rain events. Factors that directly affect the amount of flood runoff include precipitation amount, intensity and distribution, the amount of soil moisture, seasonal variation in vegetation, snow depth in the Sierra, and impermeability of surfaces due to land use decisions, development patterns, building and infrastructure material choices and project designs. Placement and integrity of existing levees and reservoir operation for flood control are also important factors. Intense storms may overwhelm local waterways, as well as threaten the integrity of flood control structures. (Butte County Department of Water Resources and Conservation, 2016). The following are the principal areas subject to flooding in the City of Chico:

### Natural Waterways

- Little Chico Creek
- Little Chico Creek Diversion
- Mud Creek
- Sycamore Creek
- Rock Creek
- Comanche Creek
- Sandy Gulch

### Flood Control Channels

- Cherokee Canal
- Lindo Channel (Sandy Gulch)
- Sycamore Bypass Channel

In addition to the streams listed above, flooding in Rock Creek and Keefer Slough, located north of Chico, occurred on several occasions in the 1980s, 1990s and 2000s, inundating State Routes 99 and 32 and several county roadways, as well as impacting extensive residential and agricultural areas in and around the North

Chico area and the unincorporated community of Nord. (Source: Butte County General Plan Health and Safety Element).

Currently, the City experiences localized flooding in several areas of the community. Localized flooding occurs during periods of severe weather and unusually high amounts of rainfall, and on occasions where stormwater infrastructure is physically impaired or inadequate. This kind of flooding event typically occurs in urbanized areas with expanses of impervious surfaces.

During a large flooding event, the City may be vulnerable to levee failure. Levee failure flooding would vary in the planning area depending on the structure to fail and the nature and extent of the failure and associated flooding. This type of flooding presents a threat to life and property, including buildings, their contents, and their use. Large flood events can affect lifeline utilities (e.g., water, sewer, and power), transportation, jobs, tourism, the environment, the agricultural industry, and the local and regional economies. (LHMP)

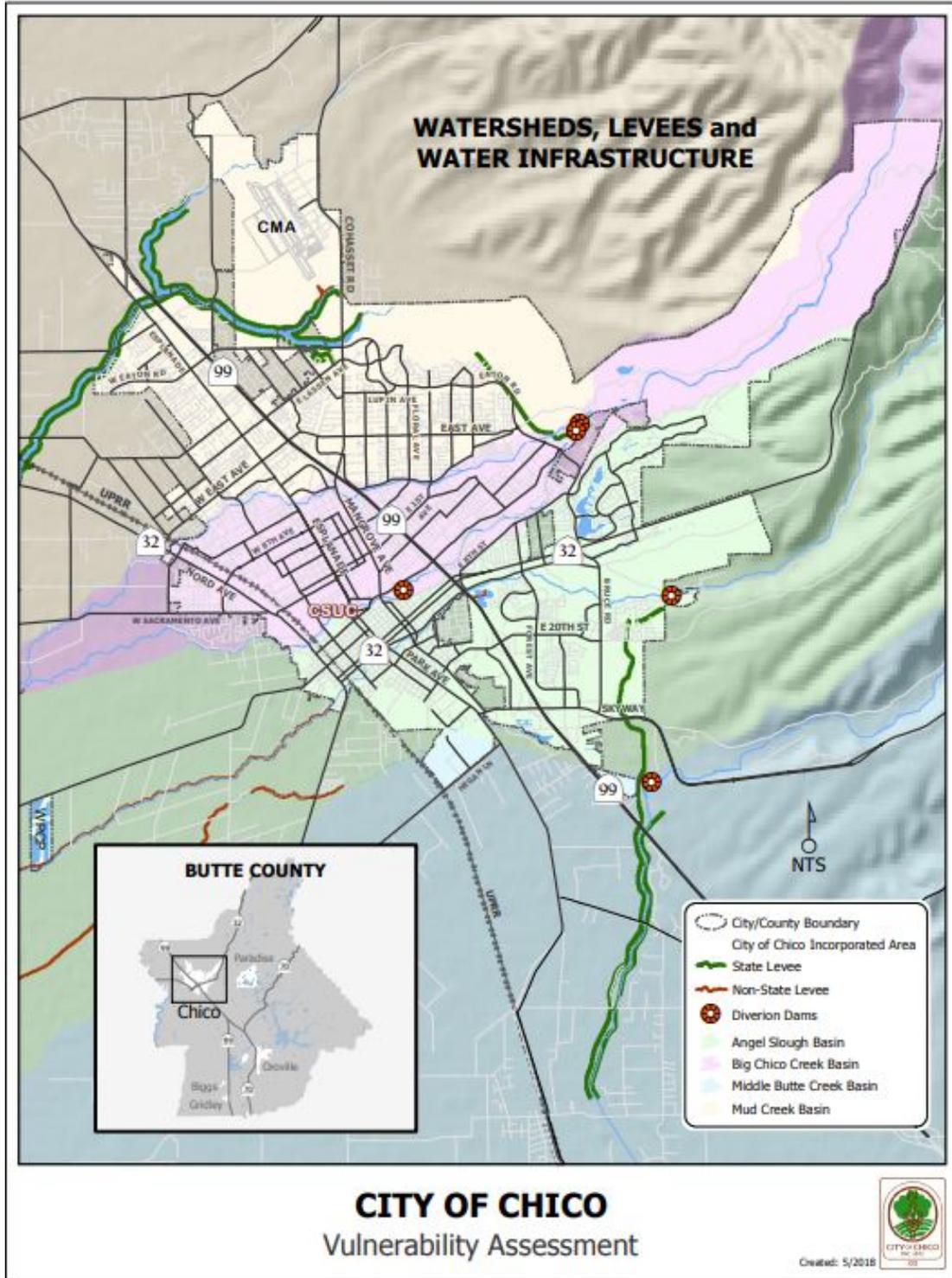


Figure 9: Map of Chico's watersheds and flood control infrastructure. Map created by Brad Pierce, City of Chico.

## 2.5 Snowpack

Changes in weather patterns resulting from increases in global average temperature could result in a decrease in the proportion and total amount of precipitation falling as snow. This phenomenon is predicted to result in an overall reduction of snowpack in the Sierra Nevada. Based upon historical data and modeling, under the Low- and High-Emissions Scenarios, the California Department of Water Resources (DWR) projects that the Sierra Nevada snowpack will decrease by between 25 percent to 40 percent from its historic April 1st average of 28 inches of water content by 2050 and by between 48 percent to 65 percent by 2100 (DWR 2008, DWR 2013). This represents a significant change in the historic runoff regime for California.

For the purpose of this assessment, we gathered data from the northern Sierra Nevada Mountain Range. This mountain range encompasses the watersheds that flow into the City. The historic average water equivalent in the snowpack for the Northern Sierra Nevada Region is 7.9 inches (Cal-Adapt, 2017) (See Figure 10). Under the Low Emissions Scenario, Cal-Adapt predicts the snow water equivalent to be at 3.6" by 2050 and 2.6" by 2090 (Cal-Adapt, 2017). Under the High-Emission Scenario, by 2050 the average snowpack will be 3.0" and 0.07" by 2090 (Cal-Adapt, 2017) (See Figure 11).

## Snow Water Equivalence

SIERRA NEVADA MOUNTAINS N SIERRA REGION

Emissions peak around 2040, then decline (RCP 4.5)

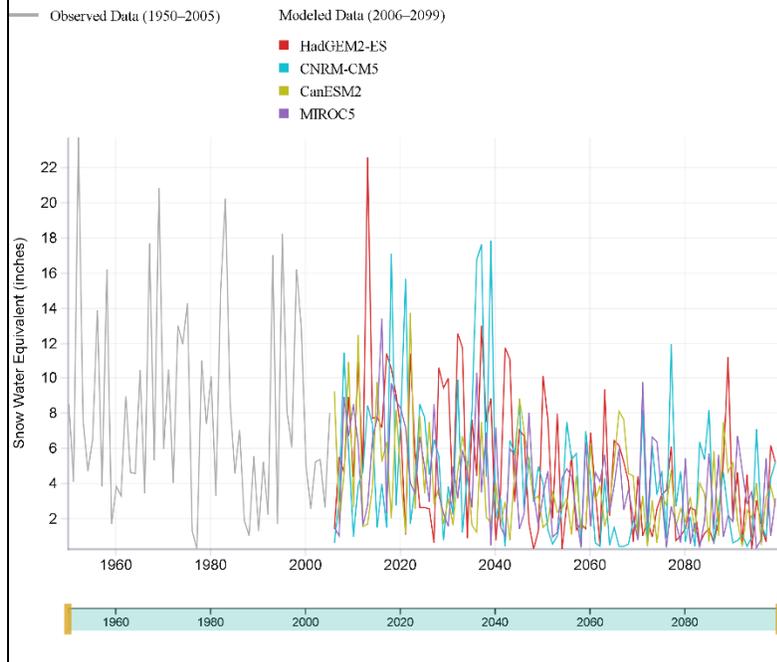


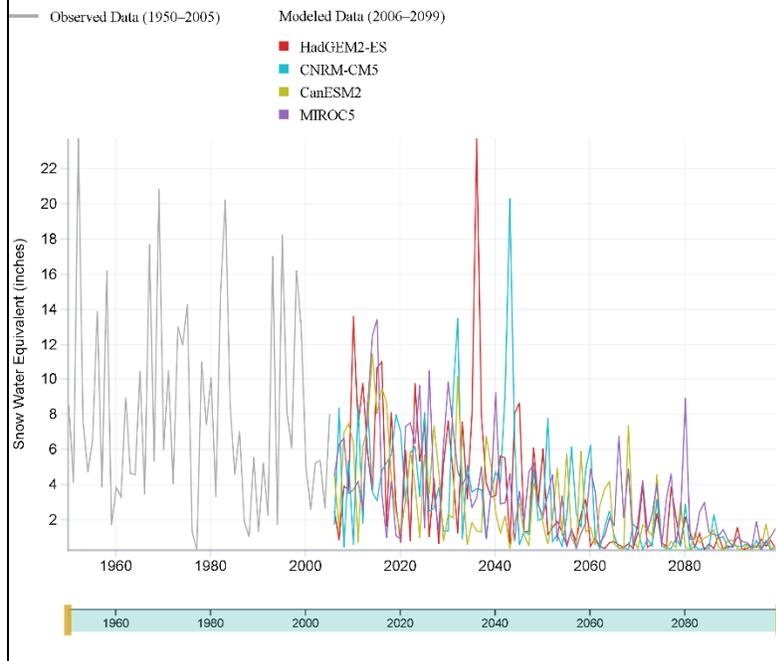
Figure 10: This chart shows monthly averages of projected Snow Water Equivalent values for the selected area on map under the RCP 4.5 scenario. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. These models have been selected by California state agencies as priority models for research contributing to California’s Fourth Climate Change Assessment. (Cal-Adapt, 2018)

Figure 11: This chart shows monthly averages of projected Snow Water Equivalent values for the selected area on map under the RCP 8.5 scenario. The colored lines (2006 – 2100) are projections from 4 LOCA downscaled climate models selected for California. These models have been selected by California state agencies as priority models for research contributing to California’s Fourth Climate Change Assessment. (Cal-Adapt, 2018)

## Snow Water Equivalence

SIERRA NEVADA MOUNTAINS N SIERRA REGION

Emissions continue to rise strongly through 2050 and plateau around 2100 (RCP 8.5)



## Surface Water

The Sacramento River, Butte Creek, Big Chico Creek, and Little Chico Creek, provide agricultural and recreational uses for the City. The flow-regimes of these rivers depend on spring and summer snowmelt in the Sierra Nevada. The ability of snowpack to retain water and release it gradually is fundamental to water supply planning throughout the watersheds of the Sierra Nevada. **See Figure 12**, a map of surface water flows in Butte County.

Average monthly flows for the Sacramento River are greatest between January and March, reflecting runoff from precipitation on the valley floor, planned reservoir releases, and reservoir spillage in some years. Flows are sustained through July or August and even into November as water is released from storage in Lake Shasta. In contrast, unimpaired flows from Butte Creek and Big Chico Creek are greatest between approximately February and May as a result of runoff from snowmelt. These flows decrease greatly between May and July once the snow has melted. If we see an earlier melt of our snowpack, this could largely affect Butte Creek and Big Chico Creek which both support the spring and winter Chinook salmon runs as well as many other federally and/or state endangered species. (Butte County Department of Water Resources and Conservation, 2016)

Runoff and groundwater flows within the City contribute to the flows in the above waterways and also to those arising within the City. These waterways represent the major streams and water supply and drainage features in the County and include:

### • Natural Waterways

- Sacramento River
- Butte Creek
- Big Chico Creek
- Little Chico Creek
- Rock Creek
- Mud Creek
- Sheep Hollow
- Sycamore Creek
- Dead Horse Slough
- Comanche Creek

### • Flood Control Channels

- Cherokee Canal
- Lindo Channel (Sandy Gulch)
- Sycamore Bypass Channel

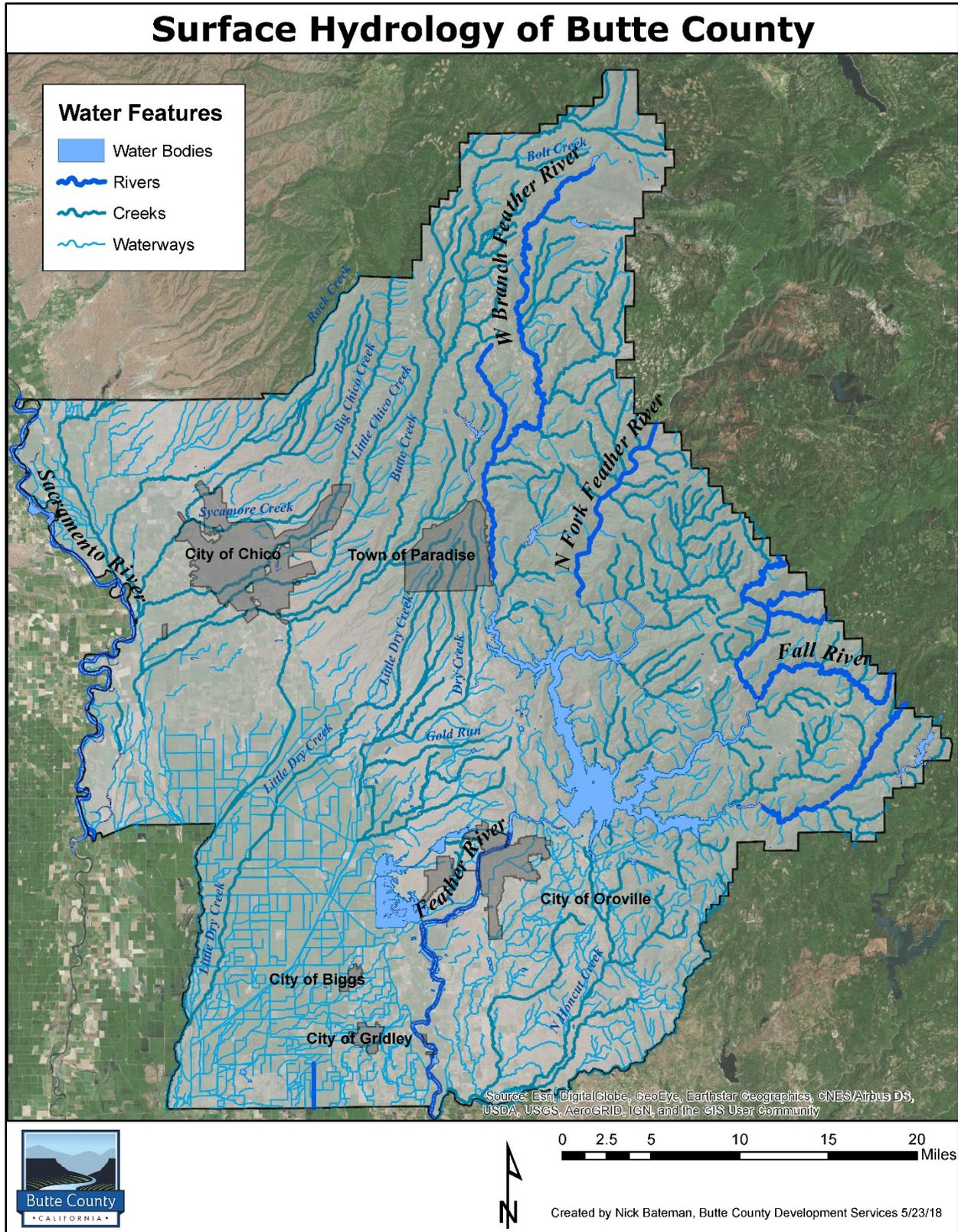


Figure 12: Surface Water Hydrology for Butte County and City of Chico

## Groundwater

The City of Chico lies over the West Butte Groundwater Subbasin (See Figure 13), which provides 100% of the city's municipal water supply through Cal Water. Shallow groundwater zones (<400ft deep) are recharged by the Upper Watershed. Intermediate and deep portions of the basin are recharged from the upper elevations of the Lower Foothills (<1800ft). Groundwater wells to the east may be recharged from Butte Creek, whereas wells to the west may be recharged by flow from the Sacramento River (Butte County Department of Water Resources and Conservation, Isotope Recharge Study Final Report, 2018). Groundwater stores are directly linked to surface water in the

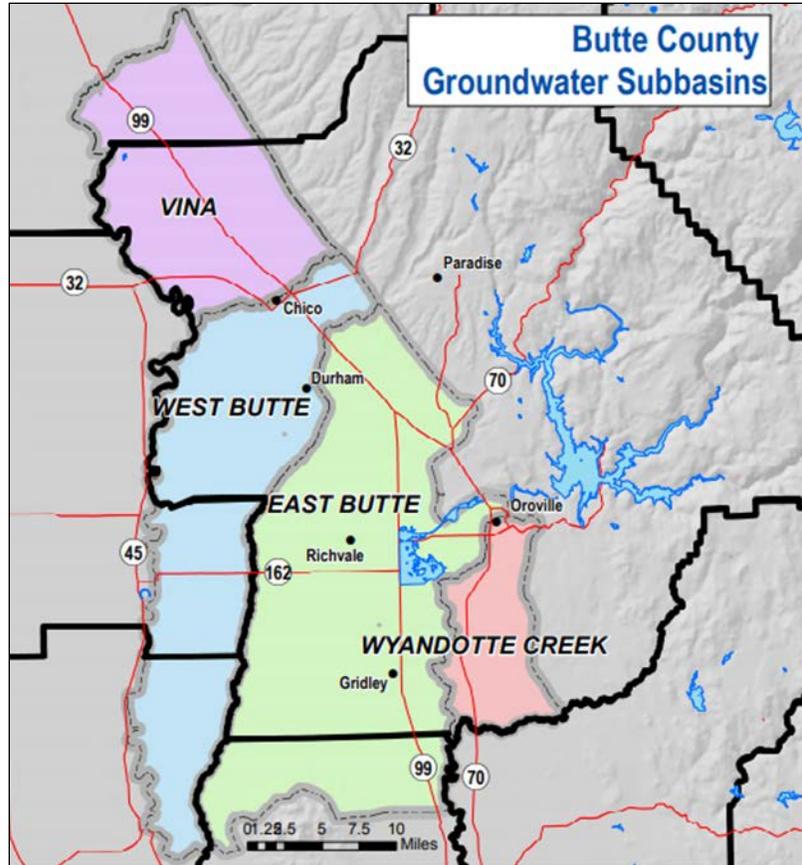


Figure 13: Butte County Groundwater Subbasin. Chico sits on the West Butte Basin. (Butte County Department of Water Resources and Conservation, 2016)

County and snowmelt in the Sierra Nevada; therefore, increased average temperatures and changes in the timing, amounts, and form of precipitation could affect local aquifer recharge for groundwater supplies (Butte County Department of Water Resources and Conservation, Isotope Recharge Study Final Report, 2018).

## 2.6 Increased Wildfire Risk

Rising temperatures, combined with changes in precipitation patterns and reduced vegetation moisture content, can lead to the secondary climate change impact of an increase in the frequency and intensity of wildfires. Changes in precipitation patterns and increased temperatures associated with climate change will alter the distribution and character of natural vegetation and associated moisture content of plants and soils (CNRA 2012b:11). Increased temperatures will increase the rate of evapotranspiration in plants, resulting in a greater presence of dry fuels in forests, creating a higher potential for wildfires (SACOG 2015:3).

Increased wildfire activity across the western United States in recent decades has contributed to widespread forest mortality, carbon emissions, periods of poor air quality, and substantial fire suppression expenditures. Although numerous factors contributed to the recent rise in fire activity, observed warming and drying have significantly increased fire-season fuel aridity, fostering a more fire-prone environment across forested systems. On October 11, 2016, the Proceedings of the National Academy of Scientists have reported that anthropogenic climate change has contributed to more than half of the documented increases in fuel aridity

since the 1970s and doubled the cumulative forest fire area since 1984. This analysis suggests that anthropogenic climate change will continue to chronically heighten the potential for western U.S. forest fire activity where fuels are not limited.

Chico's terrain is mostly flat with increasingly hilly terrain beginning at the City's eastern edge. Within the City limits are numerous open space areas (see **Figure 16**), most notably Bidwell Park, which runs five miles from the city center into the foothills of the Cascade Range and encompasses a range of habitats from dry grassland to riparian forest. During the summer dry months, the risk of wildfire in these open, vegetated areas can increase when exacerbated by extreme weather conditions, such as high temperatures, low humidity, and/or high winds. These conditions can cause small, localized fires to escalate into more intense and difficult to control wildfires.

Large areas of Chico lie adjacent to the foothills, are subject to the threat of wildland fires. The grass-oak woodland in these areas can produce flames exceeding 20 feet in height on hot summer days. Bruce Road is currently the boundary to the east of which fires receive a substantial first alarm because of the wildland fire risk. In addition, there are wildfire problems in Bidwell Park. The Chico Fire Department (CFD) has recorded hundreds of fires in Bidwell Park over the decades, citing dry fuels, heavy recreational use, and presence of motor vehicles. Some areas within Upper Bidwell Park are inaccessible by road and would require specialized wildland firefighting resources such as air tankers, helicopters, bulldozers, and hand crews should they catch fire. According to the City's Master Environmental Assessment completed in 1994, Bidwell Park, Lindo Channel, and numerous vacant parcels throughout the City represent significant amounts of dry vegetation during the summer months. (City of Chico Local Hazard Mitigation Plan, 2013). 15% of property parcels in the City are in designated Moderate and High Fire Danger Zones, nearly all on the east side of Highway 99 (City of Chico Fire Department, Community Risk Assessment, 2017).

According to the City of Chico 2013 Local Hazard Mitigation Plan (LHMP), wildfire and urban wildfire are an ongoing concern, categorized as highly likely, with high vulnerability (City of Chico Local Hazard Mitigation Plan, 2013). Generally, the fire season extends from early spring to late fall. Fire conditions arise from a combination of weather, topography, wind patterns, accumulated vegetation, and low-moisture content in the air. Urban wildfires often occur in places where development has expanded into rural areas. Currently, many homes (see **Figure 16**) within Chico are in the urban-wildland interface, characterized by zones of transition between wildland and developed areas, often including fuel loads that increase wildfire risk. These areas within Chico are located along Humboldt road, the north-eastern section of HWY 32, housing along Bruce road, the California Park Development, and communities in Butte Creek Canyon.

Chico has unique fire risks related to college student populations, especially with off-campus student housing. Nationally, from January 2000 to May 2015, there were 85 fatal fires in dormitories, fraternities, sororities and off-campus student housing, resulting in 118 fatalities, an average of approximately seven per school year. 94 percent of fatal fires occur in off-campus housing. (City of Chico Fire Department, Community Risk Assessment, 2017)

It should be noted that there is uncertainty surrounding projections for future wildfire risk. The projections contained in the City of Chico LHMP are based on models that use a variety of factors that contribute to wildfire risk (e.g., topography, vegetation type). The variations in the parameters used in wildland fire models may produce contradictory results, as discussed below.

Increased temperatures and changes in precipitation patterns associated with climate change are expected to increase the risk of wildfire in the City. According to Cal-Adapt, the current average of area burned is 35.9 hectares. Under the low emissions scenario, using the low population scenario, by 2050 Chico will see an increase in annual average hectares burned by 40.6 hectares and 44.x hectares by 2090 (See **Figure 14**). Under the High-Emissions Scenario, the amount of area at risk of burning increases to 40.6 hectares in 2050, and 59.2 hectares in 2090. Based on Cal-Adapt's Wildfire tool, the increase in burned area is most likely to occur in the eastern foothills of the City as well as open space areas (Cal-Adapt, 2017) (See **Figure 15**).

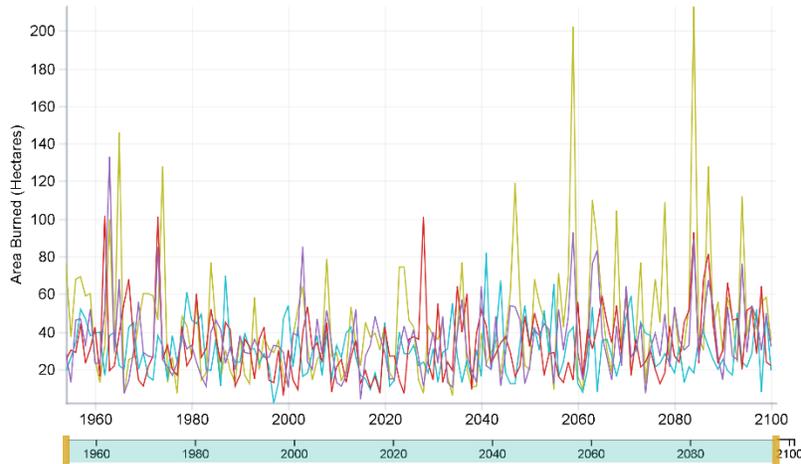
## Annual Average of Area Burned

### CHICO

Emissions peak around 2040, then decline (RCP 4.5)

Modeled Data (2006–2099)

- CanESM2
- CNRM-CM5
- HadGEM2-ES
- MIROC5



**Figure 14:** This chart shows modeled annual averages of area burned for the selected area on map under the RCP 4.5 scenario. These models have been selected by California state agencies as priority models for research contributing to California’s Fourth Climate Change Assessment. (Cal-Adapt,2018)

**Figure 15:** This chart shows modeled annual averages of area burned for the selected area on map under the RCP 4.5 scenario. These models have been selected by California state agencies as priority models for research contributing to California’s Fourth Climate Change Assessment. (Cal-Adapt,2018)

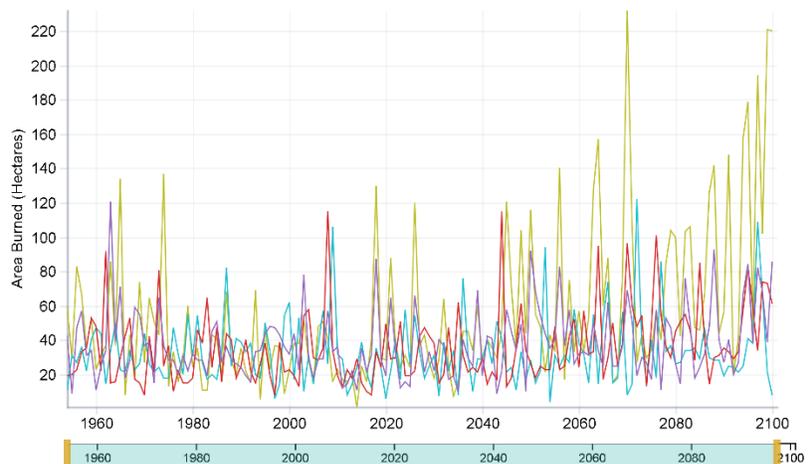
## Annual Average of Area Burned

### CHICO

Emissions continue to rise strongly through 2050 and plateau around 2100 (RCP 8.5)

Modeled Data (2006–2099)

- CanESM2
- CNRM-CM5
- HadGEM2-ES
- MIROC5



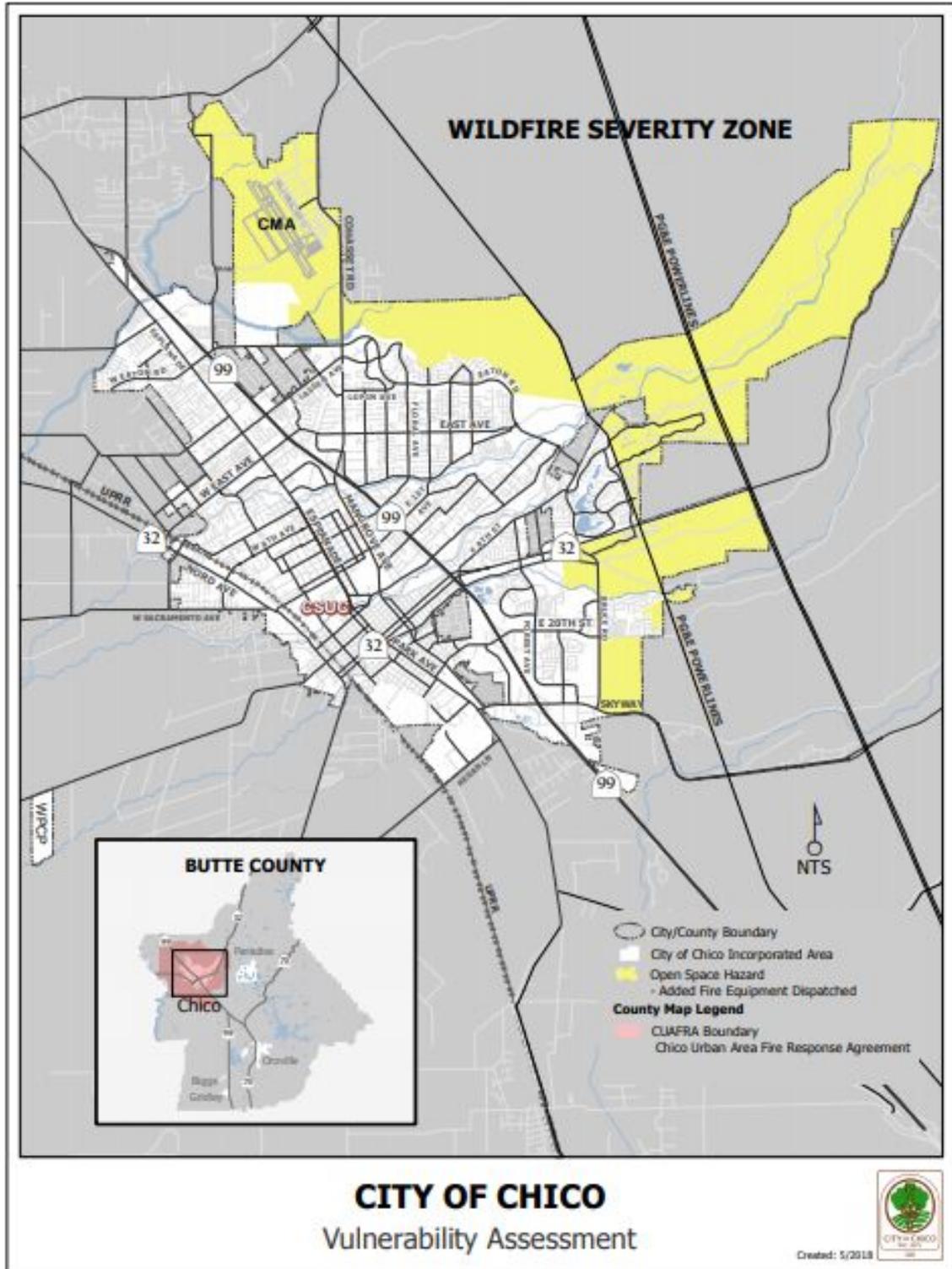


Figure 16: City of Chico Wildfire Severity Zone. Map by Brad Pierce

## 3 Sensitivity and Potential Impacts

The APG recommends that a vulnerability assessment be developed in five discrete steps; however, the next two steps in the process are closely related and are therefore discussed together. The second step in the vulnerability assessment involves using a systematic evaluation to identify populations, functions, and structures that may be affected by projected exposures to climate change impacts and their degree of sensitivity. Using the APG's recommended sensitivity checklist, this evaluation focuses specifically on resources potentially affected by climate change that were identified in the Exposure section above.

The sensitivity checklist is organized into three main categories: Population, Functions, and Structures. The categories are described in more detail below:

**Population:** Includes both the general human population and segments of the population that are most likely to be sensitive or vulnerable to climate change impacts. This applies particularly to non-English-speaking or elderly populations who may require special response assistance or special medical care after a climate-influenced disaster, as well as other disadvantaged communities.

**Functions:** Includes facilities that are essential to the health and welfare of the entire population and are especially important following climate-influenced hazard events. These facilities include hospitals, medical facilities, police and fire stations, emergency operations centers, evacuation shelters, and schools. Transportation systems, such as airways (e.g., airports, highways), bridges, tunnels, roadways, railways (e.g., tracks, tunnels, and bridges), and waterways are also important to consider. Lifeline utility systems such as potable water, wastewater, fuel, natural gas, electricity, and communications are also critical for public health and safety. Functions also include other economic systems such as agriculture, recreation, and tourism, as well as natural resources within a community, including various plant and animal species and their habitats.

**Structures:** Includes the structures of essential facilities noted above, such as residential and commercial infrastructure, institutions (e.g., schools, churches, hospitals, etc.), recreational facilities, transportation infrastructure, parks, levees, and water and wastewater treatment infrastructure. It also includes high potential loss facilities, where damage would have large environmental, economic, or public safety considerations (e.g., dams).

The third step in the assessment includes evaluating how these impacts will occur and how severe they may be (e.g. low, medium, or high). Given that climate change exposures at the local scale are inherently uncertain, the APG recommends that communities conduct a qualitative assessment that describes the potential impacts based on the exposure (CNRA 2012). This assessment is not meant to be exhaustive and prescriptive but is rather intended to provide a high-level view of potential impacts that could occur as a result of identified climate change exposures. Further evaluation and research would be needed to more precisely identify points of sensitivity and potential impacts, including specific facilities, structures, and areas of concern.

### 3.1 Increase in Temperature

Based on the High- and Low-Emissions Scenarios, annual average temperatures in Chico are projected to rise 4 to 7 °F by 2090. Increased temperatures can lead to secondary climate change impacts including increases in the frequency, intensity, and duration of extreme heat events in Chico.

## Population

The projected rise in temperature will have severe impacts on human health. Cases of heat-related illnesses such as nausea, dizziness, stroke, dehydration, and heat exhaustion are expected to rise. As identified in the Climate Change Effects section above, Chico is projected to experience four times as many days above 103 degrees (Extreme Heat Day), which will increase cases of heat-related illnesses and exacerbate pre-existing medical conditions. Higher temperatures will also mean greater instances of record high minimum temperatures. When there is not a significant drop in temperature overnight (at least 20 degrees Fahrenheit) the human body continues to behave in distress mode—high blood pressure, elevated heart rate—overtaxing the body.

With longer heat waves, Enloe Hospital is likely to see an increase in patients admitted for treatment related to prolonged heat exposure. Further, disadvantaged communities in Chico are likely to face greater challenges in dealing with extreme heat. Populations that are socially and economically vulnerable often bear the disproportionate burden of climate effects (**See figure 17**). People in low-income areas, some of which are communities of color; people with existing health issues, such as chronic diseases and mental health conditions; young children and the elderly; people experiencing homelessness; outdoor workers; and socially or linguistically isolated people are most vulnerable to the impacts of climate change. Many do not use, or even own, air conditioning because they cannot afford to pay the utility bill. Further, low-income populations often live in aging buildings with poor insulation and ventilation, leading to higher costs associated with air conditioning. Currently, 25.2% of Chico's residents are living in poverty (United State Census Bureau, 2017). These people are more likely to experience infrastructural limitations, more likely to have one or more chronic medical conditions, and less likely to own cars that can provide mobility to avoid deleterious climate effects.

A large portion of Chico's population is students who attend the community's local colleges. Many students live in the neighborhoods north and south of the CSU, Chico campus, which are older neighborhoods with older housing stock and limited heating and cooling systems. Students that do not have access to air conditioning are at risk of experiencing heat-related impacts.

Currently, 1,096 people are considered to be homeless in the City of Chico (2017 Homeless Point in Time Census and Survey Report, 2017). Homeless populations are especially vulnerable to heat-related illnesses in periods of excessively high heat, as refuge from high temperatures may not be accessible. Further, homeless persons regularly using alcohol and/or drugs may experience exacerbated reactions to excessive heat.

Higher temperatures can also worsen air quality through increased air pollution, such as from ozone formation and particulate matter generation (e.g., from wildfire smoke), which poses a health hazard to vulnerable populations. Children, elderly, and persons with pre-existing chronic diseases are particularly susceptible to respiratory and cardiovascular effects from air pollution.

Quality of life could also be affected by heat-related power outages. Loss of electricity limits the ability to cool interior spaces, which could affect people's ability to seek refuge from the heat. Food-service and grocery stores could see economic losses from food spoilage due to loss of refrigeration from power outages. The ability to communicate via internet and landline could also be affected.

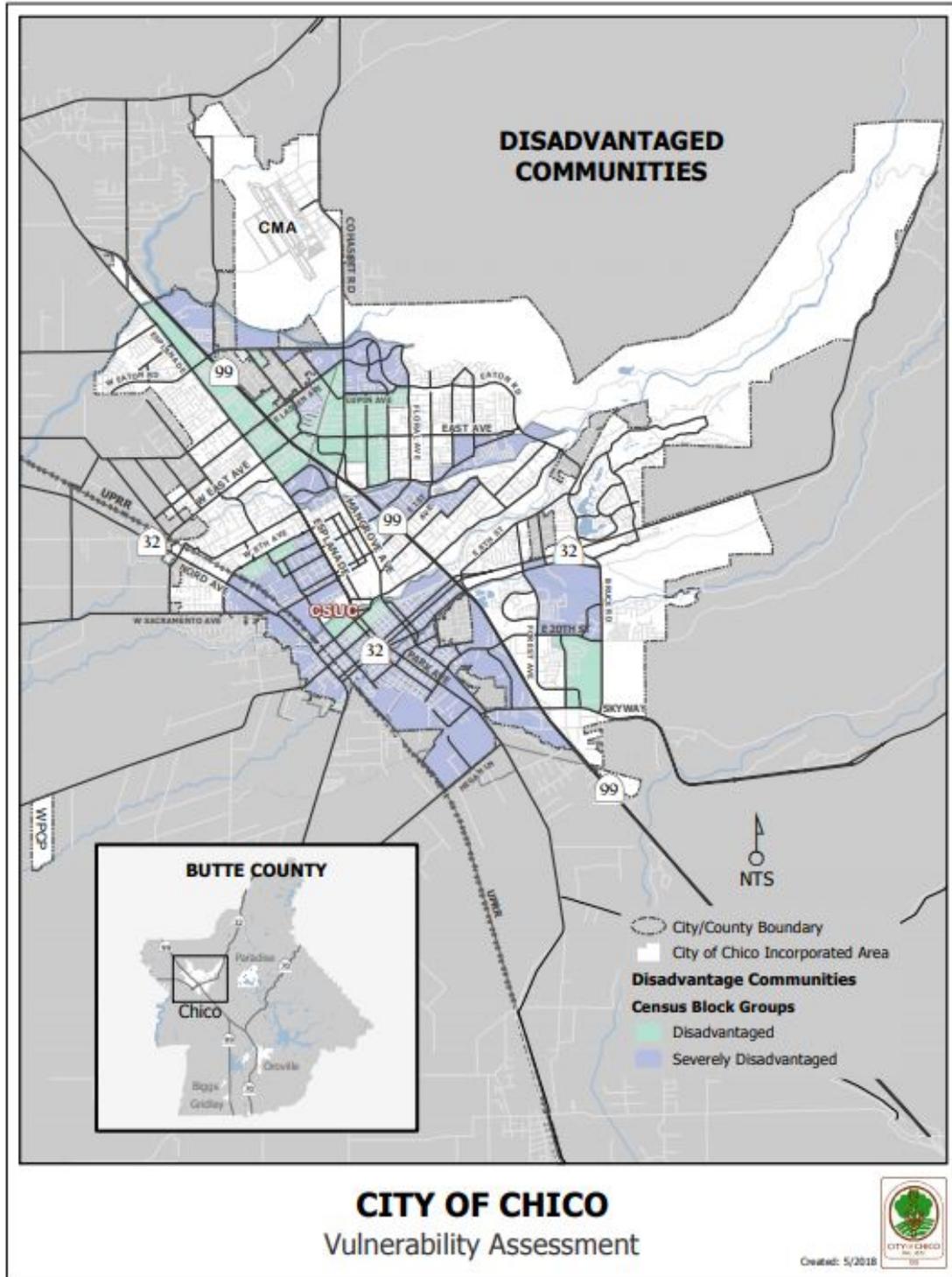


Figure 17: Disadvantaged Communities in the City of Chico. Map by Brad Pierce.

## Function and Structures

The rise in temperature also has the potential to affect Chico's transportation infrastructure. Asphalt and other road maintenance materials are not currently designed to withstand extended periods of heat. Roadway degradation could occur, as asphalt and concrete can deform at faster rates under high temperatures, resulting in pavement rutting and cracking that may present unsafe road conditions for motorists, bicyclists, and pedestrians.

Chico has a rail line that runs through the western side of the community. The power system may experience thermal expansion, which will cause expansion and lose tension leading to reduce speeds. (Maizlish Neil, 2017). Bridges can be impacted by heat as well. The temperature fluctuations can cause increased expansion and contraction of the structural joints. This could increase road maintenance costs and cause more frequent road closures, impacting public safety (Maizlish Neil, 2017).

High temperatures decrease the efficiency of power transmission lines, which can increase the potential for power outages and blackouts. At the same time, more homes and businesses will be relying on electricity to stay cool. Public health and safety will be at risk with limited ways to stay cool during these times (Maizlish Neil, 2017).

Power failure as a result of climate change-related increases in temperature and prolonged heat waves may disproportionately affect the functions of small to medium businesses (SMBs) as compared to large businesses and corporations. SMBs are particularly vulnerable to power disruptions due to lack of capital and resources combined with a low number of operational facilities (typically one) (Valley Vision 2014). SMBs are less likely to invest in backup generators, improved insulation, and other infrastructural improvements to combat temperature-related disruptions.

Chico is well known for its variety of outdoor activities. Spring and summer months are characterized by recreational activities such as hiking and swimming, outdoor community events such as farmers' markets, Friday night concerts in the plaza, and food truck gatherings. With an increase in extreme heat events, outdoor recreation will become less desirable. Recreators will become more vulnerable to heat-related illnesses which could be exacerbated by physically demanding exercise. This has the potential to affect revenue for parks and businesses in the outdoor recreation industry. This could also affect people's quality of life as exercising and spending time outdoors becomes less desirable. Ultimately, this could lead to negative health outcomes such as weight gain, obesity, and anxiety.

Increases in temperature can have severe impacts on biological resources and ecological function. Belonging to Butte County's diverse range of habitats, Calflora lists 35 species that are rare, native, or edaphically (cause by particular soil condition) inclined to serpentine soils (CalFlora, 2017). Many of these species are found in and around Chico, especially in open spaces such as Bidwell Park that span multiple habitat types. Increased heat can make plants more prone to disease and become outcompeted by invasive species, which often flourish where native species struggle to survive. Virus vectors such as aphids, soil-borne fungi, and "weeds" (nonnative invasive plants) can quickly spread disease. Plants that cannot disperse fast enough or with longer life cycles, such as perennials and trees, may have difficulty surviving under these new stressful conditions.

There are 153 invasive species in Butte County alone (CalFlora, 2017). Faster development of non-perennial crops results in a shorter life cycle, resulting in smaller plants, shorter reproductive duration, and lower yield

potential. Temperature extremes that occur at critical times during development can significantly impact plant productivity.

Bark beetles, family Scolytidae, are common pests of conifers (e.g., pines), and some attack broadleaf trees. Bark beetles mine the inner bark (the phloem-cambial region) on twigs, branches, or trunks of trees and shrubs. Bark beetles frequently attack trees weakened by drought, disease, injuries, or other stressors. Bark beetles can contribute to the decline and eventual death of trees, although only a few aggressive species are known to be the sole cause of tree mortality. Not only does this lead to the death of trees which are a key factor in Biodiversity and habitat, but once the trees are infested and/or dead they become fire hazards.

Temperatures which would be considered extreme and fall before or after specific thresholds at critical times during plant development can significantly impact plant productivity. Prolonged periods of high heat will increase rates of evapotranspiration in plants and reduce the moisture content of soils, causing increased demand for water for irrigation and landscaping. Additionally, extreme heat waves will exacerbate rates of evaporation in surface waters, resulting in the loss of valuable water resources. Water temperature will rise in streams, lakes, and reservoirs as air temperature rises. This typically leads to lower levels of dissolved oxygen in the water, stressing populations of fish, insects, crustaceans and other aquatic animals that rely on oxygen. An increase in temperature will decrease food availability, resulting in the loss of habitat for wildlife of all sizes.

The woodland and savanna ecosystems of Bidwell Park are part of the California Floristic Province, a globally recognized conservation hotspot. They are also the most at risk of suffering the effects of climate change. In California, oak woodland and savanna are some of the most biologically diverse communities, providing habitat for approximately 2,000 plant species, 5,000 insect species, 80 amphibian and reptile species, 160 bird species, and 80 mammal species. This high level of biodiversity is partly due to the provisioning of oak mast, a critically important food for many wildlife species.

Open grasslands, vernal pools, and wetlands (emergent and managed) on the east side of Chico are all vulnerable to climate change. Many of these areas are biologically rich in species and can be easily be disturbed by changes in the number of extreme heat days, heat waves, and overall increased temperatures. Vernal pools may not recover from such heat, while Woodlands and forests in the foothills would be extremely prone to wildfire risk.

### 3.2 Changes in Precipitation, Increase in Flooding and Decrease in Snowpack

This section provides an overview of how changes in precipitation, increase in flooding as well as a decrease in snowpack will impact the City of Chico. Increased average temperatures and a hastening of snowmelt in the Sierra Nevada and distant portions of watersheds, along with local and regional changes in precipitation and timing of runoff in local watershed creeks, will affect both surface and groundwater supplies.

Climate change will not only lead to an increase in frequency and intensity of storms, meaning more water falling in the form of rain and more frequent flash floods, it will also bring more prolonged periods of drought. This makes analyzing the impacts of precipitation difficult. Below are discussions regarding both drought and flooding impacts on the City of Chico.

## Population

Flooding can adversely affect populations living in 100-, 200-, and 500-year floodplains. Flood events cause considerable property damage through water and structural damage.

Flooding-related impacts will disproportionately affect populations considered socially vulnerable. Social vulnerability is defined using a composite of proxy indicators, including age, race, health, income, and quality of the built environment. Low-income status is considered the most significant contributor to social vulnerability; therefore, households with insufficient financial reserves are likely to be disproportionately affected by a disaster such as flooding (Burton and Cutter 2008:142). Low-income populations generally suffer higher mortality rates and their homes sustain greater damage due to the quality age, and location of the housing stock. Further, low-income households may not be able to afford structural upgrades or flood insurance to mitigate the effects of flooding (Burton and Cutter 2008:144). Low-income households may also lack transportation and other resources to respond to or evacuate during a flood event.

Floodwaters during storm events can interact with sources of pollution and distribute hazardous pollutants locally and regionally. The resulting water contamination may lead to human health impacts as well as degradation of ecosystems.

As mentioned earlier, climate change will also result in more periods of drought. Less precipitation during such periods will mean a decrease in surface water and a resulting increase in dependence on groundwater supplies. Due to the intensified use of groundwater during recent drought periods, many of California's groundwater basins are showing signs of overdraft conditions, with groundwater use exceeding the rate of groundwater recharge. An overdraft can lead to land subsidence wherein a gradual settling or sudden sinking of the earth's surface occurs. The effects of subsidence could impact houses and other structures such as transportation infrastructure, cause water well casing failures, and change the elevation and gradient of stream channels, drains, and other water transport structures (CNRA 2014).

Further, reduced water flows, water diversion for agriculture, and warmer water temperatures in local waterways can impact important animal species, including Chinook salmon and other fish species listed as threatened or endangered under the federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

Drought conditions can also support the spread of vector-borne illness. Coupled with higher temperatures, reduced levels of precipitation restrict the flows of underground pipelines for water and wastewater diversion. This can result in unseen, stagnant pools of water that provide conditions for the breeding of mosquitoes and other vector carrying insects and arthropods, particularly in urban areas. An increase in the populations of these organisms may result in the spread of mosquito-borne illnesses, such as dengue fever, West Nile virus, and Zika virus. Vulnerable populations susceptible to these diseases include the elderly and people with compromised immune systems or chronic illness (Capitol Region Climate Readiness).

## Functions and Structures

With the predicted warming, more precipitation will fall in the winter as rain instead of snow, increasing the frequency and severity of flooding. Extreme weather events are expected, such as back-to-back precipitation events that could overwhelm the ability of Chico's storm-water infrastructure to absorb and manage the runoff. The City of Chico is prepared for a 200-year flood event, but projections anticipate those events happening with a frequency of 150-100 years. According to the City's Local Hazard Mitigation Plan, 2,208 people are at risk of flooding from a 100-year flood event, and 18,813 people are at risk of flooding from a

200-year flood event (City of Chico Local Hazard Mitigation Plan, 2013). Climate change is expected to exacerbate these conditions and has the potential to affect a larger portion of the City's population.

During a 200-year flood event, Chico's storm drains and wastewater treatment plant would be vulnerable to overload. The City is protected by a flood control system developed in the mid-1960s. With a projected increase in precipitation, the system's capacity may be maximized requiring additional maintenance and review.

The City already has numerous drainage issues caused by localized flooding. Ditches and storm drains are needed to convey stormwater away from developed areas. However, in some areas, the topography prevents surface water from draining quickly. The City's Local Hazard Mitigation Plan rates the likelihood of localized flooding as "likely" and a "medium vulnerability." Climate change will exacerbate this issue (City of Chico Local Hazard Mitigation Plan, 2013).

During flood events, infrastructure (e.g., roadways, power lines) may be damaged, in turn disrupting communications, energy transmission, public services, and transportation systems.

As with the increase in heat discussed above, more persistent drought conditions coupled with the reduced flow of fresh water and increased water demands will likely lead to increased water temperature in streams, lakes, and reservoirs. This typically leads to lower levels of dissolved oxygen in the water, stressing populations of fish, insects, crustaceans and other aquatic animals that rely on oxygen. Butte Creek, Big Chico Creek, and the Sacramento River support Chinook salmon and are used for their spring runs. Changes in water temperature will eventually not support mating and spawning seasons.

Both an increase and decrease in **precipitation** could also affect plant life in the Chico area. Plant life will become more vulnerable to disease. If plant life deteriorates there will be a potential commensurate loss of biodiversity. Moisture can impact both host plants and pathogens in many ways. Some pathogens such as apple scab, late blight, and several vegetable root pathogens are more likely to infect plants with increased moisture content because forecast models for these diseases are based on leaf wetness, relative humidity, and precipitation measurements. Other pathogens like the powdery mildew species tend to thrive under conditions with lower (but not low) moisture. Drought conditions are also expected to increase the frequency of tree pathogens due to indirect effects on host physiology.

### 3.3 Increase in Wildfire

Increased temperatures, changes in precipitation patterns, and reduced moisture content in vegetation during dry years associated with climate change are expected to increase the potential severity of wildland fire both within and beyond the boundaries of the City. With a potential increase of 4-7.5 °F by 2100 under the Low- and High-Emissions Scenarios, grasslands in the City and surrounding area will lose moisture content. Additionally, as higher temperatures last for longer periods of time, dead fuels of wider diameter (e.g., twigs and sticks) will also become drier and contribute to increased wildfire intensity in the City. These conditions are predicted to lead to an increase in the total area burned by grassland fire, especially in the foothill areas in the eastern portion of the City, of which a section is designated a moderate Fire Hazard Severity Zone by the California Department of Forestry and Fire Protection (CAL FIRE) (Metro Fire 2014; CAL FIRE 2007).

A changing climate is also expected to subject forests outside the City to increased stress due to drought, disease, invasive species, and insect pests. These stressors are likely to make these forests more vulnerable to

catastrophic fire (Westerling 2008). Increased rate and intensity of wildfire in coniferous forests in the Sierra Nevada could adversely impact the populations, functions, and structures within City.

### **Population**

Increased wildfire activity will occur on the urban/wildland interface (i.e., where residential development mingles with wildland area) around Chico, putting homes and other structures at a greater risk of destruction. Closure of roadways and damage to transportation infrastructure during a wildfire may result in the isolation of more remote populations. Reduced access to evacuation routes increases the danger associated with wildfire, with the potential to result in physical injury or death. Fires will be more frequent and more intense, putting Chico's suppression resources under strain.

An increase in wildfire, particularly in the urban/wildland interface will have effects on communities living in these areas that are prone to wildfire. The California Department of Forestry and Fire Protection (CAL FIRE), in collaboration with the City, has developed the City's Fire Hazard Severity Zone Map. Identifying Very High Fire Hazard Severity Zones (VHFHSZ) in the City. See **Figure 16** for a look at the communities located in with in the wildfire severity zone.

Property damage associated with wildfires in California will increase under future climate change scenarios. Most of this damage will occur in the wildland/urban interface. Chico has subdivisions located within this interface, and these neighborhoods are at an elevated risk of fire damage.

In addition to increased threats to human safety, the increased frequency of wildfires will result in the release of harmful air pollutants into the atmosphere, which dissipate and can affect the respiratory health of residents across a broad geographical scope. Particulate matter (soot and smoke), carbon monoxide, nitrogen oxides, and other pollutants are emitted when vegetation burns, and can cause acute (short-term) and chronic (long-term) cardiovascular and respiratory illness, especially in vulnerable populations such as the elderly, children, agricultural and outdoor workers, and those suffering from pre-existing cardiovascular or respiratory illness.

Air quality in the City will be directly affected by wildfire activity occurring beyond the boundaries of the County as these pollutants are spread to the valley and worsen air quality. Further, as future wildfires burn at a higher intensity and for longer durations, periods of exposure to air pollutants will become more frequent and prolonged, causing increased rates of acute and chronic respiratory and cardiovascular illness, and an increase in emergency room visits and hospitalizations.

More wildfires will also produce an increased amount of fine particulate matter (PM<sub>2.5</sub>) and other air pollutants that affect respiratory health. Wildfire-associated PM<sub>2.5</sub> leads to an increase in respiratory hospital admissions. In Chico, increased wildfires, and the smoke they produce, will likely increase admissions to Enloe Medical Center for asthma, cardiovascular disease, bronchitis, bronchiolitis, and congestive heart failure. The elderly (65 and older) and small children (under 4) will be most affected by an increase in PM<sub>2.5</sub> levels.

### **Functions and Structures**

Wildfire can cause direct and indirect damage to electrical infrastructure. Direct exposure to fire can sever transmission lines, and heat and smoke can affect transmission capacity.

Higher temperatures can lead to an increase in the Bark Beetle population, which degrade the health of local trees, turning them into rotted, dry fodder for wildfires. Areas with drought-stressed trees, shrubs, grasses and other fire "fuels"—places such as Chico's Bidwell Park—will be especially vulnerable to combustion.

Overgrown vegetation along Little Chico Creek has a similar potential to act as a wildfire corridor, possibly drawing fires deep into the City center.

While periodic fires originate from natural processes and provide important ecological functions, catastrophic fire events that cannot be contained or managed can cause serious threats to homes and infrastructure, especially for properties located at the wildland/urban interface (CAL FIRE, 2009). Damage to ecological functions may result as the risk of fire increases. When rain falls in burn scarred areas, there is a higher potential for soil erosion, landslides, and mud flows into roads, ditches, and streams, which reduces water quality.

Risk of wildfire will threaten animal species. Traits that commonly make a species vulnerable to climate change include limited dispersal abilities, slow reproductive rates, specialized habitat and dietary requirements, restricted distribution and rarity, and narrow physiological tolerances, while potentially vulnerable habitats include montane habitats, savannahs, and grasslands. Also, loss of species such as deer and salmon can reduce monetary gain due to fishing and hunting. Unforeseen loss of keystone species can drastically change the food chain and negatively affect surrounding environments.

Fishery productivity can be affected by increased wildfire. Chico has numerous creeks and waterways. With more frequent and intense wildfires, there is a high probability that sedimentation within these fisheries will increase, nutrients and temperatures within the water will change, and woody debris will become more prominent in the environment. Ultimately, this will negatively affect the overall health of the water and the fisheries.

Healthy forests absorb carbon dioxide from the atmosphere and store it as carbon, helping to regulate our climate. The Sierra Nevada stores almost half of the state's total forest carbon — more than a billion metric tons. Overgrown forests are susceptible to drought, insect and disease outbreaks, and large, damaging wildfires — all of which can jeopardize carbon absorption and storage. One large, high-severity wildfire can undo much of the annual carbon storage benefits that forests provide in a very short period of time. The initial pulse of emissions from a wildfire represents only a fraction of the total emissions that will come from the burn scar over the next few decades as the trees killed by the fire decay.

Wildfires often result in the closure of roadways and/or damage to transportation infrastructure resulting in reduced availability of recreational opportunities. Hiking and mountain biking trails in the City may become inaccessible or damaged from wildfire activity, impeding recreational use as well as the associated tourism revenue.

## 4 Adaptive Capacity

The next step in the Vulnerability Assessment process is to evaluate the adaptive capacity of the populations, functions, and structures identified in Steps 2 and 3 to address climate change. Step 4 involves determining a community's current ability to address the points of sensitivity and impacts associated with climate change. Review of the City's existing policies, plans, programs, resources, and institutions provides a good snapshot of the City's ability to adapt to climate change and reduce vulnerability. Based on this information, adaptive capacity for a city can be rated high, medium, or low. High adaptive capacity indicates that sufficient measures

are already in place to address the points of sensitivity and impacts associated with climate change, while a low rating indicates a community is unprepared (CNRA 2012).

The City of Chico's adaptive capacity to respond to projected climate change impacts is analyzed below, based on identified exposure where possible. It is important to note that this review of local climate adaptation-related work offers an initial, high-level perspective on the issue and is not all inclusive nor site specific. As more specific facilities, structures, and areas are identified in the future, additional review of adaptive capacity would be valuable.

On a planning level, the City addresses current and future impacts related to existing natural hazards, as evidenced by the County's Local Hazard Mitigation Plan (LHMP) most recently updated in December 2013. The 2013 LHMP identifies current hazard risks and mitigation strategies for climate change, flooding, levee failure, drought/water shortage, severe weather, and wildfires (City of Chico, 2013). Furthermore, the City's Climate Action Plan, adopted in 2008, contains policies aimed at reducing local contributions to global climate change and encourages sustainable building practices, efficient use of resources (e.g., water, land, and energy), and ecological stewardship. The City's General Plan also addresses sustainability efforts in the Sustainability Element and addresses natural and human-caused disasters, safety management, and emergency preparedness in the Safety Element.

Disaster recovery efforts require extreme measure and commitment to the development of healthy and organized responses to chaotic situations. Every region has a unique need; if a jurisdiction is not in sync with current regulation, it may not only miss opportunities for state and federal funding, but it may also leave that jurisdiction more vulnerable to the threats of climate change-induced natural disasters. The City is conducting this assessment to see where its vulnerabilities lie and to be able to address them by incorporating adaptation strategies and emergency plans into the General Plan.

In addition to planning efforts, other work related to climate adaptation is ongoing in the City of Chico. These efforts are discussed below.

#### 4.1 Adaptive Efforts Related to Increased Temperature

The Butte County Office of Emergency Services provides the City of Chico and Butte County with information on how to stay safe during periods of extreme heat through the CodeRED application. CodeRED is a web-based critical communication solution that enables local public safety personnel to notify residents and businesses by telephone, text message, email, and social media of time-sensitive information, emergencies, or urgent notifications. The system can reach hundreds of thousands of individuals in minutes to ensure information such as evacuation notices, missing persons, inclement weather advisories, and more are quickly shared. Only authorized officials have access to send alerts using the CodeRED system.

The City of Chico participates in several Property Assessed Clean Energy (PACE) financing programs. PACE programs offer special financing options to help homeowners finance home energy and water efficiency upgrades and save money on energy and water bills. By enabling homeowners to retrofit their homes and install upgrades, this program helps to build adaptive capacity by increasing home comfort and mitigating higher energy costs associated with increasing temperatures and extreme heat events and heat waves. It should be noted that PACE programs are only available to homeowners and cannot be used by renters or occupants of multi-family housing.

Urban greening and urban forestry in the City are supported by numerous organizations and agencies. Urban forestry involves the planting and maintenance of trees within urban areas to mitigate these impacts. Trees

provide shade for homes, roadways, and parking lots, providing relief during periods of extreme heat. Further, ground-level ozone produced from excessive heat can be filtered by certain tree species, which improves local air quality (Nowak 2002). Trees provide shade coverage which can also reduce energy demand.

Given its climate and location, Chico and its residents will be vulnerable to the adverse effects of elevated temperatures as a result of climate change. As discussed previously in Section 2.1 Increased Temperature, the populations most vulnerable to extreme heat events are seniors, infants and children, individuals with pre-existing respiratory and cardiovascular illness, individuals with dementia, outdoor workers, non-English-speaking individuals, individuals with low incomes and limited mobility, and the homeless. These populations may require assistance from a variety of sources to adapt to a hotter climate, including local government, non-profits, and privately-owned businesses and organizations.

Adaptive capacity can be improved by informing and assisting individuals through proactive engagement in programs and services designed to mitigate the burdens and risks of high heat and heat events. City of Chico staff and Butte County Department of Public Health provide information and education regarding methods to stay safe during extreme heat; however, the responsibility to use these methods ultimately lies with the individual. On days when the temperature exceeds 100°F, the Jesus Center, a local homeless shelter, opens their dining hall for community members seeking refuge from the heat. As of 2018, there are no certified cooling centers in the City.

Further, the adaptive capacity of these populations can be increased through involvement in community programs to improve resiliency during periods of extreme heat. Individuals who own poorly-insulated housing and qualify based on income may work with organizations receiving grants and financial assistance to improve the efficiency of their homes. They may also participate in the PACE program to finance energy efficiency, renewable energy, and water conservation upgrades to their homes.

Dependent individuals (e.g., infants and children) or isolated individuals (e.g., seniors, transportation-limited) may not have the capacity to adapt to living in extreme heat. Individuals dependent on caretakers rely on those individuals to provide a safe environment from the effects of high heat. Further, seniors living alone, those with dementia or mental illness, the homeless, or those without a reliable form of transportation and/or access to transit services may not have the resources to mitigate against heat and are susceptible to heat-related illness such as heat exhaustion, heat stroke, or death.

To adapt to climate change-related periods of high heat, the City of Chico and Butte County Department of Public Health will need to continue to provide educational materials regarding the risks of excessive heat available on the Department of Public Health website and elsewhere. The City should also work to identify and provide cooling centers for disadvantaged, vulnerable, and homeless populations. The cooling centers should be located in areas where disadvantaged populations can easily access the facilities.

As discussed in Section 3.1, transportation infrastructure (e.g., roads, bridges, sidewalks) can be damaged from extreme heat events. Damage due to climate change would place additional strain on already limited financial resources. Existing efforts to maintain and enhance the urban forest canopy may provide some increase in shading throughout the City, mitigating portions of transportation-related surfaces (e.g., asphalt) from excessive sun exposure. However, planting of shade trees alone may not be enough to fully mitigate potential damage from increased temperatures and extreme heat. The use of cool pavements, permeable pavements, and higher-albedo impervious materials on various surfaces should be investigated.

### *Adaptive Capacity Ranking for Increase in Temperature: Low/Medium*

The City of Chico's population has a higher chance of heat-related illness and will require more extensive efforts to combat adverse heat effects. Efforts of the programs discussed above provide Chico with appreciable resources to reduce temperature-related climate change effects; however, given that residents of Chico experience heat-related illness at present, the City needs to invest more to improve its adaptive capacity as compared to other regions with cooler climates. Therefore, the City is given an adaptive capacity ranking of low/medium for increased temperatures.

## 4.2 Adaptive Efforts Related to Changes in Precipitation Patterns

Current Efforts in the City of Chico and Butte County to adapt to or reduce the impacts of changes in precipitation patterns are summarized below:

California Water Service (Cal Water) supplies the City of Chico with water sourced from a groundwater basin. Cal Water offers rebates and programs for both commercial and residential customers that support water conservation activities. Rebates include a high-efficiency toilet rebate, high-efficiency clothes washer rebate, smart irrigation controller rebate, and free high efficiency sprinkler nozzles. Cal Water also provides water conservation kits free to customers, containing a variety of water conserving tools.

Chico's 2030 General Plan contains policies and actions to help conserve water in the City of Chico. Policy OS-3.3 encourages water conservation and the reuse of water. Action OS-3.3.1 states the city will work with the California Water Service Company to implement a water conservation program to reduce per capita water use by 20 percent by 2020, pursuant to the requirements of the State Water Plan. Action OS-3.3.2 states the city will limit the use of turf on landscape medians, parkways, and other common areas in favor of native and drought-tolerant ground cover, mulch, and other landscaping design elements, and support the conversion of existing turf to less water-intensive ground cover types. Action OS-3.3.5 states the city will enforce the requirements of state water conservation legislation when reviewing landscaping plans for new projects. Action OS-3.3.4 states the city will conduct research to determine the feasibility and costs and benefits of reusing the City's treated wastewater for irrigation.

The City has a Residential Energy Conservation Ordinance (RECO), commonly referred to as the "Retrofit Program", requiring property owners to provide certain energy and water conservation upgrades upon the sale of residential properties. The intent is to lessen the impacts of rising energy and water costs on renters and homeowners. Further, the City has developed a draft residential remodel ordinance that would require a homeowner to install basic energy efficiency measures (e.g., ceiling insulation, weather stripping, programmable thermostat, etc.) for an entire home if the remodel were to exceed 50 percent of the existing floor area of the structure. The draft ordinance closely mirrors the RECO program.

Butte County's Department of Water and Resource Conservation implements programs to protect Butte County's water resources. The priorities of the Department come from the 2005 Butte County Integrated Water Resources Plan some of which include: Administering Water Resource Management Programs, Ground Water Conservation Ordinance, Ground Water Management Plan (AB 3030 Plan), Drought Management Plan, Coordinated Regional Watershed Management Plan, and more.

The Department also oversees the Sustainable Ground Water Management Act (SGMA). This program seeks to actively monitor ground water levels and increase ground water recharge throughout the region. The SGMA went into effect in January 2016 as California's new comprehensive statewide groundwater management law

designed to provide for local management of groundwater resources. The Department is currently working on developing groundwater management plans tailored to the resources and needs of individual communities that meet the requirements of the SGMA and must be adopted by 2022. These plans will provide a buffer against drought and climate change, and will contribute to reliable water supplies regardless of weather patterns. California depends on groundwater for a major portion of its annual water supply, and sustainable groundwater management is essential to a reliable and resilient water system.

The City of Chico has been working with Butte County and the other Groundwater Sustainability Agencies (GSAs) and stakeholders to evaluate the feasibility of artificially recharging the groundwater in the Vina and West Butte subbasins to help ensure groundwater sustainability by 2042. One option would be to use some of the City's treated wastewater, which is currently discharged into the Sacramento River, as a potential direct or indirect source of groundwater recharge.

The City is implementing the State-required Low Impact Development (LID) program as part of its permit process with the State. The City should consider installing permeable pavement in parking lots to capture rain water and percolate back into the ground. Throughout Chico, the City has installed several bioswales, which are landscape elements designed to concentrate or remove debris and pollution from surface water. They consist of a depressed and vegetated drainage course with gently sloped sides. Bioswales are also beneficial to groundwater recharge and are great stormwater mitigation tools. The city should continue to install bioswales where appropriate to mitigate stormwater flows and recharge groundwater.

The goal of Policy OS-3.2 in the 2030 General Plan is to protect groundwater and aquifer recharge areas to maintain groundwater supply and quality. Supporting actions are: Action OS-3.2.1– Avoid impacts to groundwater recharge areas through open space preservation, runoff management, stream setbacks and clustering of development; Action OS-3.2.2 – Work with local, state and regional agencies to identify and map groundwater recharge areas within the Sphere of Influence; Action OS-3.2.3 – Continue to implement the Nitrate Compliance Plan; and Action OS-3.2.5– Oppose regional sales and transfers of local groundwater.

### *Adaptive Capacity Ranking for Changes in Precipitation Patterns: Medium*

Water conservation programs are helping to reduce water usage in the City, but there are still vulnerabilities to drought-induced water supply issues, changes in surface water flow regimes, increased pressure on groundwater supplies, and other factors. Cal Water may face challenges in providing sufficient water supplies in the future due to climate change effects coupled with an increasing population and water demand. The City and Cal Water will need to continue to explore additional options to address projected long-term changes in water availability through advanced conservation approaches, more integrated supply management of both surface and groundwater (i.e., conjunctive use), greater water recycling, and other means. The adaptive capacity ranking for changes to precipitation patterns and water supply is medium.

## 4.3 Adaptive Efforts Related to Increased Flooding

Current efforts in the City of Chico to adapt to or reduce the impacts of flooding are summarized below:

According to the 2013 Local Hazard Mitigation Plan (LHMP), there is a total population of 2,208 within the 100-year flood plain and 18,813 within the 200-year floodplain. Residents living in areas at high risk for inundation due to levee or dam failure have limited adaptive capacity to deal with flooding. Structural improvements to modify or elevate homes and other structures, as well as the purchase of flood insurance, can reduce the financial burden of recovering from flooding; however, these options are not universally acquirable. Low-

income, mobility-challenged, and physically or linguistically isolated persons are particularly vulnerable. Localized and tributary flooding may also impact those living near creeks and streams, as well as areas with constrained infrastructure (i.e., old, undersized, and insufficient infrastructure) that could become congested when capacity is reached. The City continues to undertake projects to upgrade drainage infrastructure; however, residents need to be aware if they live in flood-prone areas and make necessary accommodations in advance when their homes or businesses may become inaccessible.

The City of Chico 2030 General Plan addresses flooding in the Safety Element Goal S-2, the intention of which is to minimize the threat to life and property from flooding and inundation. Policy S-2.1 states when areas are considered for development, a proper analysis and consideration of potential impacts of flooding should be conducted. Action S-2.1.1 states that, as part of project review, the potential impacts of flooding should be analyzed, and compliance with appropriate building standards and codes for structures subject to 200-year flood hazards should be required. Action S-2.1.4 states that the City will provide materials to the community regarding Federal Emergency Management Agency (FEMA) and California Department of Water Resources (DWR) flood mapping.

The City has relied upon the Storm Drain Master Plan to provide guidance on the status and identified needs of our diverse waterways. New development and the expansion of impervious surface area adds to overall stormwater runoff collected into the storm drain network, which ultimately leads into the City's waterways. This further adds to the flows in the creeks from upstream sources. The original master plan was developed in the early 1980s and updated in the '90s. With changing regulations and increased population growth, it will be critical to adopt an updated, holistic Storm Drain Master Plan identifying the current volumes and capacities of our network and addressing areas not operating properly. This will help ensure that current and future water-related infrastructure is built to handle increased flows, which will prevent flooding.

The City recognizes that flood events (e.g., 100-year) constitute a hazard facing the area; therefore, resources have been and continue to be invested in flood protection and management. Despite these efforts, the City of Chico will continue to be a high-risk area for increased flooding. The City should conduct an analysis on existing flood control infrastructure to best identify facilities at risk of flooding.

### *Adaptive Capacity Ranking for Flooding: Low/ Medium*

While levees and structures have been built to protect the City from catastrophic flooding, this infrastructure was constructed for protection from floods based on historic flow regimes of the City's creeks and streams. Changes in the rate and timing of snowmelt, due to rising temperatures in the Sierra Nevada, along with changes in the intensity of storm events, could overwhelm dams and levees, exceeding the capacity of the City's flood control infrastructure and increasing the City of Chico's vulnerability to major flood events. The City of Chico should invest in maintaining and bolstering flood-control infrastructure to adapt to greater pressures from changing meteorology and flow regimes. The City will need to continue investment in mitigation and flood prevention in order to provide its residents with a moderate level of flood protection.

## 4.4 Adaptive Efforts Related to Increased Wildfires

Current efforts in Chico to adapt to or reduce the impacts of wildfire are summarized below:

Chico's eastern boundary lies adjacent to the foothills of the [insert mountain range], subject to the threat of wildland fires. The grass-oak woodland in these areas can produce flames exceeding 20 feet in length on hot summer days. Bruce Road is currently the boundary to the east of which fires receive a substantial first alarm

augmentation due to the wildland fire risk. In addition, there are potential wildfire vulnerabilities in Bidwell Park. The CFD has recorded hundreds of fires in Bidwell Park over the decades, citing dry fuels, heavy recreational use, and presence of motor vehicles. Some areas within Upper Bidwell Park are inaccessible by road and would require specialized wildland firefighting resources such as air tankers, helicopters, bulldozers, and hand crews should they catch fire. According to the City's 1994 Master Environmental Assessment, Bidwell Park, Lindo Channel, and numerous vacant parcels throughout the City represent nearly 8,000 acres of dry vegetation during the summer months.

Upper Park managers currently burn 40-100+ acres of grasslands a year, with the aim of benefiting the native plants, which have evolved to be fire adapted. The current burning program aims to control yellow star thistle and reduce fuel loads that accumulate in the Park. Most of the burns conducted in the park are financed with training dollars from the various agencies that conduct the burns.

According to the City of Chico Local Hazard Mitigation Plan, 7,161 residents of the City are at risk in the moderate and higher-risk wildfire zones. According to the Local Hazard Mitigation Plan, the likelihood of future wildfire occurrence is high and therefore the vulnerability is very high. Further, the 2013 LHMP recognizes wildfire as a potential hazard and contains strategies to mitigate impacts.

The City has adopted the 2016 California Fire Code, which includes provisions to help prevent the accumulation of combustible vegetation or rubbish that can be found to create fire hazards and potentially impact the health, safety, and general welfare of the public. Provisions include ensuring that defensible spaces, which are adjacent to each side of a building or structure, are cleared of all brush, flammable vegetation, or combustible growth (City of Chico Municipal Code, Title 19, 2018).

Infrastructure development in the City of Chico must comply with the 2016 California Fire Code, which includes standards to reduce the safety risks associated with fire. This includes the incorporation of 100 feet of defensible space, which limits the proximity of combustible vegetation to new structures.

Low-income residents living in aged buildings lacking the financial ability to either relocate to a safer, more modern building or upgrade their existing residence are at higher risk for fire-related injury.

The Butte County Fire Safe Council provides portions of Butte County within its jurisdiction a plan to combat the effects of wildland fire. The Butte County Fire Safe Council serves to protect both people and structures from fire-related damage and provides useful strategies to create an environment that is not conducive to the ignition and spread of fire. Chico residents living in the foothills and around Upper Bidwell Park may wish to utilize information developed by the Butte Fire Safe Council.

Butte County Air Quality Management District (BCAQMD) takes actions to reduce exposure to harmful pollutants related to wildfire (e.g., Particulate Matter, or PM) by implementing no-burn days during periods of poor air quality. BCAQMD also provides resources to educate the public on daily air quality status, provides alerts on poor air quality days, and provides educational material on the health impacts of air pollution.

The City of Chico 2030 General Plan addresses fire in the Safety Element. Goal S-4 states that the city will continue to provide effective and efficient fire protection and prevention services to Chico area residents. Policy S-4.1 states the city will maintain adequate fire suppression and prevention staffing levels. Action S-4.2.1 states the city will work with CAL FIRE and the Butte County Fire Department on programs that will enhance fire protection and firefighting capabilities in the Planning Area, including the maintenance of aid agreements. Action S-4.3.1, encourages the city to maintain, and update as needed, the standards manual for protecting

structures in wildland fire areas. Policy S-4.4, encourages the City to support vegetation management and weed abatement programs that reduce fire hazards.

*Adaptive Capacity Ranking for Wildfire: Low*

Most of the City of Chico is not at risk for wildfires, but localized wildfire risks exist, especially where natural areas such as Bidwell Park and the lower foothills interface with urban development. Plans and policies provide the current capacity to address risks; however, the City is still vulnerable as climate conditions change. Bidwell Park, which is an area at high risk of wildfire, currently does not have a fire management plan. Climate change is projected to exacerbate current risk due to increased temperatures and changes in precipitation patterns. Further, wildfires occurring beyond the City’s sphere of influence will likely affect the welfare and health of citizens of the City of Chico (such as smoke-influenced air quality degradation). The City will need to continue to adapt to reduce these effects. The adaptive capacity for risks associated with wildfire is considered low.

Risk and Onset

Impact	Risk Certainty Rating	Onset Timeframe
Increased Temperature	High	Current
Increased Frequency of Extreme Heat Days	High	Current
Increased Frequency of Heat Waves	High	Near term
Changes to Precipitation Patterns	Medium	Current
Increase Wildfire Risk	Medium	Midterm
Increased Flooding	High	Near Term

- Current: Impacts currently (2017-2020)
- Near-term: 2020-2040
- Mid-term:2040-2070
- Long-term: 2070-2100

## References:

- Burton, Christopher and Susan L. Cutter. 2008 (August). Levee Failures and Social Vulnerability in the Sacramento-San Joaquin Delta Area, California. *Natural Hazards Review*. Pp 136-149. Available: [https://www.researchgate.net/profile/Christopher\\_Burton3/publication/228756947\\_Levee\\_failures\\_and\\_social\\_vulnerability\\_in\\_the\\_Sacramento-San\\_Joaquin\\_Delta\\_area\\_California/links/00b4953c3a884f3878000000.pdf](https://www.researchgate.net/profile/Christopher_Burton3/publication/228756947_Levee_failures_and_social_vulnerability_in_the_Sacramento-San_Joaquin_Delta_area_California/links/00b4953c3a884f3878000000.pdf). Accessed: August 4, 2016.
- Butte County Agriculture Commission. 2016. Butte County 2016 Crop Report. Accessed: December 10<sup>th</sup>, 2018
- Butte County Department of Water Resources and Conservation. 2016. Butte County Water Inventory Analysis. Available: <https://www.buttecounty.net/wrcdocs/Reports/1%26A/2016WI%26AFINAL.pdf> Accessed: January 23<sup>rd</sup>, 2018
- Butte County Department of Water Resources and Conservation. 2018. Evaluation of Restoration and Recharge within the Butte County Groundwater Basins. Available: [https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/GWRecharge/Recharge\\_Eval.pdf](https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/GWRecharge/Recharge_Eval.pdf) Accessed: January 22<sup>nd</sup> 2018
- Butte County Department of Water Resources and Conservation. 2018. Groundwater Status Report (2017 Water Year). Available: <https://www.buttecounty.net/wrcdocs/Reports/GWStatusReports/2017/2017GSRCoverReport.pdf> Accessed: January 22<sup>nd</sup> 2018
- Butte County Department of Water Resources and Conservation. 2017. Stable Isotope Recharge Study Final Report. Available: [https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/GWRecharge/Recharge\\_Eval.pdf](https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/GWRecharge/Recharge_Eval.pdf) Accessed: January 22<sup>nd</sup> 2018
- Butte County Flood Mitigation Plan. 2006. Available: [http://www.buttecounty.net/Portals/19/ButteFMP\\_FINAL1-8-10.pdf](http://www.buttecounty.net/Portals/19/ButteFMP_FINAL1-8-10.pdf) Accessed: April 30<sup>th</sup> 2018
- Butte County Community Wildfire Protection Plan. 2015. Available: <http://cdfdata.fire.ca.gov/pub/fireplan/fpupload/fpppdf1564.pdf> Accessed: April 30<sup>th</sup>, 2018.
- Cal-Adapt. 2017. *Climate Tools*. Available: <http://cal-adapt.com/tools/>. Accessed: October 19th 2017.
- Calflora. Roy West. Available: <http://www.calflora.org/about-cf.html> Accessed: October 15<sup>th</sup> 2017.
- California Environmental Protection Agency. 2013 (October) Preparing California for Extreme Heat. Available: [http://www.climatechange.ca.gov/climate\\_action\\_team/reports/Preparing\\_California\\_for\\_Extreme\\_Heat.pdf](http://www.climatechange.ca.gov/climate_action_team/reports/Preparing_California_for_Extreme_Heat.pdf). Accessed: September 29, 2017.
- California Department of Forestry and Fire Protection. 2007. Fire Hazard Severity Zones in State Responsibility Areas: Sacramento County. Available: [http://frap.fire.ca.gov/webdata/maps/sacramento/fhszs\\_map.34.pdf](http://frap.fire.ca.gov/webdata/maps/sacramento/fhszs_map.34.pdf). Accessed: October 19<sup>th</sup>, 2017

California Department of Food and Agriculture. 2013. Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience. Available: <https://www.cdfa.ca.gov/environmentalstewardship/pdfs/cc-report.pdf>. Accessed: October 19<sup>th</sup>, 2017

California Department of Water Resources. 1980. *Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924*. Available: [http://www.water.ca.gov/pubs/groundwater/bulletin\\_118/ground\\_water\\_basins\\_in\\_california\\_\\_bulletin\\_118-80\\_/b118\\_80\\_ground\\_water\\_ocr.pdf](http://www.water.ca.gov/pubs/groundwater/bulletin_118/ground_water_basins_in_california__bulletin_118-80_/b118_80_ground_water_ocr.pdf). Accessed: October 19<sup>th</sup>, 2017

\_\_\_\_\_. 2008. Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water. Available: <http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf>. Accessed: October 19<sup>th</sup>, 2017

\_\_\_\_\_. 2018. Available: <https://www.water.ca.gov/Water-Basics/Climate-Change-Basics> Accessed: January 12<sup>nd</sup> 2018

California Natural Resources Agency. 2012a. *California Adaptation Planning Guide*. Available: [http://resources.ca.gov/docs/climate/01APG\\_Planning\\_for\\_Adaptive\\_Communities.pdf](http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf). Accessed: November 15<sup>th</sup>, 2017

\_\_\_\_\_. 2012b. Our Changing Climate 2012: Vulnerability and Adaptation to the Increasing Risk from Climate Change in California. Available: <http://www.energy.ca.gov/2012publications/CEC-500-2012-007/CEC-500-2012-007.pdf>. Accessed: November 15<sup>th</sup>, 2017

\_\_\_\_\_. 2013. Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience. Available: <https://www.cdfa.ca.gov/environmentalstewardship/pdfs/cc-report.pdf>. Accessed: November 15<sup>th</sup>, 2017

\_\_\_\_\_. 2014. Safeguarding California: Reducing Climate Risk—An Update to the 2009 California Climate Adaptation Strategy. Available: [http://resources.ca.gov/docs/climate/Final\\_Safeguarding\\_CA\\_Plan\\_July\\_31\\_2014.pdf](http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf). Accessed: November 15<sup>th</sup>, 2017

\_\_\_\_\_. 2016. Safeguarding California: Implementation Action Plan. Available: <http://resources.ca.gov/docs/climate/safeguarding/Safeguarding%20California-Implementation%20Action%20Plans.pdf> Accessed: October 4<sup>th</sup> 2017

Chico Fire Department. 2017. Community Risk Assessment and Standards of Response Coverage Study. Available: <http://www.chico.ca.us/fire/documents/ChicoFinalSOCJan2017.pdf> Accessed: March 4<sup>th</sup> 2018

Housing Tools. 2017. 2017 Homeless Point in Time Census & Survey Report: Butte County Wide Homeless Continuum of Care. Available: [http://www.buttehomelesscoc.com/reports/pit/butte\\_coc\\_2017\\_homeless\\_census\\_survey\\_report.pdf](http://www.buttehomelesscoc.com/reports/pit/butte_coc_2017_homeless_census_survey_report.pdf)

Intergovernmental Panel on Climate Change. 2007. *Fourth Assessment Report*. Available: [http://www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data\\_reports.shtml](http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml). Accessed: November 15<sup>th</sup>, 2017

\_\_\_\_\_. 2014. *Climate Change 2014 Synthesis Report*. Available: <http://www.ipcc.ch/report/ar5/wg1/>. Accessed: June 15, 2016.

City of Oroville Community Climate Action Plan. 2015. Available: <http://www.cityoforoville.org/home/showdocument?id=12191> Accessed: October 4<sup>th</sup> 2017

George, Holly; David Lile; Cheree Childers; Cindy Noble; Andrea Oilar; Katherine Haworth; Kristen Schmidt; Gabe Miller. "Upper Feather River Watershed (UFRW) Irrigation Discharge Management Program" (PDF). University of California. Accessed: January 13<sup>th</sup> 2018

Maizlish, Neil; English, Dorette; Chan, Jacqueline; Dervin, Kathy; English, Paul. 'Climate Change and Health Profile Report Butte County' February 2017 Available: [https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHPRs/CHPR007Butte\\_County2-23-17.pdf](https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHPRs/CHPR007Butte_County2-23-17.pdf) Accessed: October 10<sup>th</sup> 2017

Sacramento Area Council of Governments. 2015. Sacramento Region Transportation Climate Adaptation Plan. Available: <http://www.sacog.org/sites/main/files/file-attachments/fullplanwithappendices.pdf/>. Accessed: June 15, 2016.

U.S. Department of Agriculture. 2011 (August). Social Vulnerability and Climate Change: Synthesis of Literature. Available: [http://www.fs.fed.us/pnw/pubs/pnw\\_gtr838.pdf](http://www.fs.fed.us/pnw/pubs/pnw_gtr838.pdf). Accessed: October 19<sup>th</sup>, 2017

Tapan B. Pathak, Mahesh L. Maskey, Jeffery A. Dahlberg, Faith Kearns, Khaled M. Bali and Daniele Zaccaria. 2018. Climate Change Trends and Impacts on California Agriculture: A Detailed Review. Available: <file:///E:/CS/Resources/agronomy-08-00025.pdf> Accessed: April 30<sup>th</sup> 2018

Westerling, A.L. and B.P. Bryant. 2007. Climate Change and Wildfire in California. Available: [http://ulmo.ucmerced.edu/pdffiles/08CC\\_WesterlingBryant.pdf](http://ulmo.ucmerced.edu/pdffiles/08CC_WesterlingBryant.pdf). Accessed: October 14<sup>th</sup> 2018

## Appendix A

<b><u>Low Emission</u></b>	<b><u>Historical Average</u></b> 1961-1990	<b><u>2050</u></b> 2040-2060	<b><u>2090</u></b> 2070-2099
<b>Temperature</b>	74.7°F	79.1°F	80.7°F
<b>Extreme Heat</b> Days above 103.9	4.0	18	23
<b>Precipitation</b>	29.6"	32.8"	32.5"
<b>Snow Pack</b> Sierra Nevada Mountains (North Sierra Region)	7.9"	3.6"	2.6"
<b>Wildfire</b> Low pop scenario	36.2 hectares	40.6 hectares	44.0 hectares

<b><u>High Emission</u></b>	<b><u>Historical Average</u></b> 1961-1990	<b><u>2050</u></b> 2040-2060	<b><u>2090</u></b> 2070-2099
<b>Temperature</b>	74.7°F	80.0°F	84.2°F
<b>Extreme Heat</b> Days above 103.9	4	21	44
<b>Precipitation</b>	29.6"	33.4"	35.8"
<b>Snow Pack</b> Sierra Nevada Mountains (North Sierra Region)	7.9"	3.0"	.07"
<b>Wildfire</b> Low pop scenario	35.9 hectares	40.6 hectares	59.0 hectares