All-In Clark County
D04 - Climate Summary Technical Report

Prepared by Kim Lundgren Associates, Inc. and Adaptation International
September 2021

Acknowledgments

This collaborative assessment was conducted by Clark County, Kim Lundgren Associates, Inc. and Adaptation International.

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Introduction

This technical report was developed as part of the *All-In Clark County* initiative to address climate change and create a more sustainable future for all. The focus of this report is to establish a baseline for a countywide Climate Vulnerability Assessment by providing historic trends and projections of climate conditions and identifying some of their associated impacts in Clark County. This report was produced through the completion of two separate, concurrent research efforts: (1) an assessment of existing plans, reports, and conditions and (2) a climate assessment. The former included a review of the County's most up-to-date climate and emergency related plans, reports, policies, and operational procedures from the last 5-10 years to help inform the baseline understanding of the County's and region's consideration of climate change and preparedness. The climate assessment used best available global, national, regional, state, and local climate science and meteorological data to summarize historic trends and projected climate conditions for Clark County. This report is an amalgamation of the two research efforts and aims to paint a clearer picture of historic, current, and future climate change impacts in Clark County.

For more detail on the assessment of existing plans, reports, and conditions, please see the *Assessment of Existing Plans, Reports, and Conditions Summary Memo*. Key findings from this assessment are also included throughout this report. For a summary of the main findings from this report, please see the *Climate Summary Two-Pager*.

Climate Change 101: Understanding the Science and Planning for Uncertainty

Human activity is responsible for the changes we are seeing in our climate. By burning fossil fuels like coal, oil, and natural gas to create electricity, drive our cars, and fly planes (among other things), human actions emit greenhouse gases (GHGs) into the atmosphere. These gasses, which are primarily carbon dioxide and methane, absorb solar radiation that bounces off the Earth's surface. Normally, this radiation would escape back into space, but these gases trap and re-radiate heat that warms the Earth's surface, much like a blanket traps heat and warms someone when they are sleeping; this is known as the greenhouse effect.[1] The impacts of this warming, and of climate changes, are being felt and observed across the globe, but the specific impacts vary regionally due to a multitude of factors.

Climate is the long-term average of weather conditions over a given area; whereas *weather* is what is happening in the atmosphere at a given place and time. For example, the temperature and amount of rain on a given day in Clark County is the weather, while the average temperature or precipitation in December (typically averaged over a 30-year span) is the climate. Climate can be calculated across different spatial scales: globally, regionally, and locally. Each scale is useful for understanding different components of the climate system.

[1] Rosen, J. (2021)

The exact amount of GHGs communities around the world will emit over the next century is unknown, so scientists create climate change projections using different scenarios, based on plausible societal responses to climate change and other factors. These scenarios describe future trajectories of GHG emissions and capture the relationship between human decisions and behavior, global population growth, economic development, technological advancement, and global temperature change throughout the 21st century. The most recent emissions scenarios are the Representative Concentration Pathways (RCPs), which were created in 2010. While updates are being made to the RCP scenarios by climate scientists, they are extremely accurate and represent the best available science. The different scenarios are named based on the increase in radiative forcing, or the climate "warming influence" (caused by the increase in atmospheric GHGs), in watts per square meter on the Earth's surface at the end of the century. On one end of the spectrum, the scenarios are bounded by RCP 2.6, a scenario that tracks a pathway where the world achieves net negative emissions by the end of the century. On the other end of the spectrum, RCP 8.5 is the scenario used to define emissions if there is no effort to reduce GHG emissions (**Figure 1**). RCP 2.6 is representative of a scenario that would keep the average global warming to below 3.6 °F (2 °C) above pre-industrial temperatures and is extremely unlikely given current emission levels and lack of global political will to take action on climate change. The RCP 8.5 scenario corresponds to a future where atmospheric concentrations of carbon dioxide and other GHGs continue to rise over the rest of the century.[2] Average global temperatures are likely to increase substantially more than 3.6 °F (2 °C) under RCP 8.5 and lead to significant warming. This warming is already causing rapid and extensive melting of glaciers and land ice across the poles and will continue to have global consequences (e.g., sea level rise, prolonged drought, extreme wildfires). Globally, the current emissions trajectory more closely follows the RCP 8.5 emissions scenarios, so climate exposures and projections defined in this summary will feature RCP 8.5.

To limit the most severe consequences of a changing climate, global temperatures must stay between 1.5 °C and 2 °C.[3] That means significant GHG emission reductions need to happen every year for the next 7-12 years on a global scale. It is also likely that additional carbon capture sequestration measures will be required.[4] There is still time to determine our fate if governments and the private sector implement significant GHG reductions every year over the next 5-7 years. Yet for the purposes of this assessment, the authors will use the higher emission scenario (RCP 8.5) to represent the global greenhouse gas emissions trajectory we are currently on. The lower emissions scenario (RCP 4.5) will be highlighted as appropriate to illustrate the range of potential future conditions.

It is important to take action to reduce emissions and limit the long-term impacts of climate change. The more reductions in GHG emissions globally, the less severe climate change will be in

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[2] Hayhoe et al. (2017)
[3] Covering Climate Now (2021)
[4] IPCC (2021)

the long-term. Climate change mitigation (actions that reduce GHG emissions) may include things like installing electric vehicle charging stations, implementing energy efficiency programs, and investing in renewable energy sources, among others. Climate change adaptation (actions that reduce the impacts of climate change) include things like improving regional evacuation coordination for wildfire, diversifying the water supply, supporting drought contingency planning efforts, and implementing flood protection policies, among others. Both climate adaptation and mitigation should be undertaken simultaneously, which is exactly what *All-In Clark County* aims to do.

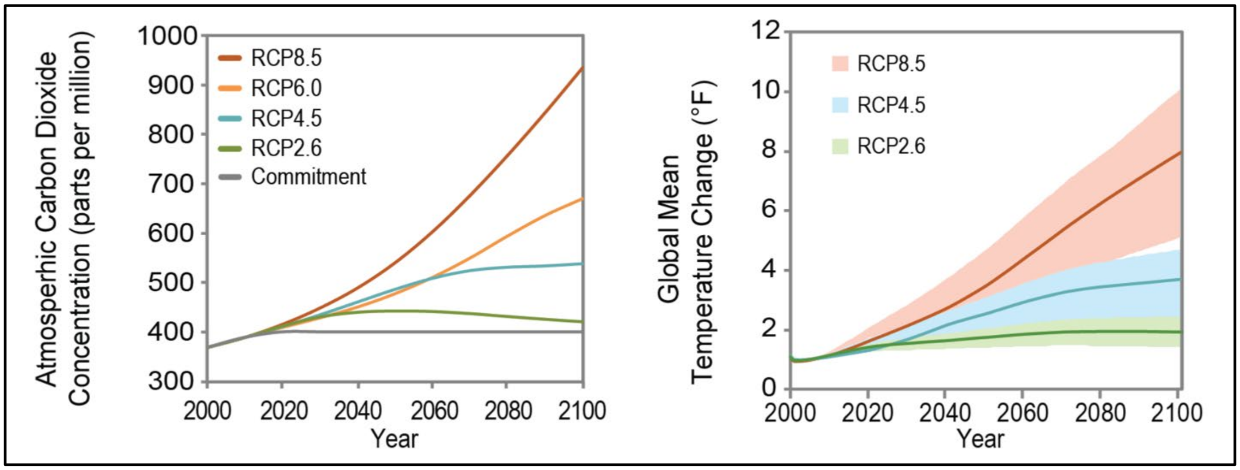

Figure 1. Future scenarios of atmospheric carbon dioxide concentrations (left) and global temperature change (right) resulting from several different climate change scenarios, called Representative Concentration Pathways (RCPs), which are considered in the fourth and most recent National Climate Assessment. Source: 4th National Climate Assessment. Retrieved at https://science2017.globalchange.gov/chapter/4/.

Clark County's Climate Factors: Past, Present, and Future

Scales of Analysis

Climate projections can be analyzed at a variety of scales, and the appropriate scale depends on the climate exposure and the topographical and geographical features of the surrounding environment. Climate models divide the area of study into a grid, and for each grid cell, the model tracks several variables (temperature, amount of precipitation, etc.). These outputs can then be visualized on a map. Most global climate models are made of very large grid cells (from 62 to 373 miles on a side). This scale is useful for studying global scale changes, but it is not useful when trying to understand impacts on a more local scale. To create fine-scale models for localized projections, scientists use various techniques to "downscale" projection data. The data used in this climate analysis is taken from Cal-Adapt and statistically downscaled so that each cell is ~3.75-mile square (**Figure 2**).[5, 6]

[5] Geospatial Innovation Facility, University of California, Berkeley (2021)

[6] CalAdapt uses downscaled climate projections from Scripps Institution of Oceanography using Localized Constructed Analogs (LOCA). LOCA is a statistical technique that uses past history to add improved fine-scale detail to global climate models. Details are described in Pierce et al., 2014.

While “downscaling” can help to analyze more localized climate projections, the spatial extent of the areas analyzed matters when considering particular climate exposures. The primary climate drivers, such as temperature and precipitation, can be averaged across Clark County to provide a more detailed representation of the projected changes over the rest of the century. However, some secondary exposure such as wildfire and flooding may require a different—and larger—spatial extent due to topographical and landscape features (such as the watershed boundaries). These larger watershed scale summaries can help to capture different environmental processes more accurately. The project team used the county geographic scale when assessing changing temperature and precipitation projections.

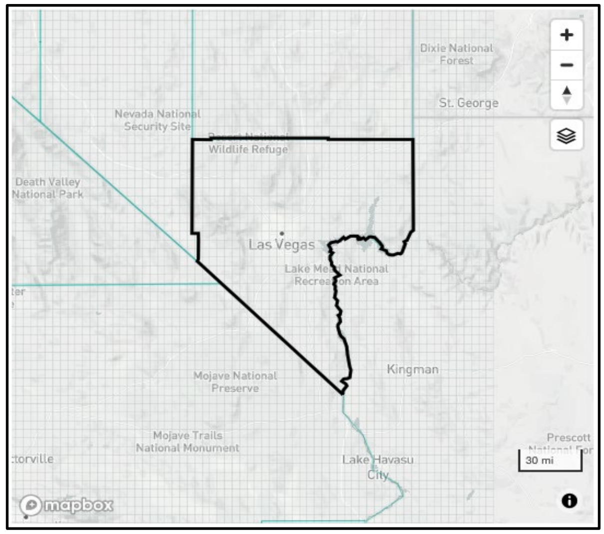

Figure 2. The map shows the Clark County boundary and the associated grid cells, used to explore projected changes in temperature and precipitation. Source: CalAdapt.

A Note on Scales of Analysis

The authors looked at a variety of regional scales for this analysis and, in coordination with the County, determined that the county scale of analysis was most appropriate due to a variety of factors. Not only did the county scale give the most nuanced assessment for regional changes, but this scale also accounted for, and averaged out, local abnormalities. That being said, additional analyses at the watershed scale were completed and considered. Generally, the watershed analyses indicated slightly more conservative projections reflecting lower annual average maximum temperature and annual average precipitation projections when compared with the county analysis. The county analysis was ultimately used because it covered the entire footprint of the county land area, as opposed to only partial coverage of the county area when using the watershed analyses. This scale ensures that the entire county land area is reflected in the climate projections.

Recommended Time Frames

For this project, Clark County is using two different time periods for future temperature and precipitation projections: mid-century (2035-2064) and late century (2070-2099). The mid-century time period provides a relatively near term look at the increasing climate related challenges on a time horizon that is useful for planning and for most infrastructure design and construction (30 years from now). The late century time period provides a long-term snapshot that can be used to guide planning efforts and better understand the magnitude of the challenges facing the county. The two climate scenarios (RCP 4.5 and 8.5) lead to temperature and precipitation projections that are very similar through the middle of the century and then start to diverge in the second half of the century. Looking at both scenarios can help motivate actions to reduce emissions because the long-term projections for the lower scenario (fewer associated GHG emissions) are significantly less severe than those of the higher scenario.

Temperatures (Historical and Projected)

Temperatures in Clark County vary daily and seasonally. Summers are warm (generally hot), winters are cool (but rarely freeze). Historical average annual maximum temperatures (modeled baseline 1961-1990) were 76.5 °F (range 76.3 °F - 76.8 °F). Weather station data from the Las Vegas Air Terminal Weather Station show the cyclical annual temperature cycles for the region with maximum high summer temperatures generally reaching about 115 °F and low winter temperatures dipping into the low 30s (**Figure 3**). Most years see only a handful of days below freezing, and a relatively significant number of days above 100 °F. Countywide, there has been an average of four extreme heat days per year where temperatures rose above 106 °F (the 98th percentile value of historical daily maximum temperatures).[7]

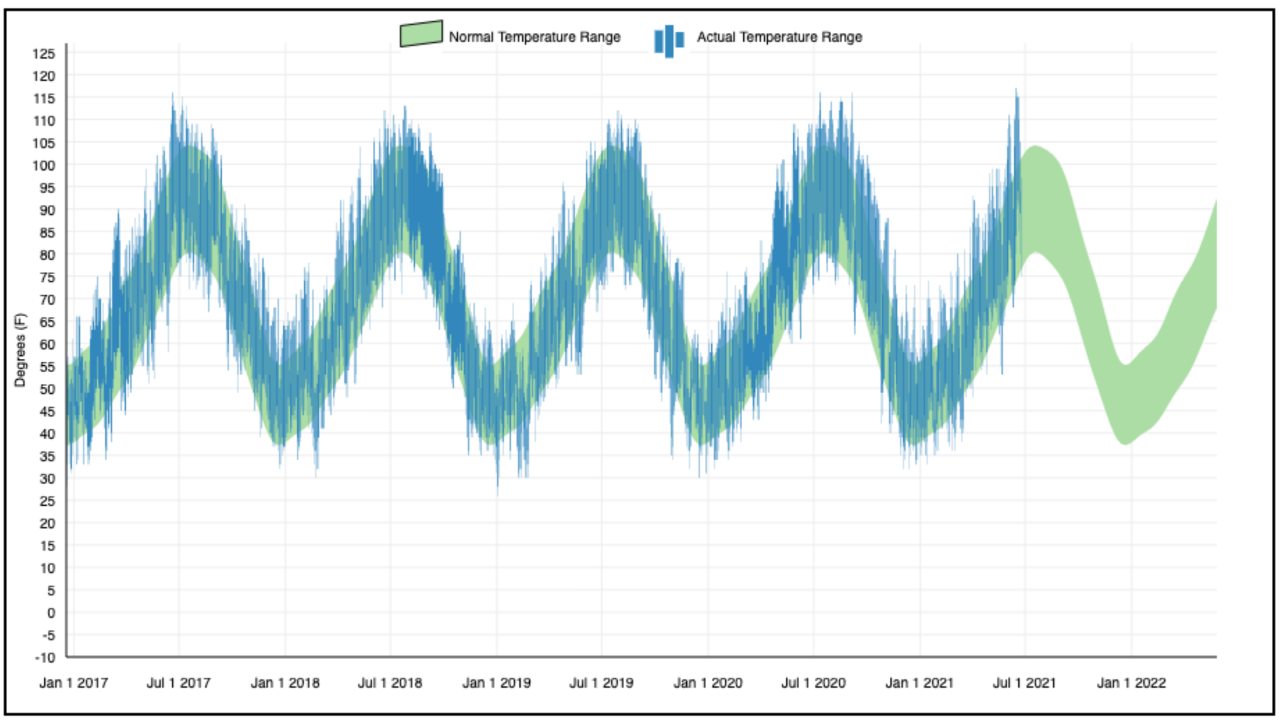

Figure 3: Average observed daily temperatures from the Las Vegas Air Terminal Weather Station (# USW00053123) shown in the green shaded area. Actual daily temperature range for the last four years (Jan 2017-Jan 2021) is shown in the blue bars. Data provided by the U.S. Climate Explorer - https://crt-climate-explorer.nemac.org - Accessed June 9, 2021.

[7] Geospatial Innovation Facility, University of California, Berkeley (2021)

Temperatures are increasing. Average annual temperatures in the State of Nevada have increased ~2 °F since the early 20th century[8] and are projected to continue to increase (**Figure 4**).[9] There has also been an increase in the number of "warm nights"—nights in a year when daily minimum temperatures are above 74.4 °F—during that same time period which can have significant implications for community health. Fewer "cold nights" have also been recorded as temperatures increase which can have important implications for food production. Across the Southwest region, the coldest recorded day of the year has increased by 4.1 °F. In addition, 9 out of the hottest 10 years on record nationally were recorded in the last decade (starting in 2012)[10] and studies show a 99% chance of the next decade continuously breaking those records.[11]

Average annual temperatures in the State of Nevada have increased 2 °F since the early 20th century. Temperatures are projected to increase 3.2 °F to 7.3 °F by mid-century and 4.8 °F to 12.8 °F by late century.

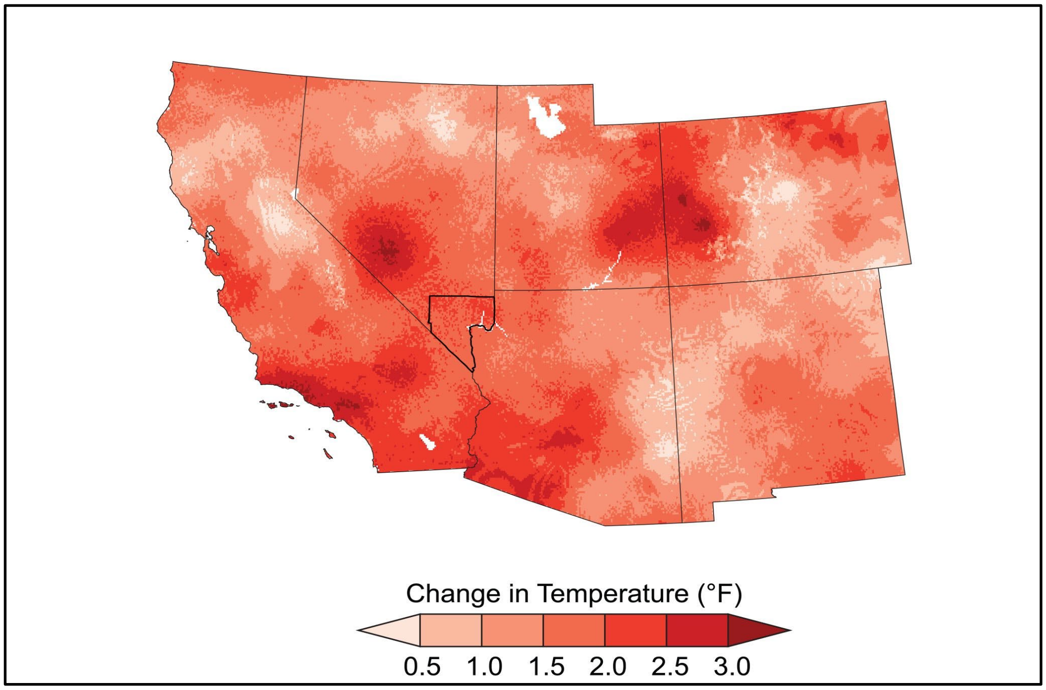

Figure 4. Change in temperature across the Southwest United States between 1901 and 2016. Temperatures increased across almost all of the Southwest region from 1901 to 2016, with the greatest increases in southern California and western Colorado. This map shows the difference between 1986–2016 average temperature and 1901–1960 average temperature. Source: National Climate Assessment, adapted from Vose et al. 2017.

[8] Clark County (2021b)
[9] Jay et al. (2018)
[10] National Oceanographic and Atmospheric Administration (2020).
[11] Arguez et al. (2020)

As shown in **Figure 5**, average annual maximum temperatures in Clark County are projected to increase 3.2 °F – 6.2 °F (RCP 4.5 average) or 4.6 °F – 7.3 °F (RCP 8.5 average) by mid-century (2035-2064) when compared with the 1961-1990 historical average. Average annual maximum temperatures are projected to increase 4.8 °F – 7.9 °F (RCP 4.5 average) or 7.7 °F – 12.8 °F (RCP 8.5 average) by late century (2070-2099) when compared with the 1961–1990 historical average.[12] For observed historical average annual maximum temperature data, reference **Figure 3**.

Extreme heat days (days with temperatures over 106 °F) are projected to increase in Clark County from 4 days/year to between 23 - 30 days/year for Clark County by the mid-century (2035-2064).

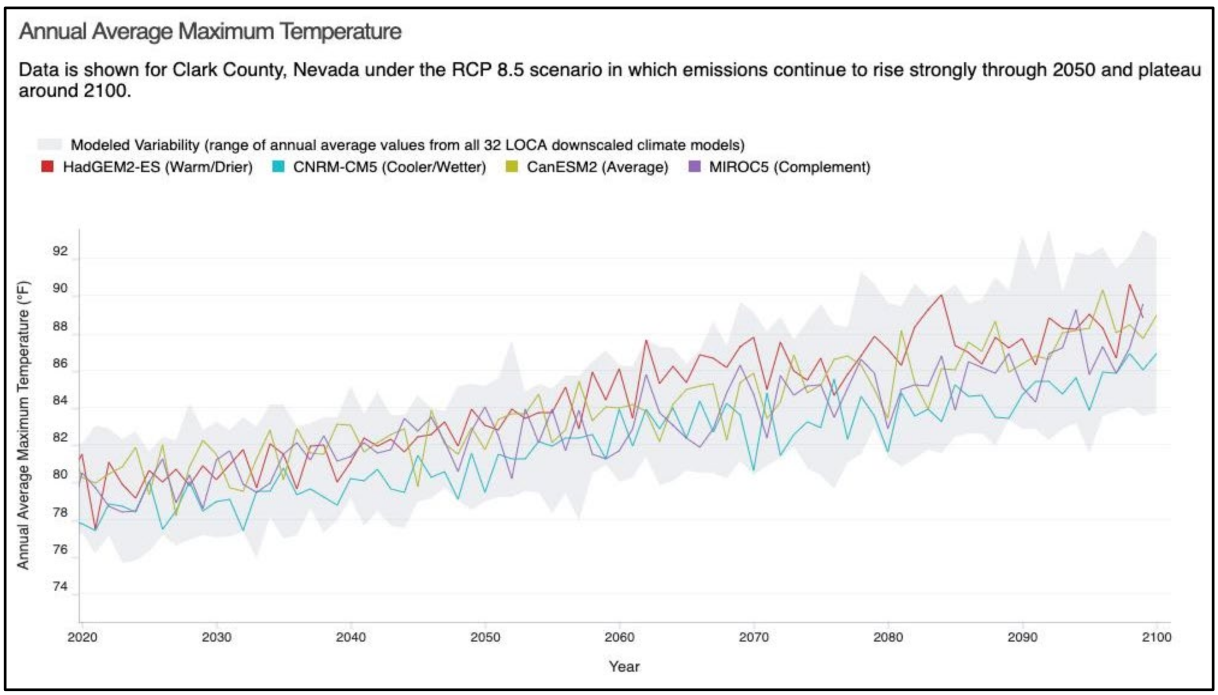

Figure 5. Average annual maximum temperature modeled for Clark County. Historical observed temperatures are shown above in Figure 3. Future projected temperatures for the higher scenario (RCP 8.5) are shown to the right. All climate models show significant warming over the course of the century and there is very little difference between the (RCP 4.5 and RCP 8.5) scenarios through mid-century (2035-2064), after which they start to diverge. Source: Cal-Adapt - https://cal-adapt.org/tools/annual-averages/.

As part of this broader trend of increasing annual average maximum temperatures, the number of extreme heat days (days over 106 °F) in a year is also projected to increase from a current average of 4 days a year to between 23 – 30 days per year by mid-century (2035-2064) and between 31 - 64 days per year by the late century (2070-2099) (**Figure 6**). Under the lower

[12] Geospatial Innovation Facility, University of California, Berkeley (2021)

scenario (RCP 4.5), the number of extreme heat days for Clark County may be limited to 31 days by the late century (2070-2099). For purposes of this analysis, an extreme heat day is defined as a day in a year when the daily maximum/minimum temperature exceeds the 98th historical percentile of daily maximum/minimum temperatures based on observed historical data from 1961–1990 between April and October.

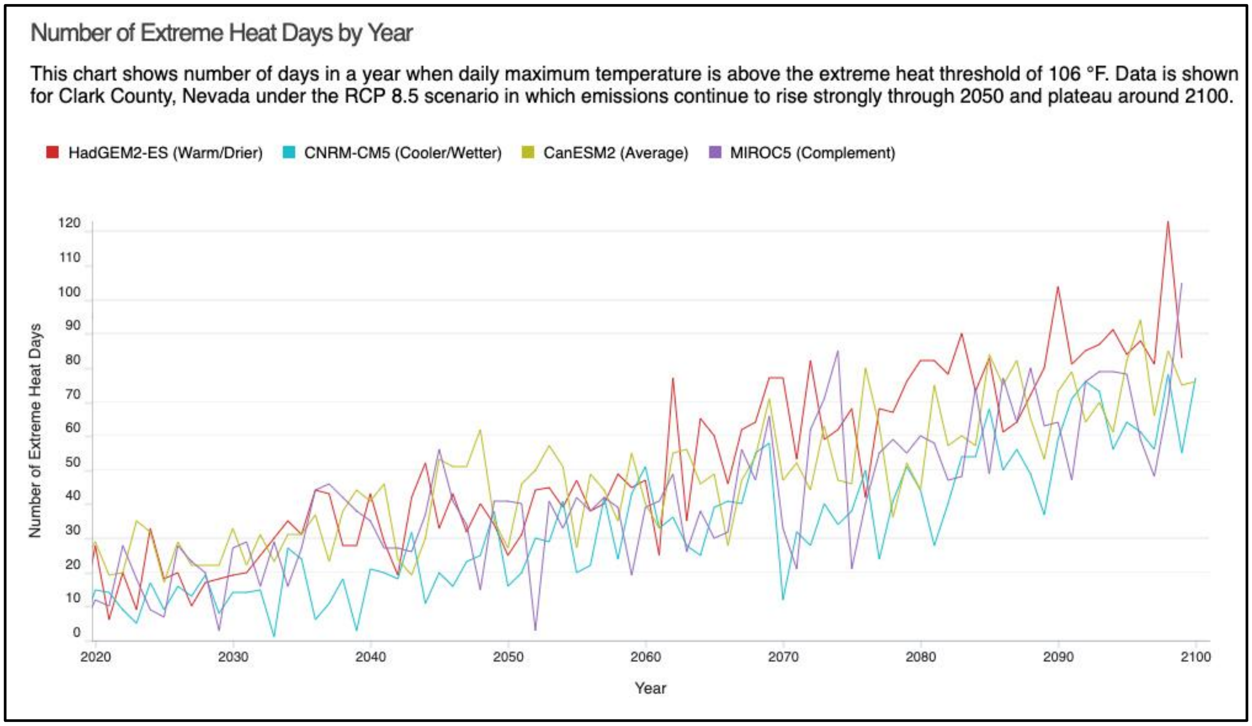

Figure 6. The projected number of extreme heat days (days with temperatures above 106 °F) for Clark County from 2020 - 2100. Future projected numbers of extreme heat days for the RCP 8.5 scenario are shown in the colored lines. This scenario (as well as the lower scenario (RCP 4.5)) shows an increase over this century with the potential for up to 63 days a year above this threshold in the higher scenario by the late century (2070-2099). Source: Cal-Adapt - https://cal-adapt.org/tools/extreme-heat/.

A summary of the historic and projected temperature changes (average annual maximum temperature and extreme heat days) listed above are shown below in **Table 1**.

Table 1. Average historical (modeled) and projected changes in average annual maximum temperature and average number of extreme heat days a year (above 106 °F) for Clark County. Projected increases are for the higher future scenario (RCP 8.5) for both the mid-century (2035-2064) and the late century (2070-2099) time scales. Source: Cal-Adapt.

Changes in Temperature					
	Historical (1961-1990)	Mid-Century (2035-2064)		Late Century (2070-2099)	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Average Annual Maximum Temperature	76.5 °F	79.7 – 82.7 °F (+ 3.2 to 6.2 °F)	81.1 – 83.8 °F (+ 4.6 to 7.3 °F)	81.3 – 84.4 °F (+ 4.8 to 7.9 °F)	84.2 – 89.3 °F (+ 7.7 to 12.8 °F)

Extreme Heat Days (at least 106 °F)	4 days / year	23 days / year	30 days / year	31 days / year	64 days / year

In summary, the climate of Clark County will be notably warmer in the future, which will have significant implications for the social, physical, and environmental systems of the region.

Precipitation (Historical and Projected)

Precipitation patterns are changing. The 30-year observed historical annual average precipitation for the region (1961-1990) is 6.8 inches, with lows of about 2.3 inches a year and highs of up to 14.3 inches a year. Clark County often experiences relatively low amounts of precipitation annually and is already familiar with drought conditions. In 2019, Clark County received higher than average precipitation, totaling around 7.5 inches. Despite much of the West being in the middle of a several year drought, annual average precipitation for Clark County in 2020 was considered average, with just less than 5 inches (**Figure 7**). Annual average precipitation in 2021 currently appears to reflect severe drought conditions (as of June 25, 2021, there was less than 2 inches of rain recorded).

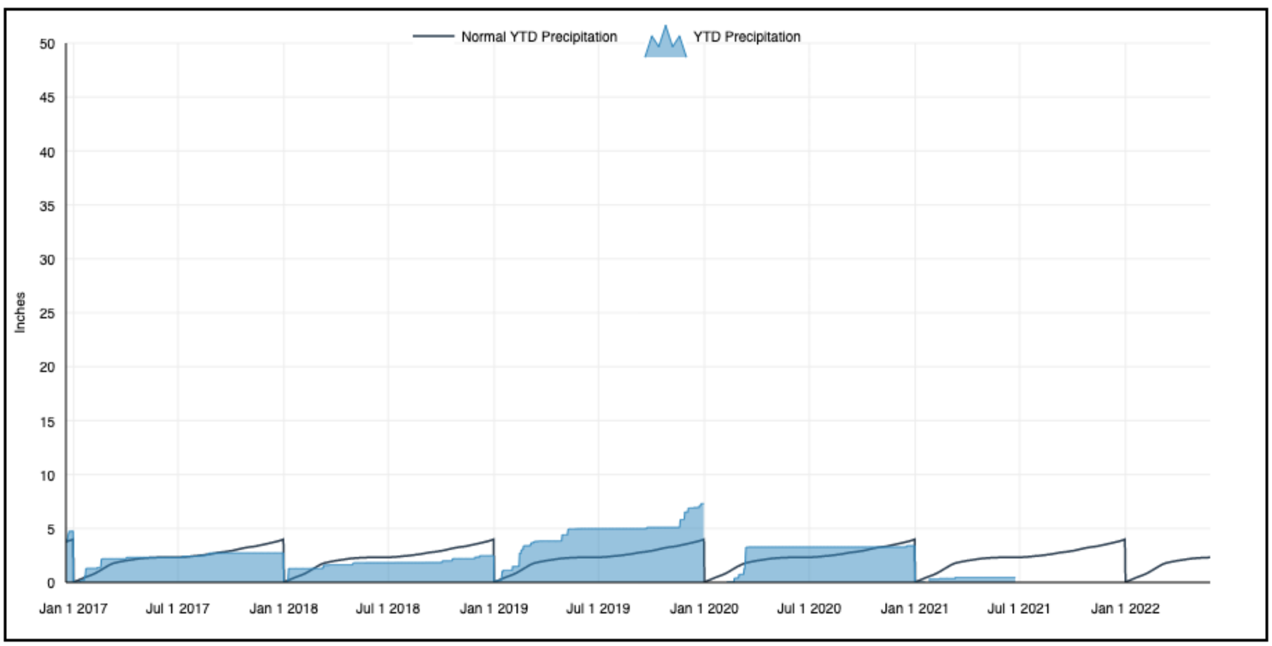

Figure 7: Daily and accumulated precipitation for 2017-2021. The long-term average water year accumulation curve is shown in the dark blue curve (which goes all the way through 2022). Observed precipitation from the Las Vegas Air Terminal Weather Station (# USW00053123) is shown in the blue shaded area. Source: U.S. Climate Explorer - https://crt-climate-explorer.nemac.org - Accessed June 25, 2021.

While total annual precipitation is not likely to increase significantly, extreme precipitation events (total amount of precipitation falling during one event) are likely to increase due to an increase in the severity and frequency of atmospheric rivers (defined as long, narrow regions in the atmosphere that transport water vapor over land and can result in extreme precipitation events).[13] In addition, climate projections show more variability in the amount of precipitation from year to year as shown in **Figure 8**.[14] Under the lower scenario (RCP 4.5), projections show average annual precipitation to be 6.1 – 8.1 inches of precipitation annually by mid-century (2035-2064) with a potential annual minimum of 1.7 inches and a maximum of 18.7 inches. Using the lower emissions scenario (RCP 4.5), projections show average annual precipitation to be 5.8 – 8.1 inches annually by late century (2070-2099) with a potential annual minimum of 0.7 inches and a maximum of 16.6 inches. Under the higher scenario (RCP 8.5), projections show average annual precipitation to be 5.6 – 8.2 inches of precipitation annually by mid-century (2035-2064) with a potential annual minimum of 1.4 inches and a maximum of 18.5 inches. Using the higher emissions scenario (RCP 8.5), projections show average annual precipitation to be 5.5 – 10.4 inches annually by late century (2070-2099) with a potential annual minimum of 1.2 inches and a maximum of 26 inches. Annual variability in precipitation will increase, with projections showing an expanded and more variable range of precipitation from as low as 0.7 inches per year up to over 26 inches per year.

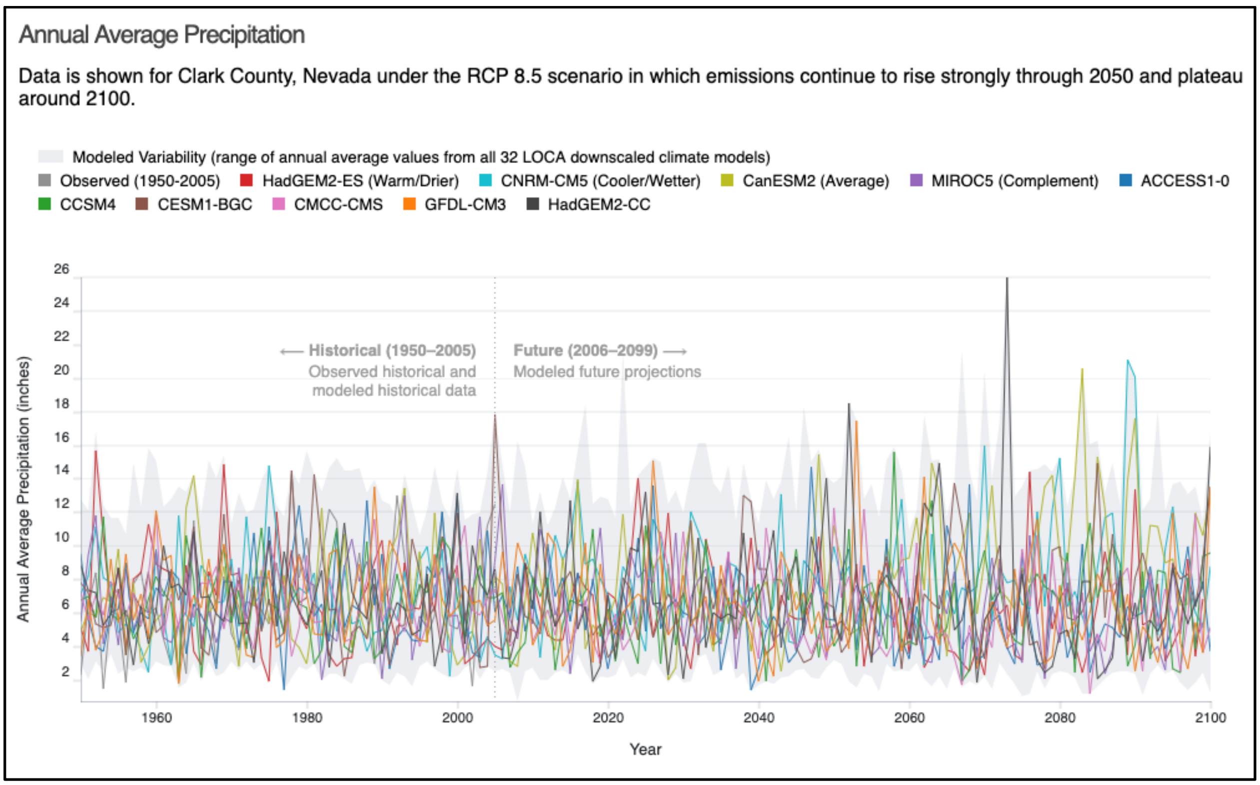

Figure 8. Average annual precipitation for Clark County shown in inches under the higher scenario *(RCP 8.5)*. Future projected annual precipitation for the RCP 8.5 scenario is shown in the colored lines. The observed 30-year historical annual average precipitation (1961-1990) is 6.8 inches with lows of 2.3 inches a year and highs of more than 14.3 inches a year. Model averages show an increase in the variability of precipitation from year to year. Source: Cal-Adapt - https://cal-adapt.org/tools/annual-averages/.

[13] Gonzalez et al. (2018)

[14] Geospatial Innovation Facility, University of California, Berkeley (2021)

Another way to look at this cycle of rainfall is to look at extreme precipitation events and dry spells. While it can be difficult to project exact changes to extreme precipitation events, scientists know that a warmer climate holds more moisture, and it is likely that extreme precipitation events will increase as the climate warms. Extreme rainfall can happen over a matter of hours or days. Based on observed historical rainfall totals (1961-1990), the county averages 7 events a year where the 1-day rainfall total is above 1.08 inches (95th percentile data) and projections under the lower and higher emissions scenarios show that that number is not expected to change (**Figure 9**). Yet, projections do show that the timing of extreme precipitation events may shift to the fall months, with fewer (or no) extreme precipitation events projected over the summer months. In addition, 10-15% of total precipitation across the Colorado River Basin is expected to fall as rain rather than snow by the late century (2070-2099).[15] In addition, snowmelt is projected to decline by 30-50% by the end of the century for most water basins in the state.

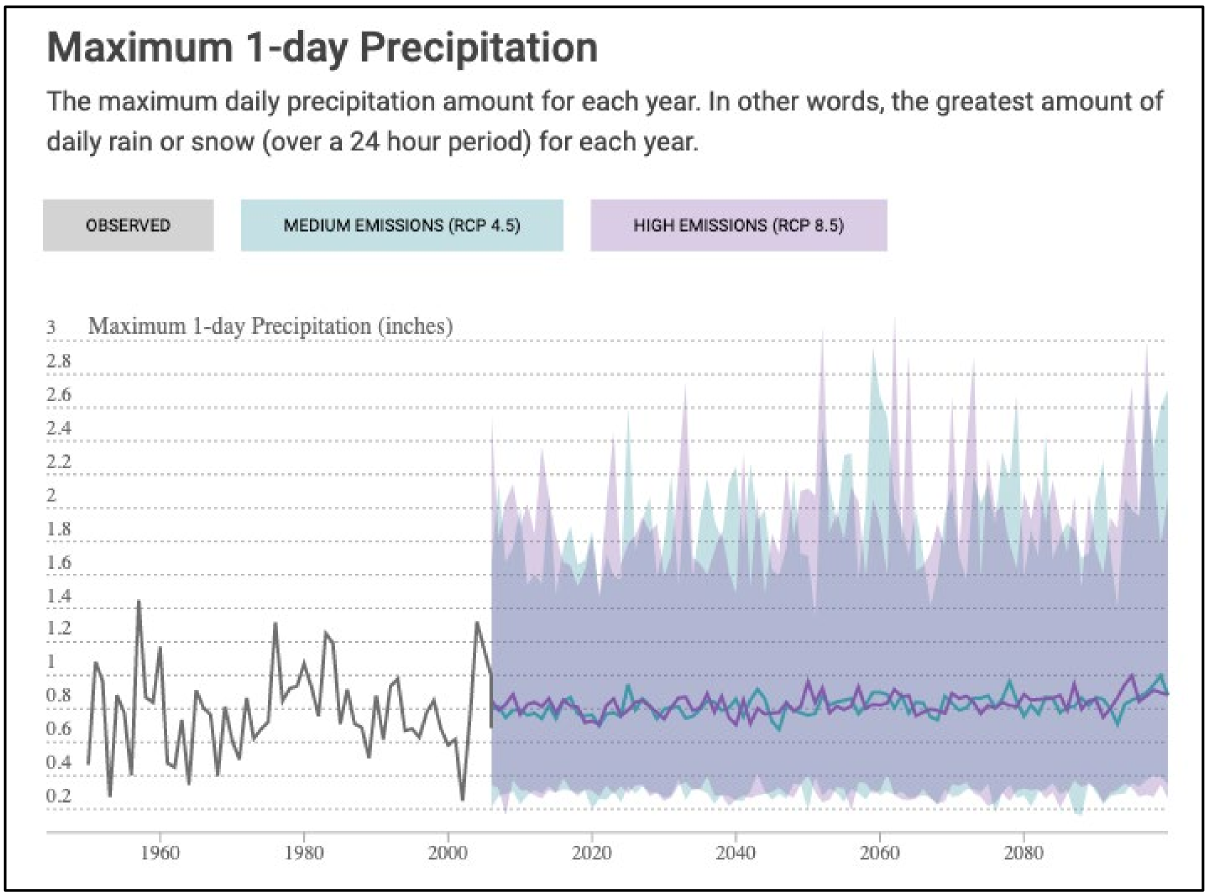

Figure 9. Maximum 1-day precipitation for Clark County shown in inches. The 30-year average (1961-1990) is 0.78 inches of rain with lows of about 0.25 inches a day and highs of around 1.32 inches a day. Observed maximum 1-day precipitation in inches is shown in the dark grey line. Future projected maximum 1-day precipitation for two different emissions scenarios are shown in the colored lines and shading. A medium scenario (RCP 4.5) is shown in teal, while a high scenario (RCP 8.5) is shown in purple. Both scenarios show little change in average maximum 1-day precipitation over the course of the century, yet the amplitude is much higher, representing the potential for more rainfall in these events. Source: Cal-Adapt - https://cal-adapt.org/tools/extreme-precipitation/.

[15] State of Nevada (2021)

Research suggests that the region will continue to experience more intense and longer drought conditions, fueled by hotter temperatures and a reduction in snowpack due to climate change.[16] In addition, "megadroughts," multi-decadal droughts (30 – 40 years long), will become more likely. Increases in temperature are likely to exacerbate aridification, potentially creating permanent changes due to increasing evapotranspiration, lower soil moisture, and changes in the timing, quantity, and quality of snowmelt.[17]

Snowpack and the Colorado River Basin

Clark County and its singular water source — Lake Mead, which is fed by the Colorado River — provides drinking water for more than 2.3 million residents (over 74% of Nevada's total population[18]) and over 45.6 million visitors per year.[19] Due to projected reductions in snowpack, more precipitation falling as rain instead of snow,[20] and altered timing and decreasing runoff,[21] Clark County is projected to experience more extreme, long-term drought conditions. This has significant implications for the current and future residents and visitors of Clark County.

Due to climate change, Clark County is expected to experience more variability in precipitation patterns from year to year, longer and more intense drought conditions, and more extreme precipitation events by mid- and late century.

As dynamics surrounding extreme precipitation events transform, seasonal precipitation patterns in the region are likely to change. In Clark County, summers are typically very dry, with more than 84 days a year in a row with less than measurable precipitation (< 0.04 inches of precipitation a day). The maximum number of consecutive days with precipitation < 0.04 inches for each year is known as a "dry spell." The 30-year average (1961-1990) saw between 71 days and 99 days with less than 1 mm of precipitation. The length of those dry spells is projected to increase as the climate warms under both the lower and higher scenarios (**Figure 10**).

For example, the length of those dry spells is expected to increase by around 9 days by mid-century (2035-2064) and 17 days per year by the late century (2070-2099) using the higher scenario (RCP 8.5), as shown in **Table 2**. Under the lower scenario (RCP 4.5), those dry spells are expected to increase by 8 days annually by the mid-century (2035-2064) from the historical

[16] Gonzalez et al. (2018)
[17] Gonzalez et al. (2018)
[18] Southern Nevada Water Authority (2020)
[19] Clark County (2021a)
[20] Gonzalez et al. (2018)
[21] Southern Nevada Water Authority (2020)

average. At the same time, these dry spells will be characterized by increasingly hot days and nights, heightening the intensity of the region's dry summer seasons.

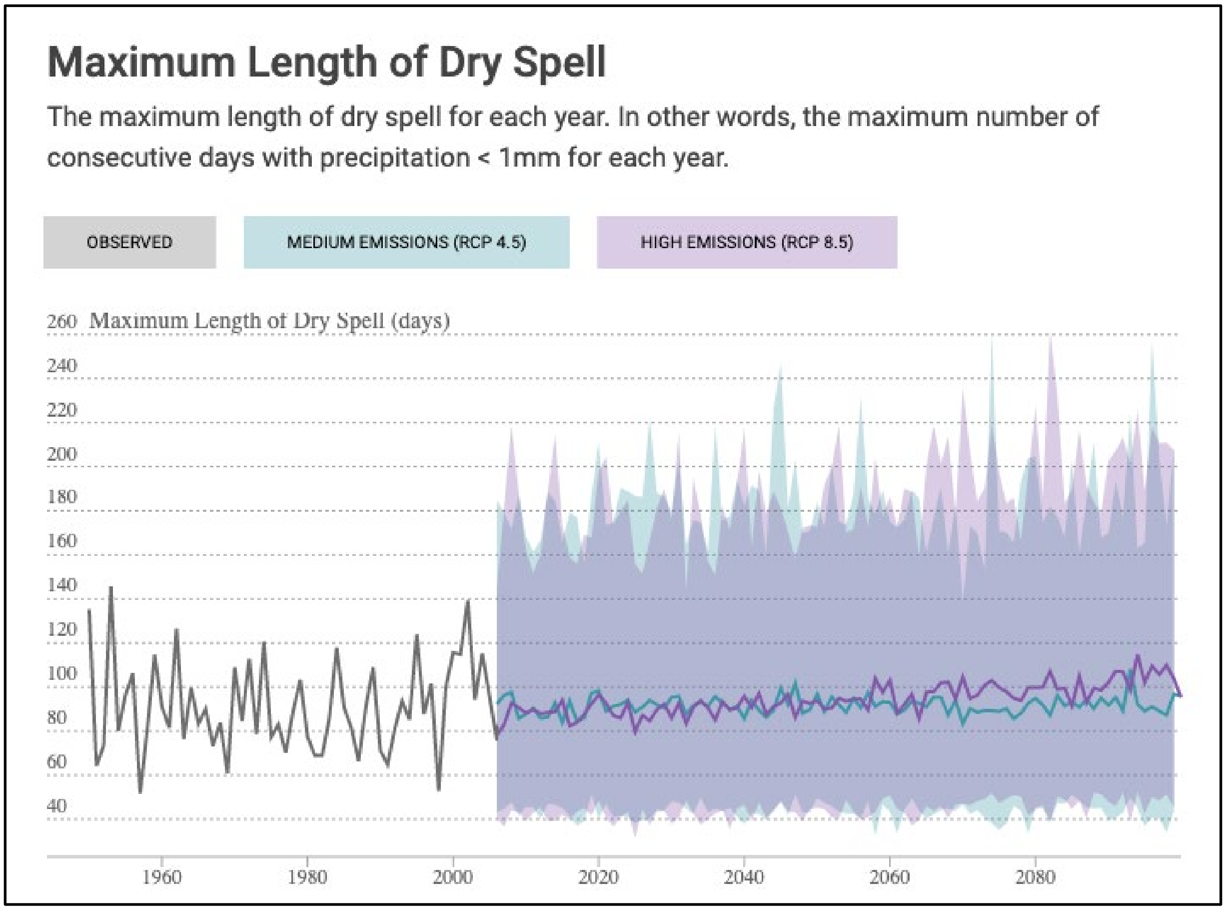

Figure 10. Maximum length of dry spell for Clark County shown in days. The 30-year average (1961-1990) is 84 days. Observed maximum length of dry spells in days is shown in the dark grey line. Future projected maximum length of dry spells for different climate scenarios are shown in the colored lines and shading. The lower scenario (RCP 4.5) is shown in teal, while a high scenario (RCP 8.5) is shown in purple. Dark lines show the annual averages while shading shows the extremes of both scenarios. Both scenarios show an increase in the length of maximum dry spells over the course of the century. Source: Cal-Adapt - https://cal-adapt.org/tools/extreme-precipitation/.

Table 2. Changes in average annual precipitation for Clark County based on modeled historical observations and future projections by mid-century (2035-2064) and by late century (2070-2099) under the RCP 4.5 and RCP 8.5 scenarios.

Changes in Precipitation					
	Observed Historical (1961-1990)	Mid-Century (2035-2064)		Late Century (2070-2099)	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Annual Average Precipitation	6.8 inches	6.1 – 8.1 inches	5.6 – 8.2 inches	5.8 – 8.1 inches	5.5 – 10.4 inches
Max 1-day Precipitation	0.78 inches	0.666 – 1.053 inches	0.665 – 1.065 inches	0.693 – 1.086 inches	0.657 – 1.112 inches

As a result, a combination of more variability in average annual precipitation, longer dry spells, higher temperatures, and additional factors (like a reduction in snowpack) will accelerate evaporation as well as transpiration from plants, resulting in less surface water and drier soils.

Clark County's Climate Hazards and Concerns

Clark County is already feeling the effects of a changing climate. Las Vegas is the fastest warming city in the country[22] and much of the state is in an "extreme" drought.[23] Set in the desert of the southwest, Clark County faces a unique set of climate challenges. The following section will define the current and existing climate conditions and hazards and establish how the climate projections in the previous section exacerbate those climate hazards.

Background and Overview

Although Clark County experiences a variety of hazards (including extreme winds), there are four main climate hazards—driven by a changing climate—that will affect the county: drought, extreme heat, flooding, and wildfires. All of these hazards are discussed and addressed in the National Climate Assessment,[24] the Clark County Sustainability and Climate Action Plan,[25] and the Clark County Wildfire Risk Assessment.[26] Each of these hazards will directly and indirectly impact people, infrastructure, natural systems, and the economy in important (as well as compounding) ways. Some hazards—like flooding or wildfire—can create immediate threats to human health and safety, whereas other hazards—like drought—can be chronic and more slowly degrade quality of life, the built environment, natural systems, and aspects of Clark County's economy. All of these hazards have direct and indirect consequences for the physical, emotional, and mental health of the communities affected. Understanding how these climate hazards have already impacted the county as well as how they may be exacerbated due to climate change is an essential step in working to become a more resilient community.

There are four main hazards—driven by a changing climate—that will affect Clark County: drought, extreme heat, flooding, and wildfires. Each of these hazards will directly and indirectly impact people, infrastructure, natural systems, and the economy in important (as well as compounding) ways.

As previously discussed, changes in temperature and precipitation are the main climate drivers, which then lead to multiple climate hazards (**Figure 11**). The graphic below describes the main

[22] Climate Central (2019)
[23] National Drought Mitigation Center (2021)
[24] Gonzalez et al. (2018)
[25] Clark County (2021b)
[26] Nevada Department of Forestry (2013)

relationships between extreme temperatures and precipitation, climate hazards, and the subsequent impacts to Clark County's people, assets, and resources.

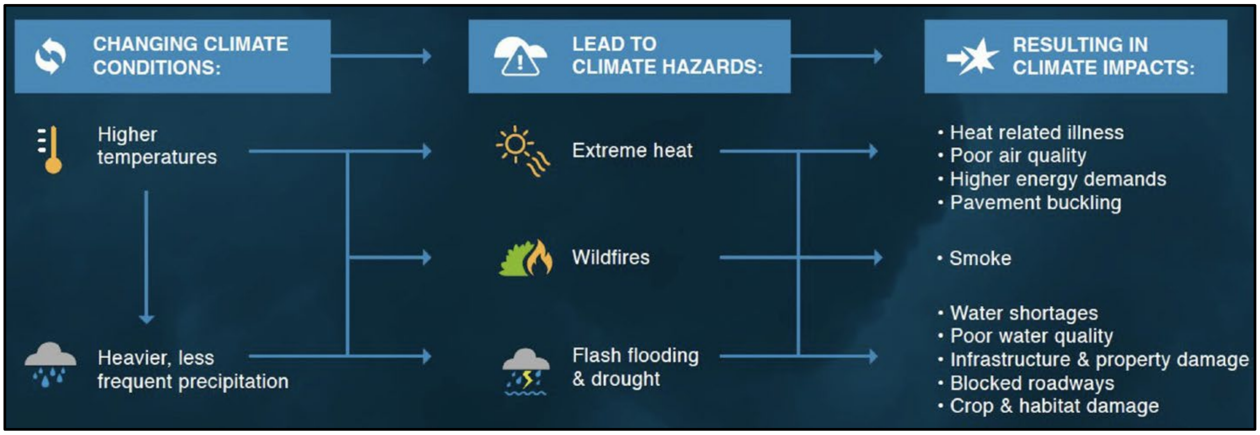

Figure 11. Graphic representation of the relationships between the climate drivers (changing and extreme temperatures and precipitation), climate hazards (extreme heat, wildfires, drought, and flooding), and the vulnerabilities and consequences to a variety of systems for Clark County.

The methodologies used to analyze and discuss each hazard vary, due to the quality and granularity of the data available. In general, a climate hazard will be discussed in the context of historical, current, and projected exposure for Clark County and the surrounding region using the best available science and information. While this summary discusses the four hazards separately, it is important to remember that climate hazards are generally interconnected. They may happen simultaneously and/or in quick succession. They may also exacerbate the vulnerability of and impact to different assets. For example, extended periods of drought exacerbate the potential for a wildfire, and if a wildfire does occur, the dry soils and vegetation can increase the severity of a wildfire and future flooding events.

Additionally, drought periods followed by a high precipitation event can lead to more severe flooding, as the soils are not able to absorb surface water, further exacerbating the impacts of flooding on the landscape and to infrastructure. Climate hazards are interconnected and influence each other in important and complex ways. The following section of this assessment will highlight information on hazards from local and regional sources, ongoing projects, and planning efforts, as well as additional analyses unique to this project.

Drought

Drought is the result of a natural decline in precipitation over an extended period and occurs in virtually every climate on the planet, including areas of both high and low precipitation. Drought conditions occur during extended periods of time with limited or no precipitation, sometimes over months or years. "Megadroughts," multi-decadal droughts that occur across a vast region, can last for decades.[27] Drought conditions often take several seasons to develop and dissipate.

[27] Freedman, A. & Frees, D. (2020)

The severity of drought can be aggravated not only by high temperatures and a lack of precipitation, but also by other climatic factors such as prolonged high winds, low relative humidity, and extreme heat. The following four definitions are commonly used to describe different types of droughts and demonstrate the complexity of the hazard:

1. Meteorological drought: Degree of dryness, expressed as a departure of the actual precipitation from the expected average or normal precipitation amount, based on monthly, seasonal, or annual time scales.
2. Hydrological drought: Effects of precipitation shortfalls on stream flows, and reservoir, lake, and groundwater levels.
3. Agricultural drought: Soil moisture deficiencies relative to water demands of crops.
4. Socioeconomic drought (or water management drought): Shortage of water due to the demand for water exceeding the supply. The severity of a drought depends on several factors: duration, intensity, geographic extent, and water supply demands for both human use and vegetation.

Drought conditions are somewhat difficult to plan for, due to the large geographic areas they can apply to, as well as the prolonged buildup and lingering impacts once drought conditions have subsided. Drought conditions have direct and indirect impacts on the County's natural, physical, social, and economic assets. Not only does drought directly impact people, infrastructure, and natural resources, it also exacerbates other climate hazards including wildfire. To understand the current and future projected drought conditions for Clark County, it is necessary to understand how drought conditions have historically impacted the region.

Historic and Current Drought Conditions

Drought conditions have historically occurred with regularity across the State for centuries, particularly in Southern Nevada. Clark County, located in the Mojave Desert, is one of the driest counties in the U.S., generally receiving between 4-8 inches of rain annually.[28] Historically, most of the County's observed precipitation has fallen in two seasons; the winter (December, January, and February) and late summer (July and August).

The U.S. Drought Monitor sets the standard for intensity of drought conditions across the United States and uses a classification system that ranges from "abnormally dry" (D0) to "exceptional drought" (D4) (reference key in Figure 13).

The 17-year drought between 2000-2016 is the most persistent drought on record in Clark County (and for much of the West).[29] In that period of time, "extreme" drought conditions were recorded in 2003, 2004, 2007, 2014, and 2015. Prior to 2000, "exceptional" drought conditions were recorded in the late 1920s, through parts of the 1950s and 1960s, and briefly in the 1990s.[30] In

[28] Kalansky et al. (2018)
[29] Clark County (2018)
[30] National Integrated Drought Information System (2021)

addition, “severe” and “extreme” drought conditions have been present in Clark County for nearly every decade on record (**Figure 12**). The National Integrated Drought Information System (NIDIS) uses the Standard Precipitation Index (SPI) to characterize meteorological drought on a range of timescales using a variety of methods (including tree ring data). The SPI for Clark County allows us to quantify precipitation patterns and drought severity classification records from 1895 until present.

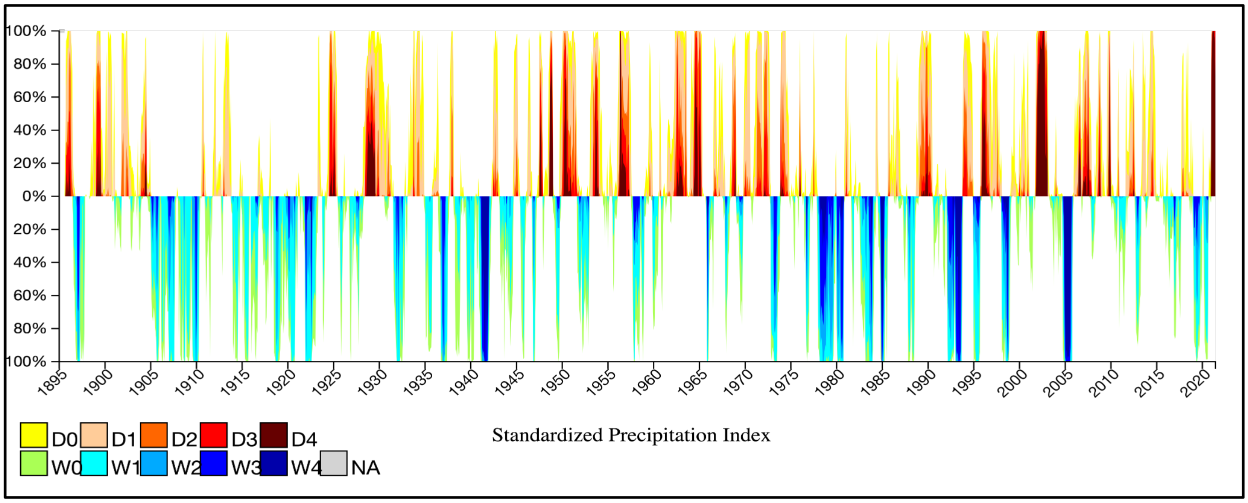

Figure 12. Standardized Precipitation Index for Clark County showing historic and current drought conditions (shown in red and yellow). (Source Drought.gov - Retrieved at https://www.drought.gov/states/nevada#historical-conditions).

As of August 3, 2021, much of Clark County is currently experiencing an “exceptional” drought,[31] as is much of the West (**Figure 13**) due to increasing temperatures and decreasing runoff in the Colorado River Basin driven by climate change.[32] Clark County and its singular water source—Lake Mead, which is fed by the Colorado River—provide drinking water for more than 2.3 million residents (over 74% of Nevada’s total population[33]) and over 45.6 million visitors per year.[34] Another 820,000 people are expected to move to Clark County by 2060, requiring additional water resources.[35] Lake Mead is the largest reservoir in the United States, but its water levels have been in steady decline since the 2000s.[36] With the completion of the Hoover Dam in 1936, lake levels have been monitored continuously. With much of the Western United States now experiencing the first climate-change induced “megadrought,” Lake Mead’s water levels are far below average.[37] In 2020, the water level in Lake Mead was at 43% of normal capacity.[38] In 2021 (as of June 18), water levels were at 36% of normal capacity, the lowest since the 1930s.[39] The

[31] National Drought Mitigation Center (2021)
[32] Southern Nevada Water Authority (2020)
[33] Southern Nevada Water Authority (2020)
[34] Clark County (2021a)
[35] UNLV Center for Business and Economic Research (2020)
[36] Cappucci, M. (2021)
[37] Freedman, A. & Frees, D. (2020)
[38] Bureau of Reclamation (2021)
[39] Yetikyel, G. (2021)

Colorado River, whose headwaters gather runoff and snowmelt from the Rocky, Wind River, Uintah, and Wasatch Mountains (all collectively known as the Colorado River Basin), has been in the worst extended drought in recorded history since 2000.[40]

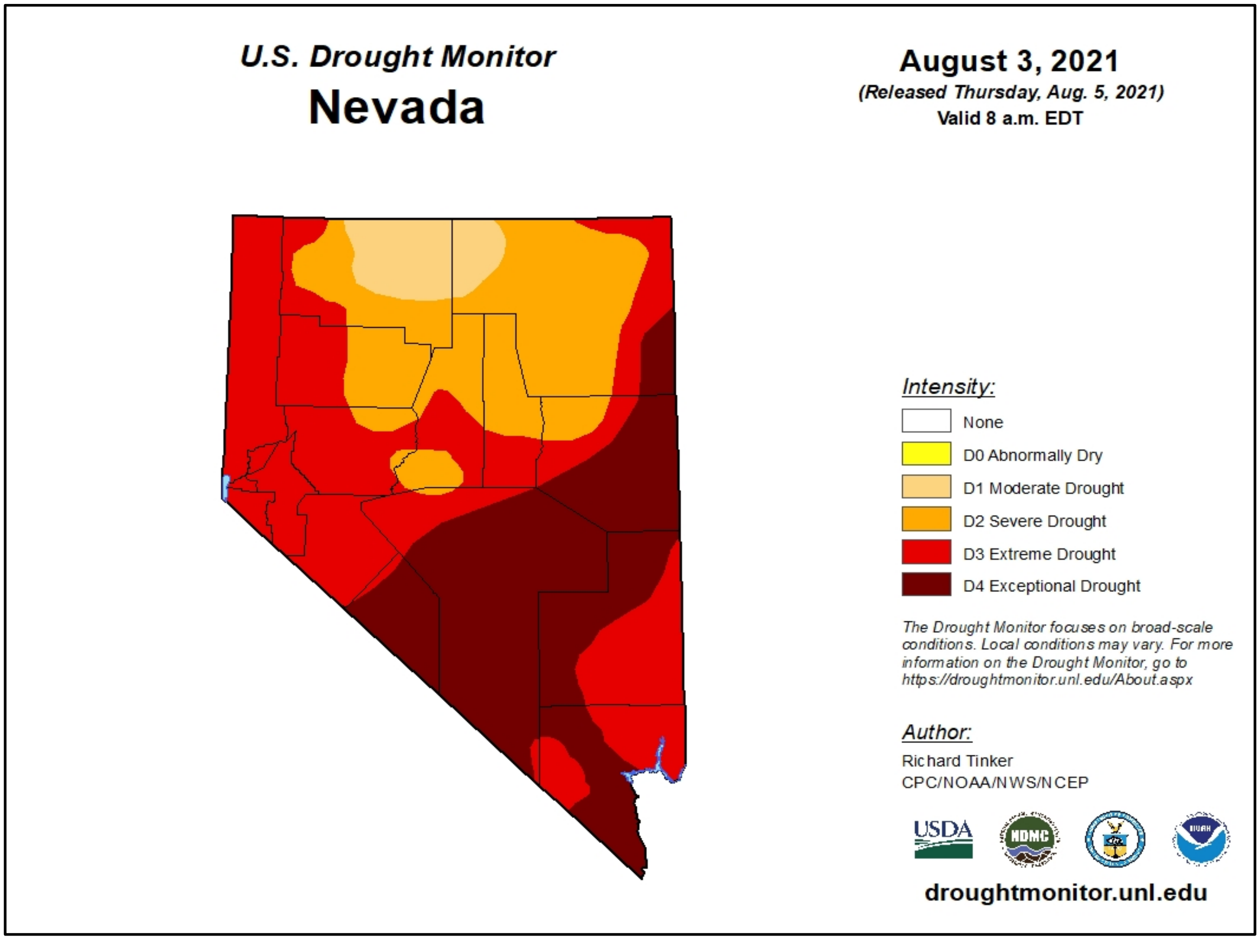

Figure 13. Much of Clark County is currently in an Exceptional Drought, August 3, 2021 (source U.S. Drought Monitor - Retrieved at https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?NV).

Not only do these drought conditions directly impact water quality and quantity, but they also impact the region's ecosystems, food production, energy systems, infrastructure, human health, the economy, and the cultural and spiritual lifeways of many Tribes located in the region. In addition, there are a variety of endemic threatened and endangered species in the region—including the desert tortoise (*Gopherus agassizil*) and Moapa dace fish (*Moapa coriacea*)—which are particularly sensitive to changing precipitation conditions.[41] Reduced water quantity and impaired water quality due to drought conditions also has implications for energy resources, as water is needed for hydroelectric capacity and additional water treatment requires significant energy resources.[42]

[40] Southern Nevada Water Authority (2020)
[41] Clark County (2000)
[42] Southern Nevada Water Authority (2018)

Projected Drought Conditions

Longer and more pervasive droughts are projected across the Colorado River Basin and across the State of Nevada by mid- and late century with increasingly significant implications for the health and wellbeing of Clark County's natural resources, water and energy systems, and people.[43] Due to climate change, scientists predict that over the next century, there is an 80-90% chance[44] Clark County will experience:

- Another drought that lasts over a decade;
- "Extreme" drought conditions (D3) becoming normal; and
- 30-40 year "megadroughts" becoming a realistic possibility.

Much of Clark County is currently experiencing an "exceptional" drought, as is much of the West due to increasing temperatures and decreasing runoff in the Colorado River Basin driven by climate change.

All these changes will have potentially devastating impacts for an area that is projected to continue to grow with increasing water demands.

What Does This Mean for Clark County?

In an area that is experiencing significant social and economic change, drought contingency planning, water infrastructure modifications, and water conservation efforts are central to Clark County's ability to effectively plan for and adapt to the changing drought conditions due to climate change. The region may also need to balance the needs of current and proposed development in context with anticipated water resources.

Longer and more pervasive droughts are projected across the State of Nevada by mid- and late century due to climate change…and 30-40 year 'megadroughts' becoming a realistic possibility.

In addition to the direct and indirect ways in which drought conditions currently (and will continue to) impact Clark County, increasing temperatures and longer dry spells are likely to lead to bigger, hotter, longer, and more severe wildfires in the region,[45] impacting air quality for Clark County residents.

Existing Clark County water conservation and protection efforts are wide ranging and multi-faceted. Examples include retrofitting and upgrading County facilities with water smart fixtures and technology, increasing the number of County properties that are being converted to xeriscapes (as opposed to ornamental turf), participating in joint water conservation plans,

[43] Gonzalez et al. (2018)
[44] Clark County (2018)
[45] Clark County (2021b)

tracking water consumption to encourage water conservation measures, and promoting effective stormwater management upgrades to ensure effective water management. Southern Nevada Water Authority (SNWA), which was created in 1991 (and manages most of Clark County's water), recently updated their 2020 Adaptation Plan which lays out specific strategies to plan for and adjust to regional drought conditions.[46]

Extreme Heat

Located in the Mojave Desert, Clark County residents are familiar with warm and hot temperatures. For example, the summertime average daytime high temperatures in Southern Nevada between 2015 and 2019 was 104 °F.[47] Similarly, in Southern Nevada in 2019 alone, there were 84 days exceeding 100 °F. Yet, warming temperatures due to human-caused climate change will create increasingly dangerous extreme heat events in the coming decades.

Historic and Current Extreme Heat Events

Clark County is located in the Mojave Desert, the hottest and driest desert in North America. Although warm and hot temperatures are common in the region, extreme heat events have continued to increase in frequency and severity for Clark County over the last century due to climate change. According to a recent analysis completed by Southern Nevada Strong and the Regional Transportation Commission of Southern Nevada (RTC), there were 437 heat-related deaths in Southern Nevada between 2007-2016.[48] In addition, 23 excessive heat warnings—which are issued by the National Weather Service when excessive temperatures are projected—were issued in Southern Nevada between 2015-2019. The average daytime high during the summer months between that same period was 104 °F, and in 2019 alone, 84 days exceeded 100 °F. Across the US, July 2021 became the hottest month on record in 142 years of recordkeeping, a record that has been broken in July every year for the last seven years.[49]

Throughout the Summer of 2021, Clark County has experienced several extreme heat events and record-breaking temperatures. On July 11, 2021, nearby Death Valley reached highs of 130 °F, tying records for the hottest temperature ever recorded globally.[50]

This was the third heatwave to hit the region this summer alone. Across the West, more than 31 million people have been under excessive heat warnings or heat advisories in July 2021. Hot temperatures are common for Clark County residents. That being said, as of August 5, 2021, Clark County was experiencing excessive heat warnings, with temperatures expected to reach between 100-118 °F.[51] These temperatures can be particularly extreme when they are prolonged in duration, and present significant safety and health concerns for residents. This is particularly true

[46] Southern Nevada Water Authority (2020)
[47] Clark County (2021b)
[48] Clark County (2021b)
[49] Borenstein, S. (2021)
[50] Craig, M. & Kasakove, S. (2021)
[51] National Weather Service (2021)

for residents who do not have access to air conditioning and/or have pre-existing health conditions.

Experienced in urban areas and coupled with the urban heat island effect, the impacts can be deadly. Excessively warm temperatures and heat rank as one of the top deadliest natural hazards, yet heat-related illnesses and deaths can be largely prevented with planning and preparation (i.e., cooling stations that provide shelter and water to the public).[52]

On July 11, 2021, nearby Death Valley reached highs of 130 °F, tying records for the hottest temperature ever recorded globally.

Projected Extreme Heat Days

Las Vegas is the fastest warming city in the country,[53] and extreme heat events are projected to get worse.[54] The people and environment of Clark County have adapted to the historical temperature ranges, yet the projected increase in annual and seasonal average can cause significant health stress on organisms at the top of their temperature thresholds. The number of excessively warm days in Clark County are expected to increase as are the frequency and duration of extreme heat events (back-to-back days of extreme heat). Some regional projections indicate that the number of days over 115 °F in Clark County could increase by 10 times by the end of the century.[55]

What Does this Mean for Clark County?

Not only does an increase in temperatures and extreme heat days directly impact Clark County residents, transportation systems, agricultural systems, water infrastructure, and natural resources, it also strains energy systems and increases GHG emissions due to an increase in the demand for cooling. If conditions are severe enough, extreme temperatures can cause critical community services to fail.[56]

Increasing temperatures and extreme heat can have significant impacts on human health. This is particularly true for "very warm" nighttime temperatures (temperatures above 74.4 °F) which are projected to increase through the months of August and September across much of the state.[57] There are a variety of indicators that make systems and people more vulnerable to the impacts of extreme heat including those who live in mobile homes, individuals who live in older housing, individuals experiencing homelessness, low-income communities, and individuals

[52] California Environmental Protection Agency and California Department of Public Health (2013)
[53] Climate Central (2019)
[54] Geospatial Innovation Facility, University of California, Berkeley (2021)
[55] Clark County, NV (2021b)
[56] Kalansky et al. (2018)
[57] Clark County (2021b)

experiencing pre-existing health conditions (like heart disease, respiratory disease, and diabetes, among others).[58]

Las Vegas is the fastest warming city in the country, and extreme heat events are projected to get worse.

According to ongoing research being conducted by the Guinn Center, in partnership with Morrison Institute at Arizona State University, the majority of heat impacts experienced by people in Southern Nevada occur in transit due to lack of shade at transit stops or along pedestrian corridors, or broken air conditioners in personal vehicles.[59] It also significantly impacts the elderly and the young, particularly for those who also have existing conditions or illnesses. Heat stroke and heat exhaustion are prevalent occupational hazards for individuals working outdoors. This includes not just farmers, construction workers and landscapers but also grocery delivery and curbside pickup workers, an emerging occupation from the COVID-19 pandemic.

Extreme heat has disproportionate impacts on historically and currently marginalized populations, including Black and Indigenous individuals and people of color (BIPOC) and low-income communities, due to historic and current housing policies.[60] It can trigger organ failure,[61] promote renal disease or failure (as a result of dehydration),[62] and result in premature, underweight, or stillborn pregnancies (particularly for Black mothers).[63] The exposure, sensitivity, and adaptive capacity of Clark County residents to extreme heat based on a variety of indicators were determined in the RTC Extreme Heat Vulnerability Analysis in 2021 (**Figure 14**).[64]

Efforts aimed at reducing residents' exposure to extreme heat conditions are critical to Clark County's ability to adapt to increasing temperatures due to climate change. Urban design standards or updates to local building or zoning codes could help to mitigate urban heat island effect, particularly at transit stops and along pedestrian corridors in high ridership areas.[65] Education and communication are also important strategies and may include educating residents about the impacts of heat and its associated health impacts or activating communication systems when extreme heat days are expected.

[58] National Geographic (2021)
[59] Guinn Center (2021)
[60] Hoffman et al. (2020)
[61] Mellen, R. & Neff, W. (2021)
[62] Sorensen, C. & Garcia-Trabanino, R. (2019)
[63] Flavelle, C. (2020)
[64] Regional Transportation Commission of Southern Nevada (2021)
[65] Guinn Center (2021)

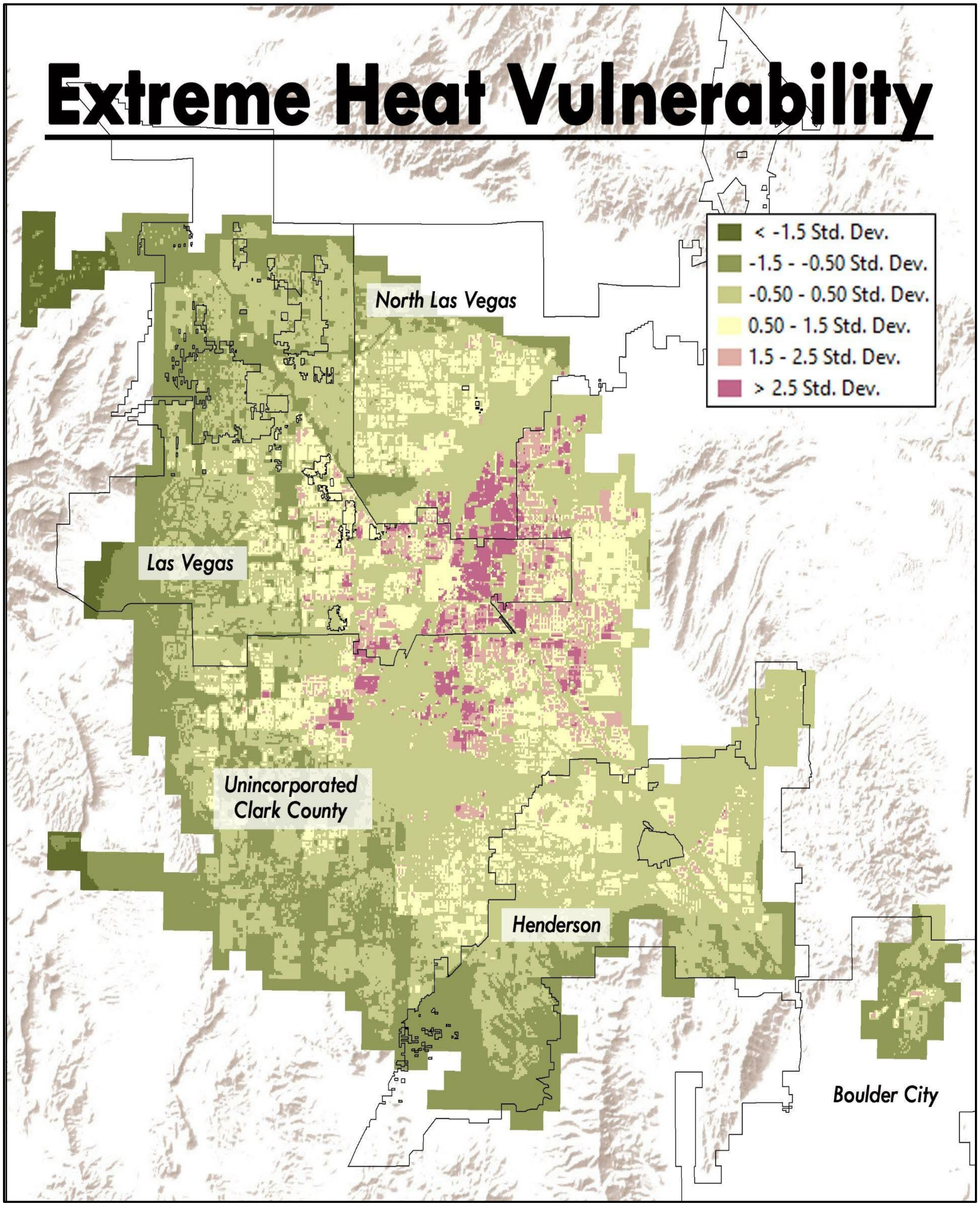

Figure 14. Extreme heat vulnerability for Clark County. Source: Regional Transportation Commission of Southern Nevada - https://www.arcgis.com/apps/webappviewer/index.html?id=5aff8de1f90a4d8e97a199d780b49513.

The County is already taking some measures to reduce the impacts of extreme heat on residents and employees including:

- Implementing Title 30 regulations that require that residential and commercial buildings use materials and colors that align with the natural landscape.[66] Not only does this garner aesthetic benefits, but the mandates also minimize the use of dark surfaces to help further prevent urban heat island effects.
- Preserving and planting tree canopy and green infrastructure across the County, with particular attention to equitable distribution for all neighborhoods.

Although life-threatening impacts are preventable, it will take further preparation and planning for Clark County to prevent significant impacts to people, natural systems, and critical infrastructure.

Flooding

Although Nevada has the lowest average annual rainfall among U.S. states and territories (as measured since 1895), it is nonetheless regularly affected by flood events. This apparent incongruity is the result of multiple concurrent factors, including high variance in statewide rainfall totals from year to year, differences in rainfall between different parts of the state, and a tendency for precipitation to occur in less frequent, heavy rainfall events.[67] In addition, the arid region is known for its fine desert soils which have low infiltration rates resulting in more runoff and flash flooding during extreme precipitation events.[68]

Flooding in Nevada most often occurs when there is an increase—even a small one—in the amount of rain that is sustained over a short period of time. Stormwater associated with heavy downpours travels quickly down steep slopes and across impermeable landscapes and urban geographies, accumulating in streets, parking lots, and low-lying areas. This is a common phenomenon in Clark County, where localized accumulation of stormwater over impermeable urban surfaces is exacerbated by runoff that has drained down from the surrounding hillsides and "armored" desert surfaces.[69] Inundation manifests in the urbanized and suburban developed areas as channel flooding, sheet flooding, alluvial fan flooding, and flash flooding.[70]

Flash flooding presents the most significant flood-related risk to life and property in Clark County. Flash flooding remains relatively unpredictable, despite advances in meteorological forecasting.[71] Although December, January, and February are the months with the highest average precipitation rates,[72] flash flooding occurs most often during and after the intense

[66] Clark County (2021b)
[67] North Carolina Institute for Climate Studies (2021)
[68] Miller et al. (2008)
[69] Clark County Regional Flood Control District (2021b)
[70] Rossi-Mastracci, J. (2020)
[71] Clark County Regional Flood Control District (2021c).
[72] Your Weather Service (2021)

summer thunderstorms linked to the region's natural monsoon cycle.[73] These storms result from tropical depressions that approach Clark County from the south or southeast. Summer or winter storms, which are typified by longer durations yet lower intensity, have not resulted in high rates of discharge similar to what has been observed during monsoon-driven rains.[74]

The topography, terrain, and ground cover that exists within and around the Las Vegas metropolitan area contribute significantly to the region's high propensity for short- or no-notice flooding. Whereas in other locations where high ground permeability retains or detains higher volumes of rainfall, this combination of land factors can result in the occurrence of flooding following a downpour of as little as one half (0.5) inch of rain during a 24-hour period. High rates of stormwater accumulation occur because the majority of Clark County's population resides in a natural depression that has been described as being oriented like a "bowl turned on its side."[75] The Las Vegas Watershed, which at 1,520 square miles is the largest of the county's 10 distinct watersheds, has a 10,500 foot elevation drop that spans from the peak of Mt. Charleston (12,000 ft) to the shores of Lake Mead (1,500 ft) (**Figure 15**). Stormwater runs across highly impermeable ground cover as a result of soil type, lack of agriculture, and other factors.

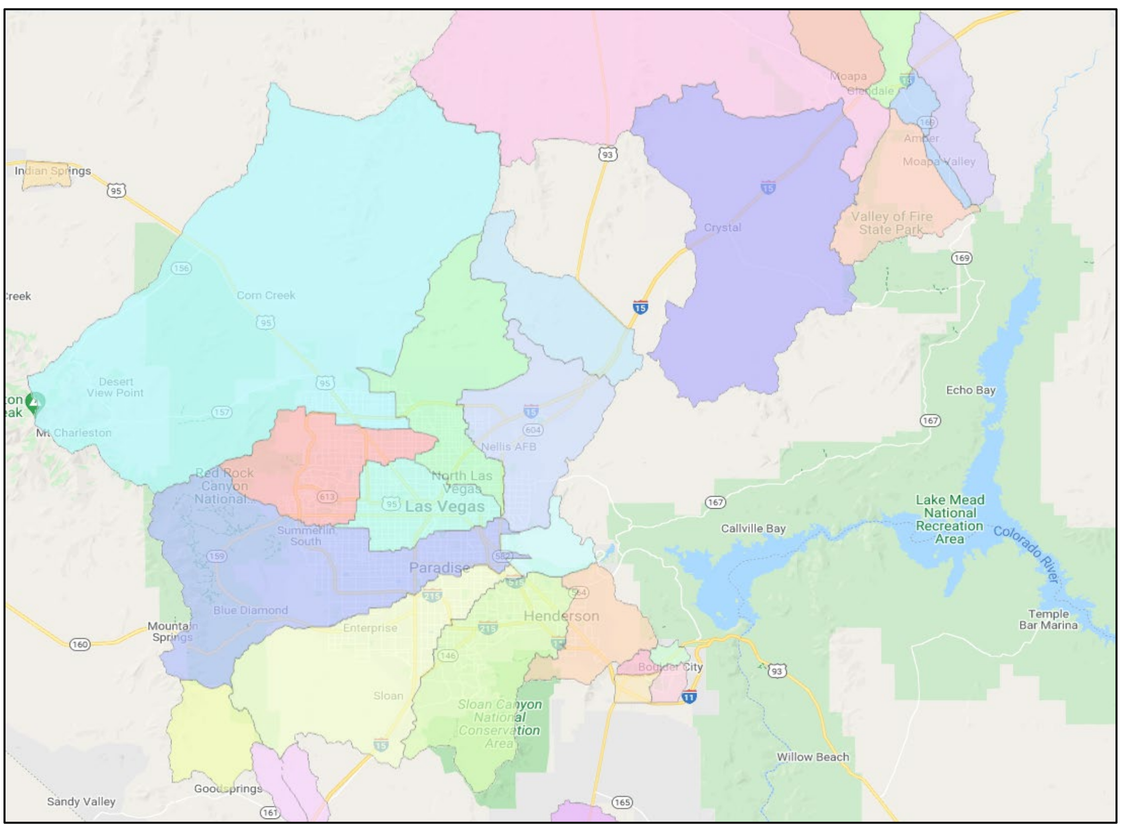

Figure 15. Map showing the mosaic of Clark County's watershed areas.

[73] Climate Action Nevada (2021)
[74] Federal Emergency Management Agency (2011)
[75] Marlow, J. (2011)

The Federal Insurance and Mitigation Administration (FIMA), which oversees FEMA's National Flood Insurance Program (NFIP), maintains spatial assessments of flood risk in every incorporated jurisdiction in Clark County. FIMA's Digital Flood Insurance Rate Maps (D-FIRMs) indicate that approximately 5.2% of Clark County's land mass (417.1 square miles) lies within a Special Flood Hazard Area (SFHA) designated zone (areas determined to have at least a 1% annual chance of flooding, also known as the "100-year floodplain").[76] Land included in the SFHA – which is mostly rural and not heavily populated – is concentrated along the Virgin, Muddy, and Colorado rivers in the eastern and southern portions of the County.

The majority of Clark County's flood risk, as a factor of at-risk people and property, exists in an area that encompasses several watersheds that empty into a 12-mile channel leading to Lake Mead called the Las Vegas Wash (**Figure 16**). Although these smaller watersheds are distinct and have their own drainage patterns, they are collectively referred to as the Las Vegas Wash Watershed.[77] In 2013, the Las Vegas Wash Watershed was by far the most populated in Nevada, housing almost 2 million people. It contains multiple municipalities, including Las Vegas, North Las Vegas, and Henderson.

The Las Vegas Wash Watershed originates in the mountains approximately 28 miles north of Las Vegas and continues in a southeast direction for approximately 42 miles, where it terminates at Lake Mead. The drainage basin is bounded by the Spring Mountains on the west; by parts of the Desert, Sheep, and Las Vegas Ranges on the north; by the Frenchman and River Mountains and a low range of hills on the east; and by the Spring Mountains and the Bird Spring and McCullough Ranges on the south. The drainage area of Las Vegas Creek is bounded on the west by La Madre Mountain, which has an elevation of approximately 7,000 feet. Three miles east of this boundary, the drainage area consists of a well-defined alluvial fan that continues eastward to Interstate 15 in downtown Las Vegas. Flows on this fan are often the result of intense short duration rainstorms. The flow pattern on the fan is complex, and areas of concentrated flow can shift often. Urban development of this fan is changing its runoff potential and flow paths.[78]

There are other watersheds in Clark County that also present a flood risk, including those in the northcentral and north-eastern areas. Each of these watersheds also leads to Lake Mead, including the areas alongside the Muddy River (which flows through Overton and Logandale) and the Virgin River (which runs along the southern boundary of Mesquite). The current Clark County Hazard Mitigation Plan estimates that a severe flash flood event will occur at least once every 2-12 months. This mirrors FEMA's National Risk Index rating for flood in the county which indicates an annualized frequency of 6.68 flood events per year based on a record of 147 flood events during the past 22 years.[79]

[76] Clark County (2018)
[77] Nevada Division of Water Resources (2013)
[78] Federal Emergency Management Agency (2011)
[79] Federal Emergency Management Agency (2021)

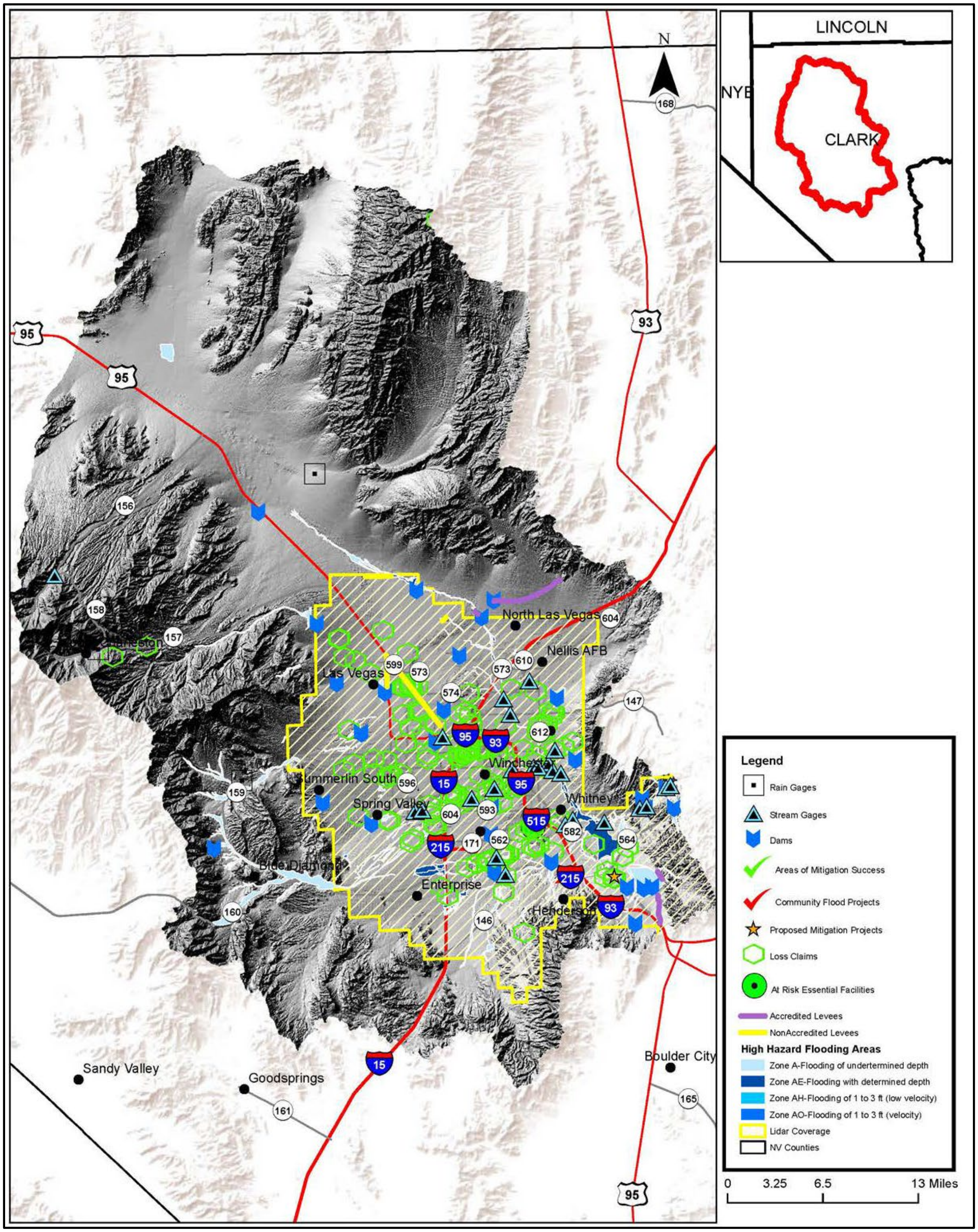

Figure 16. High hazard flooding areas in Clark County. Source: Nevada Division of Water Resources - http://water.nv.gov/programs/flood/hazards.pdf.

Historic and Current Flooding Events

Flooding has remained a major problem in Clark County since its 1909 establishment and was a problem for many years prior to that year. An annotated history of flooding from 1905 through 1975 details 184 floods, or an average of more than 2.5 notable events per year. These events are described to have caused a broad range of detrimental effects, from disruptions of railways, communications and power transmission network breaks, damage to homes and other buildings, washouts of bridges and road segments, the loss of livestock and crops, losses of entire trains and land, damages to businesses, and loss of life.[80]

Flood exposure and vulnerability in Clark County has increased in parallel to an increasing rate of immigration, settlement, and urban development. Since 1960, Clark County has experienced more than 12 floods—typically between the months of July and September—resulting in at least $1 million in property damage for each event, and 22 flash floods that caused a combined 33 fatalities.[81] In recent years, the incidence of flooding has only increased. FEMA's National Risk Index, which tracks several natural and technological hazards, reports 147 flood events as having occurred in Clark County since just 1999.

Most floods remain locally significant, but not large enough to result in a major Presidential Disaster Declaration (an event that requires Federal response or recovery intervention in keeping with the provisions of the Robert T. Stafford Disaster Relief and Emergency Assistance Act). While the State of Nevada has received 11 flood-related Major Presidential Disaster Declarations from FEMA since passage of the Disaster Relief Act in 1950, only three of these occurred in Clark County, including:

- DR-4202-NV: November 2014 (Moapa Band of Paiutes Reservation, Public Assistance)
- DR-723-NV: September 1984 (Clark County, Public Assistance)
- DR-645-NV: August 1981 (Clark County, Individual Assistance)

The fact that declarations are so rare despite the common nature of floods in Clark County is indicative of the historically extensive (rather than intensive) nature of flood impacts and the County's stormwater management system. This points to many small, locally impactful events over an extended period of time rather than fewer, more impactful events that are rarer but affect large areas and result in significant loss of life and/or damage to property. Despite this, the total impact from flooding in Clark County remains significant, even if individual events are not large enough to warrant a major disaster declaration.

Projected Changes to Flooding in Clark County

Peak daily runoff, the principal source of flash flood risk in Clark County, is expected to increase over time due to the ongoing meteorological effects of climate change (**Figure 17**). Using

[80] US Department of Agriculture (1977)
[81] Clark County Regional Flood Control District (2019)

conservative greenhouse gas concentration trajectories (RCP 4.5), there are areas of the county—including in the Las Vegas metropolitan area—that will experience as much as a 150-200% increase over historical averages. Using less optimistic figures (RCP 8.5) there are parts of the county that would be expected to experience increases of 200% or more. Compared to the rest of Nevada, Clark County is an area of notable concern in this regard.

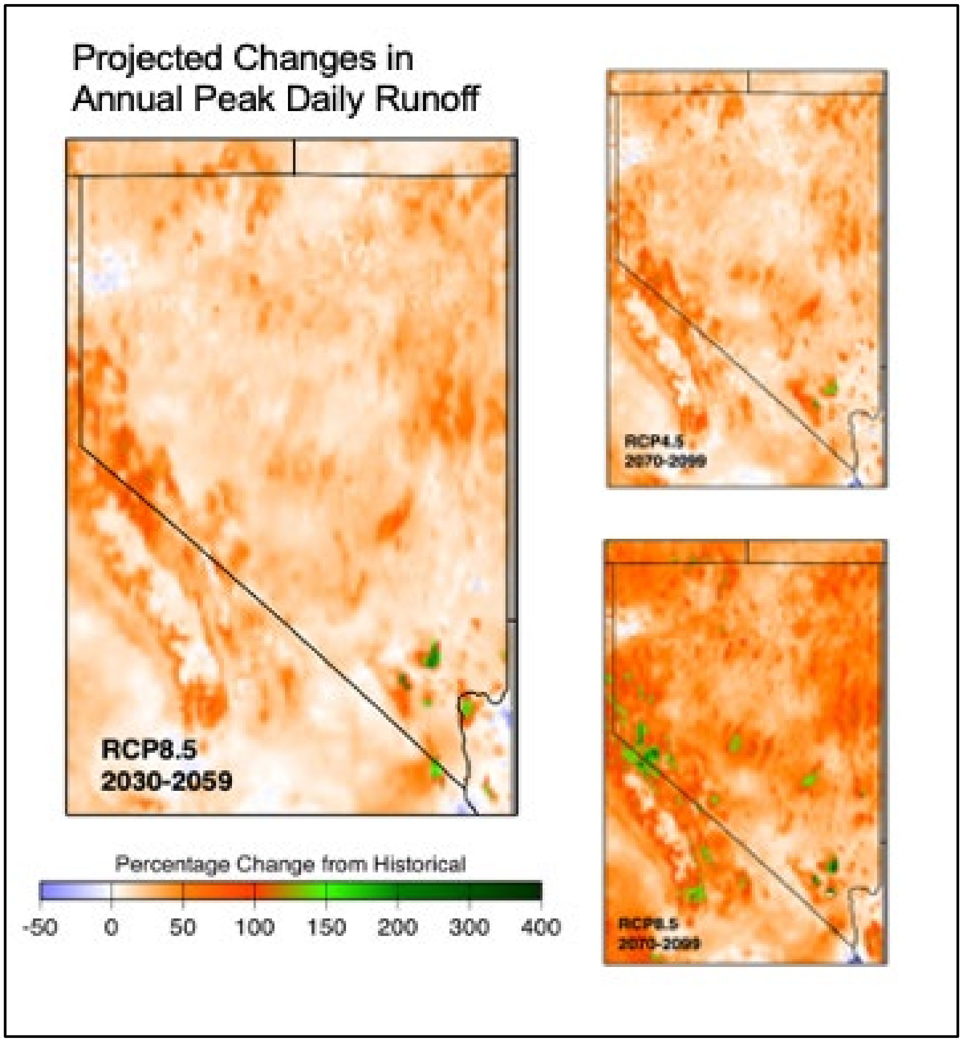

Figure 17. Projected changes in annual peak daily runoff for Nevada. Source: State of Nevada - https://climateaction.nv.gov/policies/climate-nv/#iLightbox[2dc839929ba38c2d002]/0.

Exacerbating the link between precipitation and flash flood risk is the fact that more precipitation is expected to fall as rain instead of snow. This has the effect of shifting the annual sequences and streamflow and aquifer recharge peaks to the winter and early spring. Warmer atmospheric conditions will allow the retention of more water vapor, which will cause precipitation to fall in concentrated bursts rather than gradually over time.[82] Storms will become more intense, leading to higher runoff volumes and likewise more rapid accumulation and flow in populated and

[82] State of Nevada (2021)

developed areas. This is exacerbated by the reduced absorption capacity of the land due to increased temperatures and more extended periods of drought. In Clark County, where monsoons are also tied to flash flood events, increasing thunderstorm intensity is expected to result in more-severe flooding risks.[83]

What Does This Mean for Clark County?

Flood exposure and vulnerability in Clark County are complex factors. The direct physical exposure to flooding, and likewise the impacts that often occur (e.g., inundation of and damage to buildings, infrastructure, and private property, as well as injuries and deaths) are dictated by topography and urban development. These areas are well defined in community flood maps. The secondary effects of flooding, however, which include public health and medical, social, environmental, economic, and other impacts, can extend far beyond these directly exposed areas. Moreover, a robust tourism economy that brings over 40 million visitors to the area in a typical year[84] presents an elevated degree of unpredictability in terms of tourists' poor risk awareness, ever-present fluctuations in population densities and demographics, the risk of detrimental effects that hazard-driven media can have on tourism revenues, and more.

A 2012 flood risk analysis conducted during an update to the Clark County Hazard Mitigation Plan (HMP) found that 15.2% of the county's population and 12.4% of residential buildings were in the SFHA and were thus exposed to the direct impacts of future flood events. Six years later, when the plan was again updated in 2018, the percentage of exposed people and buildings decreased such that only 10.4% of people and 10.7% of residential buildings were considered to be at-risk (within the SFHA).[85] This represented both a relative (percentage of the total) and absolute (actual count of people and structures) decrease in exposure. Several factors contributed to these reductions, including the passage of regulations to limit additional development in flood prone areas, flood control efforts that reduced flood exposure thereby removing the "at-risk" distinction of thousands of existing homes, and reassessment of existing flood zone designations considering advances in flood control to represent risk more accurately.[86,87,88]

Flooding, which is exacerbated by climate change, is expected to result in $3.72 million total losses every year across Clark County's five metropolitan areas (Las Vegas, North Las Vegas, Mesquite, Henderson, and Boulder City).

[83] State of Nevada (2021)
[84] Las Vegas Convention and Tourism Authority (2021)
[85] Clark County (2018)
[86] Fries, B. (2017)
[87] Drummond, C. (2019)
[88] Clark County Regional Flood Control District (2019a)

FEMA's National Risk Index (NRI) has calculated the total value of exposed buildings in Clark County to be $2.276 billion. However, because the type of flooding that occurs in Clark County does not generally impact broad geographic areas, the expected annual losses among these at-risk structures is only $2.164 million.[89] There are 16,755 people who reside in these structures, per census data, but given the past flood experience, and expectation of future floods, only 1 fatality every 3.4 years is expected to occur as a result of flood risk. Flood Factor, a nonprofit organization that uses alternative measures to assess flood risk over time, estimates that the total annualized losses expected across Clark County's five metropolitan areas (Las Vegas, North Las Vegas, Mesquite, Henderson, and Boulder City), is $3.721 million per year, with 41,649 properties facing some level or risk. The difference between these figures is that the Flood Factor methodology looks at properties outside of special flood hazard areas (where traditionally more than 25% of all flood insurance claims originate, and almost one-third of disaster assistance is required), and incorporates predictive factors associated with climate change.[90] The inhabitation of the Las Vegas stormwater tunnel system by upwards of 1,000 of the county's estimated population of approximately 5,300 homeless people[91] represents an acute life safety risk in the event of no-notice flash flood events, and the furniture and other possessions these people introduce into the system threatens to reduce its capacity to divert stormwater off of the city's streets. One person per year is estimated to drown in the tunnels during periods of flooding,[92] though there are known cases where multiple residents drowned in a single event.[93]

A rapid expansion of the County's housing sector, which in 2018 was assessed to have been growing at the second fastest pace nationwide, has the potential to change the County's flood risk profile.[94] Such rapid expansion, if improperly planned and managed, threatens to increase flood exposure and vulnerability. Expansion also presents an increased future risk if climate change effects expand the special flood hazard area or if flash flood severity increases in areas already known to be exposed.

Flooding poses a significant economic risk for Clark County. Although the specific impacts of a given extreme precipitation event will depend largely on when and where precipitation falls, they may yield more dramatic and destructive outcomes for people, the environment, and infrastructure. The volume of tourists that Las Vegas hosts each year, which prior to COVID reached more than 40 million people for 6 years straight, represents the largest source of business income, jobs, and tax revenues for the County. Flooding can impact tourism in several ways. In addition to disruption or destruction of tourist facilities and infrastructure, as has happened in several past floods (e.g., flooding of hotels and casinos), tourists have oftentimes required rescue and other emergency assistance when they try to drive through unfamiliar areas that are experiencing flooding, or when their transportation or lodging becomes inaccessible.

[89] Federal Emergency Management Agency (2021).
[90] Federal Emergency Management Agency (2019)
[91] Clark County (2021c)
[92] Desert Home Treatment Center (2021)
[93] Hernandez, D. (2016)
[94] Clark County Regional Flood Control District (2019)

Floods impact access to tourist and hospitality industry facilities, and press related to flooding can act as a deterrent—thereby reducing the potential to draw an increasing number of tourists in the future.[95]

While not a significant contributor to the region's economy, agriculture is also directly exposed to flood risk, and the NRI estimates that crops and livestock valued at $3.94 million are exposed. Of this amount, approximately $43,500 in losses are expected on an annual basis.[96] Like the reduction in at-risk properties and people observed between the last and current hazard mitigation plans, this low flood risk rating observed in the NRI is the direct result of an expansive, ongoing, and highly coordinated regional flood control program.

The changing nature of flood risk in Clark County poses a significant risk to the County's drinking water quality. Almost all stormwater throughout the Clark County watershed areas drains untreated into the Las Vegas Wash and ultimately into Lake Mead, the region's primary source of drinking water. Although regulated at the county and state levels, this can present a significant risk because stormwater can pick up contaminants or cause a hazmat release. The Clark County Regional Flood Control District (CCRFCD) maintains responsibility for developing and implementing a comprehensive stormwater quality management program for the Las Vegas Valley. The natural systems through which this water flows provides a natural filtering of the water, but there are limits to how much capacity exists, especially during periods of intense rainfall. Each of the municipalities that participate in the CCRFCD is required to implement a variety of monitoring measures and compliance actions designed to protect Las Vegas Wash and Lake Mead from stormwater pollution. These activities include: inspecting industrial and construction sites to make sure that pollutants do not come in contact with stormwater; detecting and mitigating illegal spills and dumping; and performing public outreach.[97]

There has been such a significant amount of work done to mitigate and manage storm-driven flooding in Clark County that the county's distant flood history is somewhat irrelevant to present day risk. Driven by recognition that flood risk was increasing rapidly in concert with rapid population increases, the Nevada State Legislature established the CCRFCD in 1986. The CCRFCD is funded through a .25% state sales tax increase that today generates more than $45 million in annual revenues to support flood prevention activities. Under the CCRFCD's current 10-year Construction Program Plan, there are more than 667 miles of flood control channels and 102 detention basins that hold billions of gallons of stormwater (the Pittman Detention Basin alone has a capacity exceeding 550 million gallons).[98,99] Because of the CCRFCD's ongoing flood control efforts, precipitation events that would have likely generated disruptive, highly destructive, and potentially fatal flash floods are now much less likely to accumulate water to any significant extent.

[95] Clark County Regional Flood Control District (2019)
[96] First Street Foundation (2021)
[97] Clark County Regional Flood Control District (2019a)
[98] Federal Emergency Management Agency (2021).
[99] Clark County Regional Flood Control District (2021d)

Flood likelihood is dictated in part by the ability of waterways, including several interconnected washes, that convey excess water during periods of heavy precipitation. The Las Vegas Wash system, which has been heavily engineered through the efforts of the SNWA, Clark County, and the Las Vegas Valley Watershed Advisory Committee, and its accompanying wetlands, play a vital role in Clark County's water quality and flood prevention profiles. The Wash, as it is called, routes urban runoff, shallow groundwater, reclaimed water, and stormwater away from populated areas towards Lake Mead.[100] Although volume increases substantially during periods of heavy precipitation, it moves approximately 200 million gallons of water on an average day. In addition, the majority of the water in the Wash comes from the county and cities' wastewater treatment facilities, which is highly treated. Maintaining the capacity to flush excess runoff away from developed areas before it accumulates requires that the Wash remain clean and clear.[101] A series of erosion control structures called weirs help to direct flow, including during periods of increased precipitation. Other washes in the area that flow into the Las Vegas Wash and make up the larger system include the Flamingo Wash, Tropicana Wash, Pittman Wash, and Range Wash.

Risk communication is critical to flash flood management in Clark County, given the speed of onset. Efforts to support effective risk communication include pre-disaster flood awareness campaigns using print, television, radio, and digital announcements (including billboard messages). Flood prevention and response are a formal component in the local school curriculum and through media partnerships.[102]

To address the flood risk for structures located in the floodplain, Clark County supports a comprehensive home mitigation, buyout, and relocation program in partnership with Federal agencies that provide financial support and technical assistance. This is performed in conjunction with detailed flood mapping studies, which better define the flood-exposed areas in the County. By improving flood map accuracy, CCRFCD has reclassified thousands of formerly at-risk homes as no longer facing a 1% annual risk of flooding (per FEMA guidelines).[103] By participating in and remaining compliant with the FEMA NFIP, the District has also been able to provide county citizens with up to 25% reduction in flood insurance premiums.[104,105]

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100 Las Vegas Wash Coordination Committee (2021a)
101 Las Vegas Wash Coordination Committee (2021b)
102 Kousky et al. (2020)
103 Clark County Regional Flood Control District (2019)
104 Clark County Regional Flood Control District (2021a)
105 Clark County Regional Flood Control District (2019)

A Quick Look at Extreme Wind Events

Clark County experiences extreme winds somewhat regularly, which can significantly impact infrastructure, businesses, and communities. This is particularly true when coupled with other climate hazards, including drought and wildfire. For example, between 1961 and 1990, Clark County experienced 57 high wind events (dust storm, high wind, strong wind, thunderstorm wind), resulting in at least three deaths (see **Table 3**). Between 1990 and 2020, Clark County experienced more than 500 high wind events, resulting in at least six deaths. Across the U.S., extreme winds are responsible for the most insured losses of any event annually.

Table 3. Number of high wind events (dust storm, high wind, strong wind, thunderstorm wind) and deaths in Clark County. Source: NOAA - https://www.ncdc.noaa.gov/stormevents/.

Year Range	Number of High Wind Events	Number of Deaths
1961-1990	57	At least 3
1991-2020	500	At least 6

Although Clark County has not planned for wind as a separate hazard, the County is considering it in the context of extreme storms, particularly in the Multi-Jurisdictional Hazard Mitigation Plan. Climate models are surprisingly accurate predictors for temperature and precipitation projections,[106] but have a rather limited ability (currently) to project the frequency and intensity of changing wind patterns due to climate change. As the models continue to evolve over the coming years, this will continue to improve. While there are no projections at this time, extreme wind is an important issue that will be considered as a part of the conversations around the vulnerability of countywide systems and assets.

Wildfire

Wildfires are a regular occurrence in many parts of Nevada, with the greatest risk existing in the north and northwest parts of the state where most major historic wildfire events have occurred (**Figure 18**). Clark County is nonetheless exposed to wildfire risk, including large-scale events that have originated in the county and which have originated elsewhere and subsequently crossed county and state boundaries.

Wildfires do occur on an annual basis in the county, but most of these events are small and are contained before they cause considerable damage. Fires typically ignite in areas where vegetation has recently experienced a cycle of high rainfall and then rapid drying that is accompanied by high temperatures. Historically, the number of acres burned rises dramatically in hot and dry periods that immediately follow abnormally high precipitation.[107]

[106] Hausfather et al. (2019)
[107] Stinnesbeck, J. (2020)

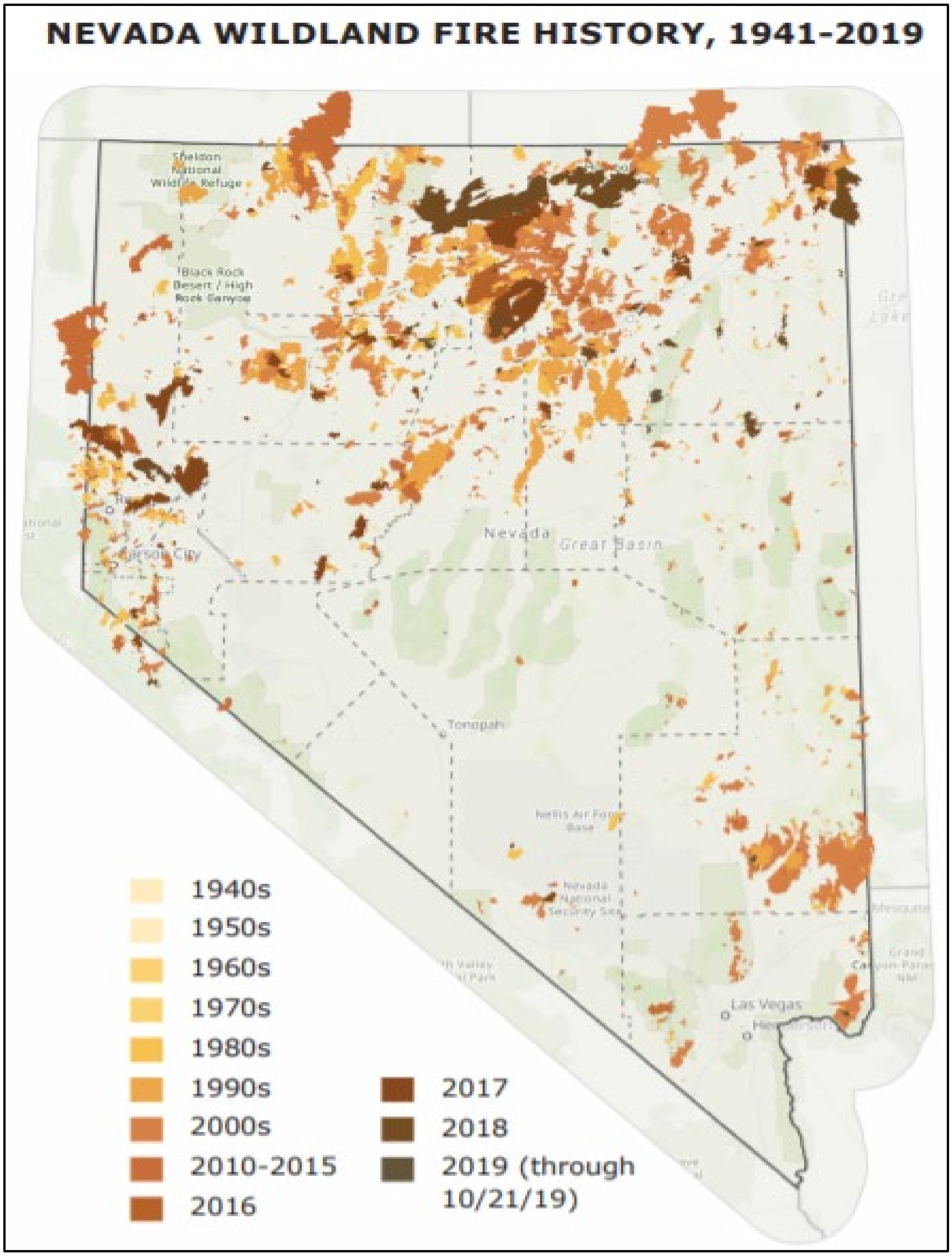

Figure 18. Nevada Wildland Fire History, 1940-2019. Source: https://www.leg.state.nv.us/Division/Research/Documents/Wildfires-in-Nevada-2020-FINAL.pdf

Once ignited, wildfires can spread very quickly in Clark County on account of the hilly topography, availability of brush and other natural fuels, and hot windy weather—considered the three legs of the wildland fire behavior pyramid.[108]

Most of the land in the county is characterized as being directly exposed to wildfire. However, the areas exposed when considered only in the county's populated areas represent a much smaller total percentage (**Figure 19**). Urbanization and development in these areas are generally on more level ground, and a lack of natural fuels provides effective fire breaks. Many structures are also farther from the wildland intermix and wildland urban interface (WUI), where direct wildfire exposure is greatest.[109]

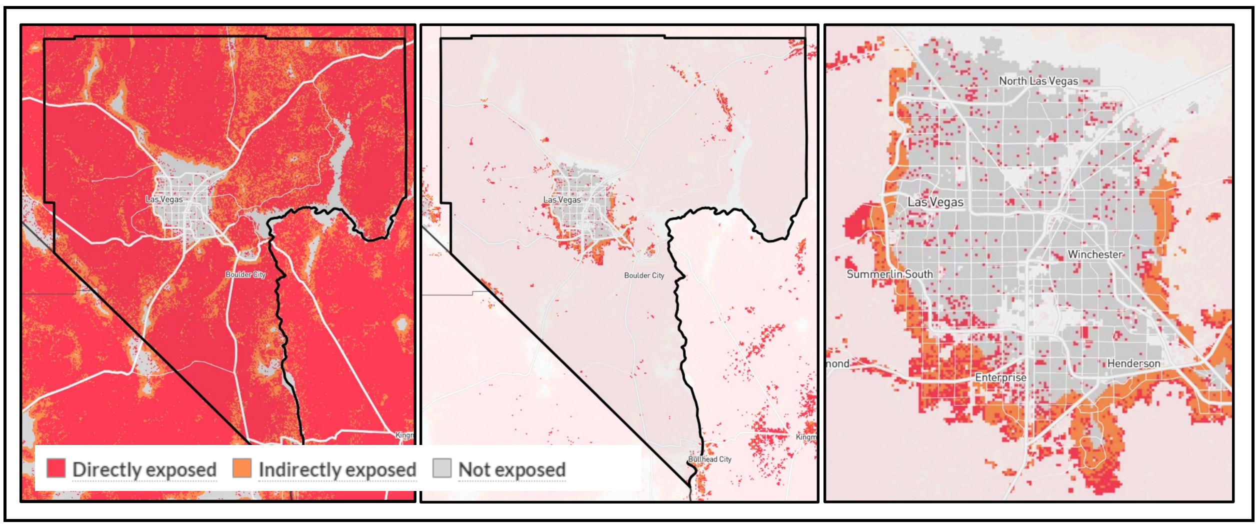

Figure 19. The image on the left details wildfire exposure in all areas of Clark County, the image in the center details wildfire exposure in populated areas only, and the image on the right includes additional wildfire risk detail for the Las Vegas metropolitan area. As percentages of the populated areas in Clark County, 9% are directly exposed to wildfire, 19% are indirectly exposed, and 72% are not exposed at all. Source: USDA, USFS, 2021. https://wildfirerisk.org/explore/0/32/32003/

Although wildfire risk is generally associated with direct impacts to people and property, the indirect effects of wildfires, including smoke inhalation hazards and poor air quality, disruptions to critical infrastructure, environmental degradation, and other problems, can and often do have an impact on life and the economy in Clark County. For example, smoke from regional and intrastate wildfires (e.g., California) can significantly impact the air quality for Clark County residents, particularly for those with pre-existing health conditions.

Wildfire risk is increasing because of climate change and is expected to continue to increase over time due to increasing development that pushes people closer to and into the wildland Fire Interface Zones. Furthermore, factors that help wildfires ignite and spread are exacerbated by changes to wind, temperature, and precipitation as a result of climate change.

[108] National Park Service (2021)
[109] Nevada Fire Safe Council (2005)

Historic Wildfire Events in Clark County

Across the region, small wildfires occur every year, and in many cases the total acreage burned has numbered in the thousands. The Clark County Fire Plan reports that 1,838 wildfires occurred between 1980 and 2003, or about 77 wildfires per year. Although the number of acres that have burned averages to 774 acres per year, the actual annual tallies range from a low of 6 acres in 1991 to a high of 13,698 acres in 1981 during this period. Despite a wide array of wildfires burning from 1984-2017, four of the five years with the most area burned have occurred since 2005.[110]

More recent wildfires (**Figure 20**), as described in the County Multi-Jurisdictional Hazard Mitigation Plan and in the media, illustrates increasing risk, including individual fires that have burned significantly more acres of land than previously recorded. Examples of these include:

- The Goodspring Fire (June/July 2005): This fire reached within 15 miles of Las Vegas, burning 33,569 acres before being contained.
- The Scenic Fire (September 2006): This fire, ignited by a lightning strike, burned 1,600 acres of State Park land less than 4 miles from Las Vegas.
- The Gass Complex Fire (July 2006): This fire, comprised of five fires that merged, burned more than 40,000 acres, and threatened Las Vegas power transmission lines.[111]
- The Carpenter Fire (July 2013): This fire reached within 20 miles of Las Vegas before being contained and burned nearly 28,000 acres. Six buildings were destroyed.
- The Mount Potosi Fire (July 2017): This fire reached within 28 miles of Las Vegas, burning 420 acres before being contained.[112]
- The Cottonwood Fire (July 2020): This fire burned over 2,800 acres of land within 15 miles of Las Vegas, causing changes to flight patterns at McCarran International Airport due to smoke.[113]
- The Dome Fire (August 2020): This fire, which ignited in California, reached within 59 miles of Las Vegas, burning 43,273 acres before being contained.
- The Cottonwood Valley Fire (June 2021): This fire reached within 8 miles of Las Vegas, burning 373 acres before being contained.[114]

[110] State of Nevada (2021)
[111] US Fish and Wildlife Service (2006)
[112] Clark County (2018)
[113] Pahrump Valley Times (2020)
[114] InciWeb (2021)

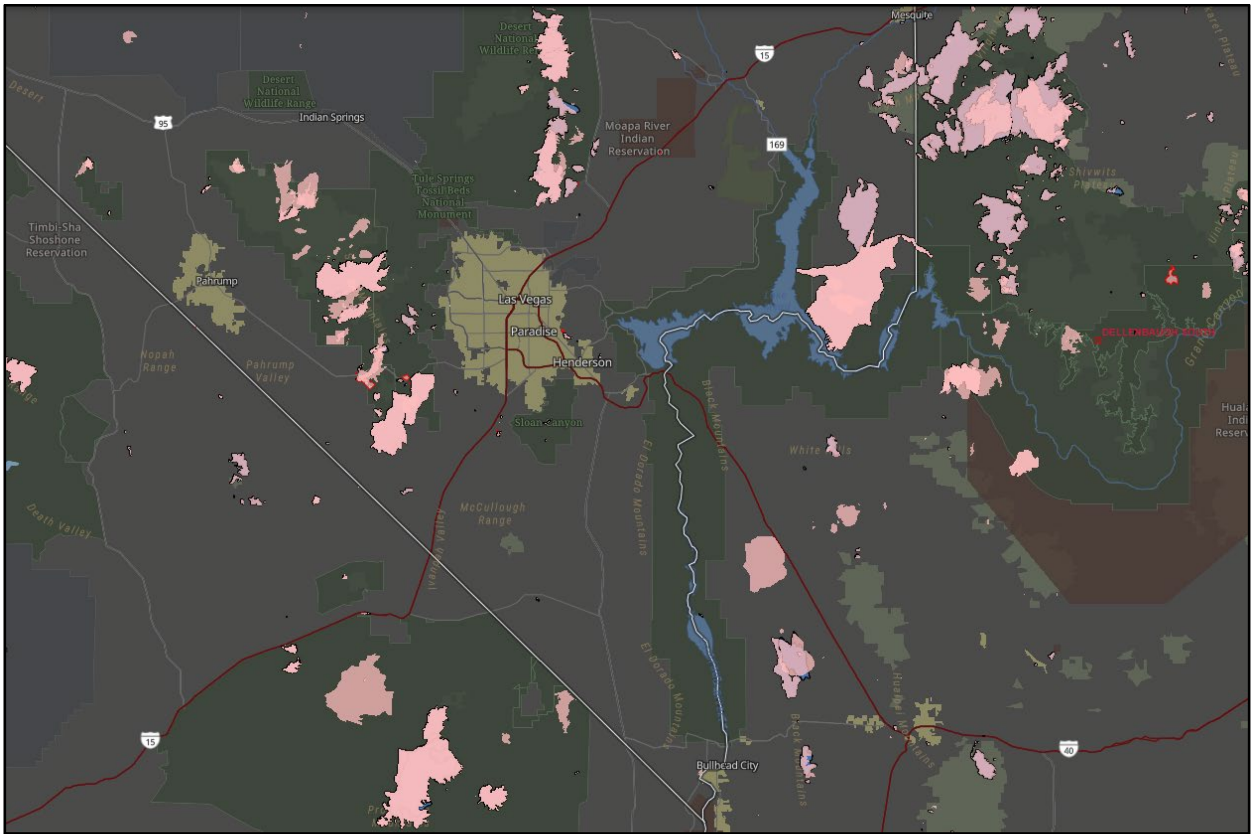

Figure 20. This image shows historic wildfire perimeters (shown in pink) as recent as December 2020. Source: National Interagency Fire Center, retrieved from https://bit.ly/2TVxbuC (Be sure to identify Clark County using the ArcGIS Web Application).

Clark County's Current Exposure to Wildfire

Measured solely in terms of physical exposure, there is a large amount (approximately 17.3%, or 1,396.1 square miles) of county land that has high to very high wildfire risk, and as a result there are dozens if not scores of small wildfire events that occur each year, caused by natural and man-made ignitions.[115,116] The threat posed by wildfires to people and/or property is nonetheless considered to be comparatively low given that most are quickly extinguished and because such a small percentage of people and property are located in these areas of exposure (1,282.2 square miles, or 92% of all at-risk county land, is in unincorporated areas).

Most of the medium to large, incorporated jurisdictions in Clark County are classified as having a "Low Hazard" risk rating for wildfire in the most recent county wildfire plan (2005). In almost all locations, this rating is the result of flat terrain, good access from multiple major roadways, adequate defensible space around almost all at-risk structures, the use of non-combustible construction materials in almost all at-risk structures, sparse wildland fuels, and sufficient fire

[115] Clark County (2018)
[116] Nevada Firesafe Council (2005)

suppression resources.[117] There are seven Clark County communities that have "high" or "extreme" hazard ratings, including: Cold Creek (high); Kyle Canyon (extreme); Lee Canyon (extreme); Mountain Springs (extreme); Nelson (high); Torino Ranch (high); and Trout Canyon (extreme). Five communities have a moderate wildfire risk rating, including: Cactus Springs; Goodsprings; Moapa; Sandy Valley; and Searchlight.[118]

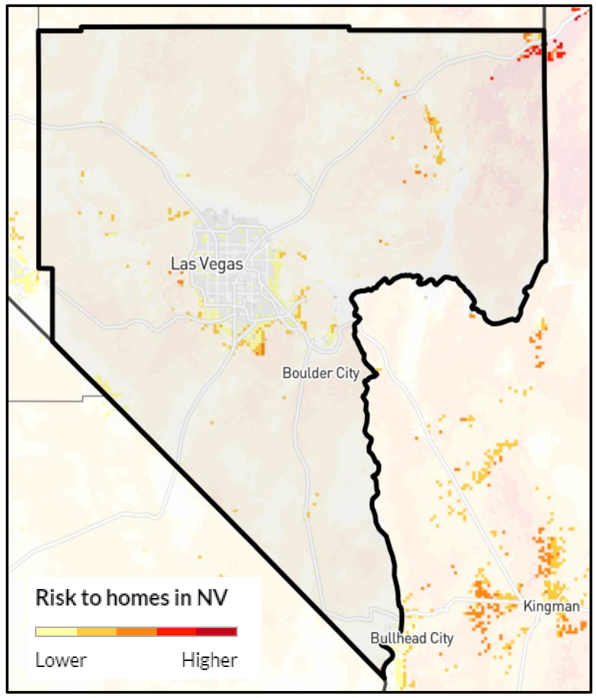

Figure 21. This map illustrates the risk posed to homes in Clark County. This map only details risk in populated areas, which represent a small portion of all county land. Although most of these populated areas do have low or negligible risk to homes, the risk to housing in Clark County is higher than in 44% of all Nevada counties. Source: USDA, USFS, 2021. Retrieved at https://wildfirerisk.org/explore/0/32/32003/

The exposure of housing to wildfires in Clark County is relatively low overall (**Figure 21**). Although the number of residential buildings considered to be high or very high risk from wildfires increased in number from 838 to 921 between assessments conducted in 2012 and 2018, the number of people who inhabit those buildings decreased from 1,960 to 1,396.[119] Of these, 813 buildings (88%) and 1,173 people (84%) are located in unincorporated areas of the County. 18 out of the 1,830 of the County's critical facilities and infrastructure sites are located in areas of high or very-high wildfire hazard potential, and only one of these identified facility/infrastructure sites is located outside of an incorporated jurisdiction.[120]

Future Wildfire Projections

Climate change is exacerbating wildfire risk in Clark County because of several interrelated factors. First, changing precipitation patterns are causing an intensification of the drying of grasses and other fuels. Climate change is also helping invasive plants that are much more susceptible to wildfire ignition and spreading, such as cheatgrass, to take hold and thrive.
Statewide, wildfire risk more than doubled from the 1980-1999 period to the 2000-2019 period (from 4.2 million acres burned to 9.5 million acres burned).[121] Drier conditions are also expected to make wildfires more frequent and intense events.

[117] Nevada Fire Safe Council (2005)
[118] Clark County (2018)
[119] Clark County (2018)
[120] Clark County (2018)
[121] Stinnesbeck, J. (2020)

What Does Changing Wildfire Risk Mean for Clark County?

Clark County, which is the 6th largest county (by square mileage) in Nevada[122] and the 14th largest county in the U.S. (7,891 miles), presents a significant wildfire management challenge, given how susceptible the county's rugged and undeveloped terrain is to wildfire ignition and spread (**Figure 22**).[123] Moreover, 73% of Nevada residents live in Clark County alone.[124]

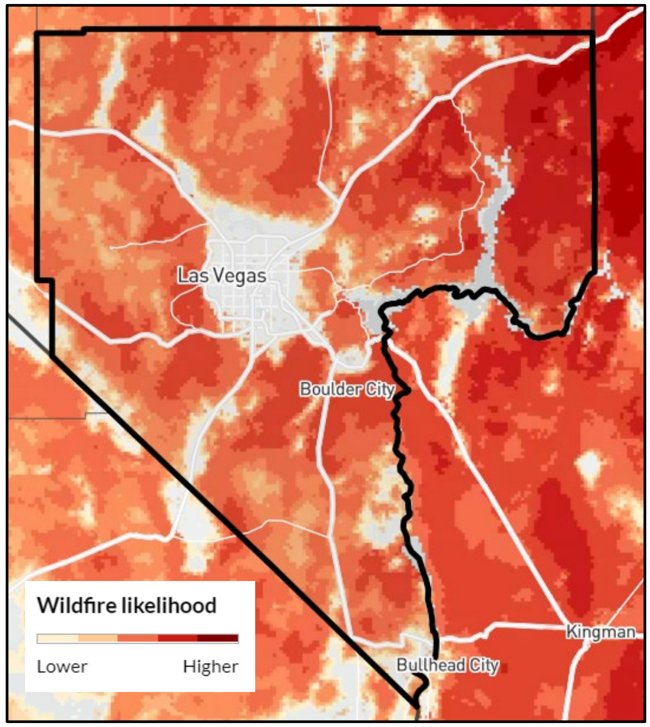

Figure 22. Wildfire likelihood in Clark County. Source: USDA, USFS, 2021. Retrieved from https://wildfirerisk.org/explore/0/32/32003/

However, because the vast majority (86.2%) of land in Clark County is federally owned and managed, and the County's population of 2.3 million people live in the remaining area, the County's responsibility for wildfire preparedness, capacity building, and mitigation activities apply to only a small fraction of wildfire hazard exposed areas.[125]

Federal management of so much land in the county does present a challenge for County wildfire management, however, because wildfires that originate in those lands or in the Tribally-managed and private lands can easily spill over into land that falls under local jurisdiction. This also provides an opportunity to enhance existing collaborations among county, state, federal, and other partners. For inhabited areas considered to be high or very high risk, efforts should be taken to reduce exposure, such as limiting new development or educating landowners about steps to reduce wildfire risk to property (e.g., altering vegetation patterns to reduce fuel loads, changing roofing/building materials).[126] Fortunately, as was previously explained, most of this local land is urban or otherwise not conducive to wildfire ignition and/or spread but wildfire cannot be negated in any part of the county on account of increasing 'firestorm' behavior. The 2018 Multi-Jurisdictional Hazard Mitigation Plan does not address such risk, and in fact the mitigation priorities it contains apply only to the County's unincorporated areas (focusing primarily on public education and wildfire fuel management).[127]

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[122] U.S. Census Bureau (2021)
[123] Clark County (2021a)
[124] Clark County (2021a)
[125] Solano-Patricio et al. (2020)
[126] Clark County (2019)
[127] Clark County (2018)

There are several indirect effects from wildfires that can have a detrimental impact on Clark County communities and the surrounding natural environment. With an increase in wildfires, each of these indirect effects should be expected to have an increased influence on the County's people, environment, and economy. For example, wildfire-scorched land is susceptible to introduction or expansion of invasive species, which can outcompete and displace native species. In addition to causing local species loss, causing erosion, and other environmental impacts, many invasive species can increase wildfire risk by increasing fuel loads. In addition, indirect impacts of regional and intrastate wildfires can present significant health concerns for residents, particularly for those with pre-existing health conditions. Clark County and its Federal wildfire partners have taken action following past major fires to conduct aerial spraying to reduce the spread of invasive species, which could cause adverse health impacts if residents are exposed to the chemicals used. Wildfire smoke inhalation rush is another major indirect hazard associated with wildfires (both within and outside of Clark County).

Although wildfire risk is generally associated with direct impacts to people and property, the indirect effects of wildfires, including smoke inhalation hazards, disruptions to critical infrastructure, environmental degradation, and other problems, can and often do have an impact on life and the economy in Clark County.

The Impact of Regional Wildfires on Clark County Residents
Although wildfires can present a direct risk to Clark County residents, wildfire smoke from wildfires across the state or in other nearby states (like California, Oregon, and/or Utah) also significantly impacts the health and wellbeing of Clark County residents. In addition to causing significant health impacts or death in susceptible individuals,[128] wildfire smoke can have a negative impact on crops, fresh water, and other resources, and can deter tourism to the region.

Conclusion

Clark County is already experiencing the impacts of a changing climate and those hazards are expected to get worse. Precipitation patterns are becoming more variable from year to year, drought conditions are becoming more extreme and lasting longer, and more precipitation is falling as rain instead of snow in the Colorado River Basin. Relative temperatures continue to increase, and extreme heat events are becoming more intense and more frequent. These drivers

[128] Aguilera et al. (2021)

exacerbate the way drought, extreme heat, flooding, and wildfire will continue to impact Clark County residents, natural resources, infrastructure, and the economy. Las Vegas is the fastest warming city in the country, [129] which is particularly poignant for a place that hosts 73% of the state's population and is continuing to experience significant growth and over 45 million tourists annually. These changes are pervasive, impact Clark County in unique and important ways, and will continue to worsen as global greenhouse gas emissions continue to rise.

In addition to reducing GHG emissions at a local and regional level, Clark County will need to continue to invest in climate adaptation and resilience efforts targeted at reducing the impacts of climate change. The *All-In Clark County* initiative builds off of municipal, regional, state, and national climate change planning work and will serve as a foundation for building a more resilient, equitable, and sustainable future for the entire county.

[129] Climate Central (2019)

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