SA CLIMATE READY

Vulnerability & Risk Assessment

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CITY OF SAN ANTONIO
OFFICE OF SUSTAINABILITY

NAVIGANT

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Executive Summary

The climate in Texas is becoming more extreme with rising temperatures and more frequent and heavy precipitation. Climate projections for the region indicate that under all scenarios, by the 2040s, San Antonio will see an increase in warm nights (>80°F), hot days (>100°F) and the introduction of very hot days (>110°F). Precipitation is expected to become more extreme and variable in terms of timing as well as amount. While the annual average rainfall, the number of dry days, and the longest annual dry period are likely to decrease, precipitation will be more concentrated, resulting in rising maximum rainfall amounts in a short period of time. As a result of these latest climate projections, the City of San Antonio commissioned an update to the 2016 vulnerability assessment.

This report focuses on projected changes in temperature and precipitation patterns for San Antonio. Climate change projections for San Antonio do not address the occurrence of hail, high winds, tornados, or ice storms as there is a lack of confidence in climate models projecting the impacts of climate change on these severe weather phenomena. As part of this study, over 20 representatives from across multiple city departments and partner agencies were interviewed (see Appendix) and approximately 100 external sources were consulted to identify vulnerabilities. A risk assessment for priority vulnerabilities was undertaken, resulting in the identification of 12 priority risks.

The 12 priority risks identified for San Antonio include:

1. Increased exposure and risk of injury of vulnerable groups (heatwaves) - High
2. Increased impacts from high ozone concentrations (heatwaves) - High
3. Increased infrastructure damage (wildfires) - High
4. Increased injury and mortality at low water crossings (precipitation) - Medium
5. Increased exposure & risk of injury of vulnerable groups (precipitation) - Medium
6. Increased infrastructure damage to buildings (precipitation) - Medium
7. Increase in vector-borne diseases (heatwaves, drought, precipitation) - Medium
8. Increased need for waste & debris management (drought, precipitation) - Medium
9. Reduction in local food security & production (heatwaves, drought, precipitation) - Medium
10. Reduction in the abundance and health of native species and ecosystems (heatwaves, drought, precipitation) - Medium
11. Increased mobility disruption to local population (precipitation) - Medium
12. Increased need for emergency management resources (precipitation) - Medium

San Antonio recognizes the importance of exploring actions to address these risks given the cost of impacts historically.

1. Increased Temperatures

San Antonio will experience increased temperatures through the next century, resulting in greater exposure, decreased health outcomes, and even an increased likelihood of death for certain individuals. The Fourth National Climate Assessment indicates that the death rate for elderly populations with chronic health conditions could increase by 2.8% to 4.0% per 1.8°F (or 1°C) increase in summer temperature.[1] For San Antonio, where our temperature is expected to increase by 6°F to 10°F by the end of the century, this could mean a 9% to 20% increase in the death rate for elderly populations with chronic health conditions.

[1] "Ch. 23: Southern Great Plains," NCA4.

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In the general population of the Southern Great Plains, defined as Texas, Oklahoma, and Kansas, the projected temperature extremes under a high global GHG emissions scenario are expected to cause 1,300 additional deaths per year and a 6% loss in labor hours in the Southern Great Plains that includes Texas, by 2100.[2]

2. High Ground-Level Ozone Concentrations
Ground-level ozone forms when sunlight reacts with volatile organic compounds (VOCs) and nitrogen oxides (NO_X), which is one of the GHGs tracked and reduced through mitigation. Exposure to ground-level ozone poses significant threats to human health, including premature death, aggravated asthma, and hospital admissions related to respiratory issues. Under a high global GHG emissions scenario it is expected that premature deaths in the Southern Great Plains region will increase by 3.2% on average and cost about $40 million by 2050.[3]

For Bexar County, studies show that ozone levels above the current National Ambient Air Quality Standard (NAAQS), which is the county's current status, result in 19 additional deaths annually, with an associated cost of $170 million.[4] Beyond human health concerns, the current nonattainment ozone level in the San Antonio metropolitan area is estimated to cost anywhere between $3 to $36 billion related to the expansion/relocation of companies, conformity costs, inspection and repair costs, etc.[5]

3. Increased Wildfires
Rising temperature and more sporadic precipitation is expected to increase wildfire risk and the duration of the fire season in the Southern Great Plains region.[6] Texas has already experienced a significant wildfire event recently – the Bastrop Fire of 2011, which caused the destruction of over 1,500 homes, resulted in several human fatalities, killed thousands of cattle, and caused community displacement.[7] Climate models show that these types of wildfire events could become more common in our region.

We don't often think of the wildfire threat as significant to San Antonio, but between 2007 and 2014, the city experienced 83 wildfire events – an average of nine events at the cost of $27,778 per year.[8] Two recent wildfires in 2011 and 2014 resulted in approximately $250,000 (2014 USD) in property damage.[9] Within our metropolitan area, it is estimated that there are 15,649 homes in areas of high wildfire risk and an additional 117,409 homes in areas of medium wildfire risk.[10] In total, this represents an estimated $16.6B of property value in areas of considerable wildfire risk.[11]

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[2] NCA4
[3] NCA4
[4] How Ozone Pollution Affects Public Health in San Antonio: An Analysis Commissioned by the City of San Antonio, 2017
[5] Potential Cost of Nonattainment in the San Antonio Metropolitan Area, 2017
[6] NCA4
[7] NCA4
[8] SA Hazard Mitigation Plan (HMAP), Section 8: Wildfire, 2017
[9] HMAP 2017
[10] City of San Antonio Community Wildfire Protection Plan (CWPP), 2016
[11] CWPP 2016

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Drawing on the knowledge of local experts, including city staff and partner agency experts, as well as best practices in climate adaptation, a range of adaptation actions were developed to address the specific risks the City of San Antonio is facing due to climate change. These adaptation measures are summarized by the following action areas:

1. **Increase Infrastructure Resilience:** Understanding infrastructure vulnerabilities and preparing for climate impacts by future-proofing our buildings, roads, utilities, and other critical assets.
2. **Strengthen Public Health Systems:** Tracking the impacts of climate change on the health and well-being of San Antonians and ensuring our public health systems can respond to increasing health risks.
3. **Enhance Emergency Management and Community Preparedness:** Regularly updating and strengthening our emergency plans, policies, and procedures to respond to climate risks and increase our community's resilience.
4. **Promote, Restore, and Protect Green Infrastructure and Ecosystems:** Protecting our local ecosystems, including sensitive species and habitats, to preserve our City's environmental health.
5. **Protect Local Food Security:** Taking action to protect against future climate-related shocks to our food supply by increasing opportunities for local food production.
6. **Increase Resiliency Awareness and Outreach:** Educating the public about the benefits of adaptation to ensure our community is prepared for future climate impacts.
7. **Ensure Equity in Adaptation:** Prioritizing the needs of our most vulnerable residents and identifying opportunities to address inequities so that all San Antonians benefit from community resilience efforts.

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Glossary of Terms

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptive capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Blue and green infrastructure: Types of Ecosystem based Adaptation measures (EbA): green infrastructure refers to land-based measures; blue infrastructure refers to water-based measures.[12]

Climate projection: A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative-forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.

Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate.

Critical infrastructure: Physical or virtual systems and assets, which their incapacity or destruction would lead to debilitating impact on security, national economic security, national public health or safety or any of these combined. There are 16 critical infrastructure sectors identified by the Department of Homeland Security - chemical, commercial facilities, communications, critical manufacturing, dams, defense industrial base, emergency services, energy, financial services, food and agriculture, government facilities, healthcare and public health, information technology, nuclear reactors, materials and waste, transportation systems, as well as water and wastewater systems.

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual

[12] http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A mega drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Ecosystem-based Adaptation (EbA): A nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change.

Energy poverty: A distinct form of poverty associated with a range of adverse consequences for people's health and well-being – with respiratory and cardiac illnesses, and mental health, exacerbated due to changing weather and stress associated with unaffordable energy bills.

Food desert: Any urban area where (1) the nearest grocery store is over one mile away, and (2) the income of at least 20% of residents is at the federal poverty level.

Food insecurity: The state of being without reliable access to a sufficient quantity of affordable, nutritious food.

Impacts (Consequences, Outcomes): Effects on natural and human systems. In this report, the term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Likelihood: The probability of a projected impact occurring.

Maximum daily temperature: Maximum daily temperature is defined as the change in the number of days with maximum temperature above the 90th percentile of the reference period (1961-1990).

Phenology: The scientific study of periodic biological phenomena, such as flowering, breeding, and migration, in relation to climatic conditions; the timing of a periodic biological phenomenon in relation to climatic conditions.

RCP (Representative Concentration Pathways) Scenarios:[13] Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/land cover. The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative-forcing characteristics. The term pathway emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. RCPs usually refer to the portion of the concentration pathway extending up to 2100. Four RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the Intergovernmental Panel on Climate Change (IPCC) Assessment as a basis for the climate

[13] IPCC http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html

predictions and projections in WGI AR5. These include 8.5, 6.0, 4.5, and 2.6, the SRES equivalents of which are A1F1, B2, B1, and none, respectively.

Risk: Often represented as probability (likelihood) of occurrence of hazardous events or trends multiplied by the impacts (consequence) if these events or trends occur.

Urban heat island (UHI): Occurs when a city experiences much warmer temperature than nearby rural areas due to the amount of heat-absorbing buildings and impervious surfaces.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Vulnerable groups: Groups that are disproportionately burdened by the impacts of climate change or face a greater number of risks associated with climate change and other stressors. This includes people of color, indigenous groups, low-income individuals and households, children, older adults, individuals with limited English proficiency, people with pre-existing or chronic medical conditions, pregnant women, people with disabilities, socially isolated individuals (homeless, homebound), and vulnerable occupational groups (e.g. outdoor workers).[14, 15,16]

[14] Climate Change and Vulnerable Populations, American Public Health Association, 2018 https://www.apha.org/topics-and-issues/climate-change/vulnerable-populations
[15] NCA4, Ch. 14: Health
[16] 2016 Climate and Health Assessment, Ch. 9: Populations of Concern https://health2016.globalchange.gov/populations-concern

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Introduction

San Antonio recognizes the importance of ensuring that the goals and strategies outlined in the city's long-term plans to 2040 within 'SA Tomorrow' also build resilience to the multiple challenges that climate change will bring to the city. The Fourth National Climate Assessment confirms that these changes are "*expected to further disrupt many areas of life, exacerbating existing challenges to prosperity posed by aging and deteriorating infrastructure, stressed ecosystems, and economic inequality. Impacts within and across regions will not be distributed equally.*"[17]

Climate projections for San Antonio were updated in June 2018,[18] and indicate the San Antonio area will become hotter, drier and will experience more intense rainfall events. In light of the updated climate projections, Navigant carried out an update of the city's previous vulnerability assessment (2016). With the support of the City of San Antonio, the team spoke to representatives of over 20 city departments and partner agencies and consulted the wider community through public Technical Working Groups from September to December 2018. The focus of the vulnerability and risk assessment is primarily from a municipal city perspective and the recommendations in the report include the need to consult more widely to understand the full range of community-wide needs, such as those of local businesses. The team researched over 100 different sources and further analyzed medium and high priority vulnerabilities through a risk assessment. The report identifies a range of existing actions, programs, and strategies directly tackling some of these impacts which could be expanded or rolled out further, as well as additional adaptation strategies to be undertaken to manage the priority risks the city is facing due to climate change.

[17] NCA4
[18] Climate Projections for the City of San Antonio. UTSA, June 2018

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Climate and the City of San Antonio

It is clear the climate of Texas and other parts of the U.S. is changing. The climate in Texas is becoming more extreme with rising temperatures and more frequent and heavy precipitation.

To better understand what San Antonio's changing climate will look like in the future, an analysis was performed examining two Representative Concentration Pathway (RCP) scenarios from the IPCC:

- **RCP 4.5 scenario** assuming a gradual decline of global emissions (1.1°C - 2.6°C / 1.98°F–4.68°F warming by 2100); and
- **RCP 8.5 scenario** assuming continuous growth in emissions (2.6°C - 4.8°C / 4.68°F –8.64°F warming by 2100)

The following climate events are assessed under these two scenarios, based on the climate projections for the City of San Antonio.[19]

Temperature projections
By 2040, maximum summer temperatures and average maximum summer daytime temperatures will increase under both scenarios. Additionally, the number of warm nights, hot days, and very hot days will also increase significantly, whereas cold nights will reduce in both scenarios. The results are summarized in Table 1.

Table 1: Temperature projections for the City of San Antonio

Temperature	Base-Line (1971-2000) Observed	Near-Term (2011-2040) Lower pathway	Near-Term (2011-2040) Higher pathway	Long-Term (2071-2100) Lower pathway	Long-Term (2071-2100) Higher pathway
Summer maximum temperature	101.1 °F	105.3 °F	105.5 °F	107.8 °F	111.8 °F
Average summer daytime maximum temperature	94.7 °F	97.3 °F	97.3 °F	99.5 °F	103.1 °F
Cold nights (min. temp. <32 °F)	21.8 days	15.9 days	15.5 days	10.9 days	5.7 days
Warm nights (min. temp. >80°F)	0.03 days	2.1 nights	2.2 nights	10.1 nights	55.6 nights
Hot days (max. temp. >100°F)	7 days	30.7 days	31.0 days	55.1 days	101.4 days
Very hot days (max. temp. >110°F)	0 days	0.06 days	0.12 days	0.64 days	8.22 days

[19] Climate Projections for the City of San Antonio. UTSA, June 2018

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Precipitation projections
Under both scenarios, precipitation is expected to become more extreme and highly variable in both time period and amount. By 2040, annual average rainfall, the number of dry days, and the longest annual dry period are likely to decrease. Precipitation will be more concentrated, resulting in rising maximum rainfall in a short period of time and an increase in severe flooding. The results are summarized below in Table 2 and Table 3.

Table 2: Precipitation projections for the City of San Antonio

Precipitation	Base-Line (1971-2000) Observed	Near-Term (2011-2040) Lower pathway	Near-Term (2011-2040) Higher pathway	Long-Term (2071-2100) Lower pathway	Long-Term (2071-2100) Higher pathway
Annual precipitation	32.5 inch	29.4 inch	29.8 inch	29.7 inch	28.7 inch
Dry days (precip. <0.01" in 24 hours)	243.3 days	228.9 days	228.4 days	233.2 days	241.1 days
Longest dry period	63.4 days	46.6 days	43.7 days	54.1 days	56.6 days
Wet days (precip.>2" in 24 hours)	1.09 days	0.53 days	0.54 days	0.74 days	0.79 days
Wettest 5 days	4.96 inch	4.5 inch	4.5 inch	4.99 inch	5.14 inch

Table 3: Precipitation projections for 24-hr design storms[20]

24-hr rainfall (in.)	1971-2000	2011-2040	
	Baseline	RCP 4.5	RCP 8.5
10-yr storm	6.0	7.6	6.1
100-yr storm	10.3	13.0	10.4
500-yr storm	14.0	17.7	14.2

Severe weather: tornados, high winds, hail, and thunderstorms
The current scientific understanding of the relationship between climate change and the frequency and intensity of hail events, high winds, tornados, and severe thunderstorms is not developed enough to confidently project future trends in these phenomena.[21] While several modeling studies suggest an increase in the number of days with conditions favoring severe thunderstorm development indicating a possible relationship between climate change and severe thunderstorm events, confidence in these model projections is low.[22] Local climate projections for San Antonio do not attempt to model trends in these severe weather phenomena. As such, tornados, high winds, hail, and thunderstorms are not the focus of this vulnerability and risk assessment.

[20] A "10-year storm", or a 1-in-10-year storm, is a storm that has a 10% probability of its rainfall amount being equaled or exceeded in any given year. A "500-year storm" is one that has a 0.2% annual probability of occurrence.
[21] NCA4
[22] NCA4

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Vulnerability Assessment

As part of the vulnerability assessment update, the project team spoke to over 20 representatives (see Appendix B) from ten city departments and ten partner agencies to identify where San Antonio has been exposed to climate hazards in the past through extreme weather events which led to impacts on city services or the wider community.

Sensitivity
Where impacts were identified, the vulnerability was assessed by looking at the sensitivity of the service area on a scale of 1-5:

If the impact occurs, will it affect the functionality of the service area?

1. No - Functionality remains the same (S1)
2. Unlikely – Functionality likely to stay the same (S2)
3. Yes – Functionality likely to get worse (S3)
4. Yes – Functionality will get worse (S4)
5. Yes – Functionality will become unmanageable (S5)

Adaptive capacity
The adaptive capacity of the areas affected was also rated on a scale of 1-5:

Can the service area adjust to the projected impact with minimal cost and disruption?

1. No ability to adapt – Will require substantial costs ($$$$$) and staff intervention (AC1)
2. No – Will require significant costs ($$$$) and staff intervention (AC2)
3. Maybe – Will require some costs ($$$) and staff interventions (AC3)
4. Yes - Will be able to adapt – But will require some slight costs ($$) and staff intervention (AC4)
5. Yes - Can adapt – No/ few costs ($) nor staff intervention are necessary (AC5)

A detailed list of impacts were identified through the course of the study and are included in the Appendix 1.

Impacts assessed as medium vulnerabilities or higher were then further analyzed in the risk assessment. Many of the lower-ranked vulnerabilities are also linked to higher vulnerabilities and are therefore considered as part of the risk assessment. Some impacts were assessed as low vulnerabilities when discussing them with city departments and partner agencies, due to the actions they are taking to mitigate these impacts. However, it is recommended to review some of those impacts on an ongoing basis as new information comes to light and to consult with the wider San Antonio community. In particular, the impacts of climate change on utility services, such as water and energy, are important to keep under review, in light of the increased need for energy and water for cooling given future climate projections.

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Impacts of climate change on energy sector

As set out in the Fourth National Climate Assessment, the energy sector in all regions will be affected by climate change with various degree and type of impacts. Extreme precipitation can cause flash floods that damage energy infrastructure (e.g. power line, transformers, refineries) and fuel transport infrastructure (e.g. railroads, fuel barge ports, and storage facilities). Rising temperatures and higher demand for air conditioning are likely to result in an increase in energy cost up to 18% by 2040, in which Bexar County is likely to face a rise in cost close to this upper limit.[23]

In the Southern Great Plains region, more frequent and intense drought is likely to hamper fuel production, oil refining, and thermal power generation due to the limited supply of water for cooling. For example, nationwide energy output from river-cooled power plants is expected to decline by over 13% due to the lack of cooling water by 2050. Higher temperatures and reduced soil moisture will adversely affect the cultivation of biofuel crops and the availability of wood for electricity and fuel in the Southern states.[24]

With regard to the resilience of San Antonio's electric grid, CPS Energy has historically planned for adequate resources over a 25-year outlook. As part of its extensive planning program, CPS Energy also addresses the security and reliability of its transmission and distribution systems. This part of the program focuses on detailed planning over a 10-year outlook. Additionally, seasonal preparedness plans are also created and executed annually.

CPS Energy ensures that its infrastructure can cope with extreme temperatures and weather conditions. Real-time monitoring of system conditions ensures that energy infrastructure is not operated beyond its functional limits, especially during extended exposure to very high or low temperatures. Finally, as a highly effective and experienced operational and asset-management company, CPS Energy is now strategically using its Flexible Path to assess the most optimal and needed replacement of infrastructure that naturally ages year-after-year. ERCOT's Long-Term System Assessment, which guides transmission planning for the ERCOT system 10 to 15 years into the future, incorporates drought and extreme weather scenarios to develop load forecasts and generation expansion analyzes.[25]

Impacts of climate change on water availability

In the U.S., much of the nation's critical water infrastructure is aging and deteriorating and is subject to an increased risk of failure under future climate extremes. Current design procedures, failure probability estimates, and risk assessments of water infrastructure rely on historical data, and future risks from a changing climate could be underrepresented or underestimated. Compound extremes – such as the combination of two or more hazards or risks cascading

[23] NCA4
[24] NCA4
[25] 2016 Long-Term System Assessment for the ERCOT Region. http://www.ercot.com/content/wcm/lists/89476/2016_Long_Term_System_Assessment_for_the_ERCOT_Region.pdf

through interlinked systems – could cause failure of interconnected systems across regions and sectors (e.g. water-energy infrastructure).[26]

Extreme precipitation could put stress on Texas' water infrastructure, which is aging and often deficient. For example, a total of 82 dams failed in Texas between 1982 and 2012, along with seepage observed in the Lewisville Dam in 2015.[27]

A case study on the Edwards Aquifer highlighted in the Fourth National Climate Assessment states: "The population of Texas is projected to grow by more than 70% between 2020 and 2070, with the majority of the increase projected to occur in urban centers. Increased demand for water will come from municipal, power generation, agriculture, manufacturing, and livestock uses. Over this same period, water availability in the U.S. southwest is projected to decrease due to a shift to a more drought-prone climate state."[28]

The SAWS 2017 Water Management Plan includes projections for increased water demand (Figure 1); for "long-term supply and demand outlook shows no supply gap with further supply development, with desalination and Expanded Carrizo fully built. Scenario below represents a Drought of Record."[29]

[26] 2017 Water Management Plan http://www.saws.org/Your_Water/WaterResources/2017_WMP/docs/20171107_SAWS-2017-Water-Management-Plan.pdf
[27] NCA4
[28] NCA4
[29] 2017 Water Management Plan http://www.saws.org/Your_Water/WaterResources/2017_WMP/docs/20171107_SAWS-2017-Water-Management-Plan.pdf

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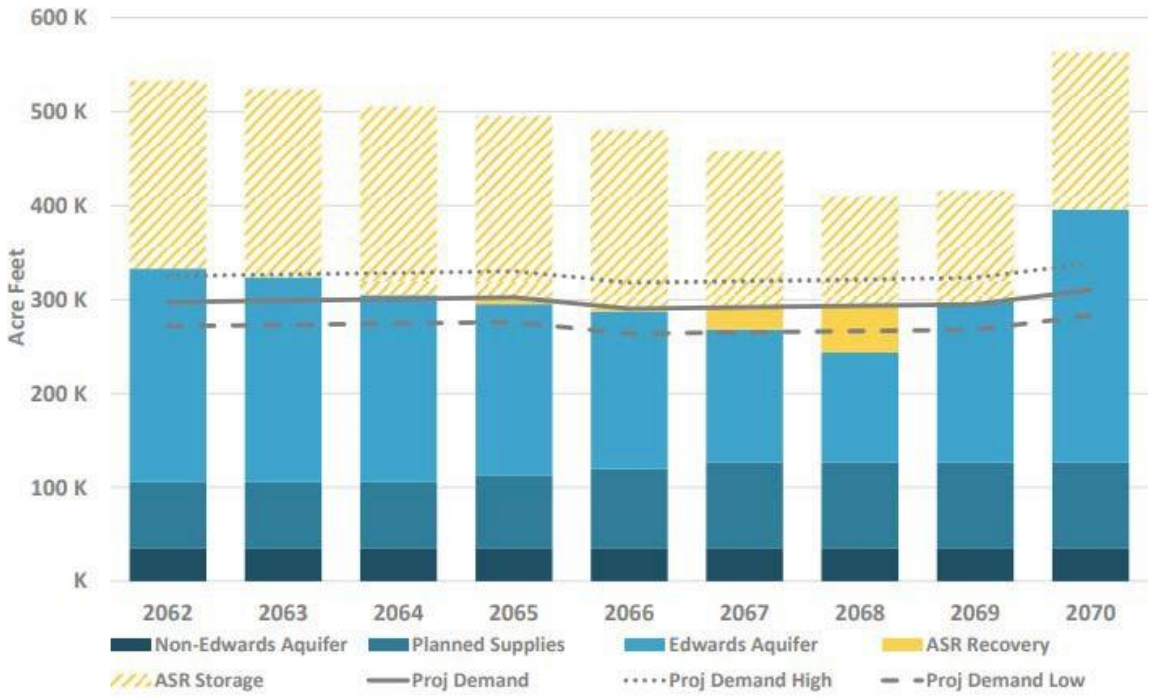
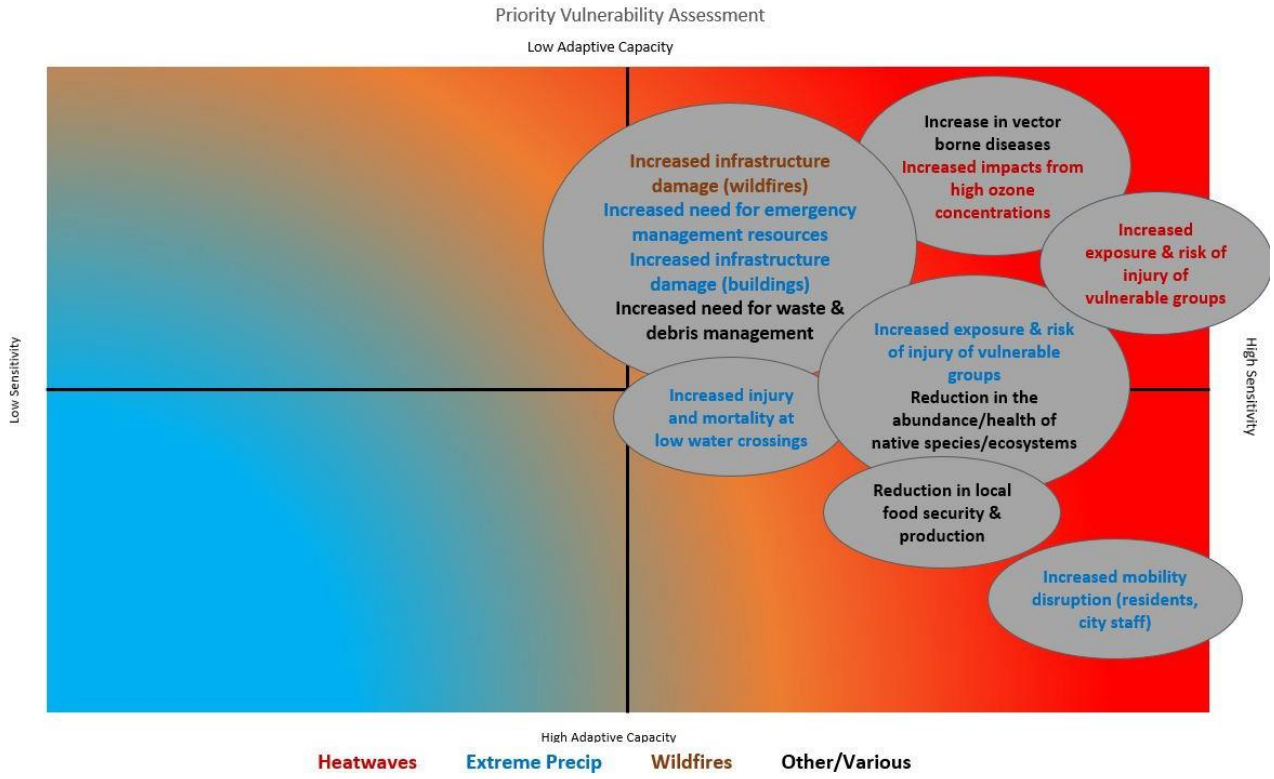
Figure 1: **SAWS Long-Term Supply and Demand**



Vulnerability assessment results

Figure 2 indicates the impacts which were rated as medium vulnerabilities or higher, which were then taken forward into the risk assessment.

Figure 2: Impacts rated as medium vulnerabilities or higher



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Risk Assessment

Risks are assessed based on both the likelihood and consequence of their impacts.

Likelihood refers to whether the impact is reoccurring or is a single event and can be described as:[30]

- *Rare*: unlikely to occur in the next 25 years, or has a close-to-zero probability
- *Unlikely*: could occur once in 10 -25 years, or has a low but greater than zero probability
- *Possible*: could occur once in 10 years, or has a probability < 50%
- *Likely*: could occur once per year, or has a 50/50 chance
- *Almost certain*: could occur several times per year, or has a probability > 50%

Consequence is defined as the magnitude of a particular impact and can be categorized as:

- *Negligible*: appearance of threat but no harm, minor disruption or stress, no damage
- *Minor*: serious near-misses/minor injuries, isolated but noticeable examples of reversible decline/disruption
- *Moderate*: small number injuries, general reduction of economic/services/environmental damage reversible with intense efforts
- *Major*: isolated incidence of serious injuries/loss of life/regional stagnation/severe environmental damage continuing
- *Catastrophic*: large number of injury/loss of life/widespread failure/irrecoverable damage

Priority risks
Both likelihood and consequence are taken into account in order to identify the levels of risk. Risks were categorized into three levels:

- *High*: requires actions and delegation to senior operational management
- *Medium*: requires actions, review and reporting by relevant managers, who are explicitly assigned to handling the risk
- *Low*: remains under review with existing control measures unless it becomes more severe

Table 4 summarizes the identified priority risks.

Table 4: Identified priority risks

Impact	Risk Level
Increased exposure & risk of injury of vulnerable groups (heatwaves)	High
Increased impacts from high ozone concentrations	High
Increased infrastructure damage (wildfires)	High
Increased injury and mortality at low water crossings	Medium
Increased exposure & risk of injury of vulnerable groups (precipitation)	Medium

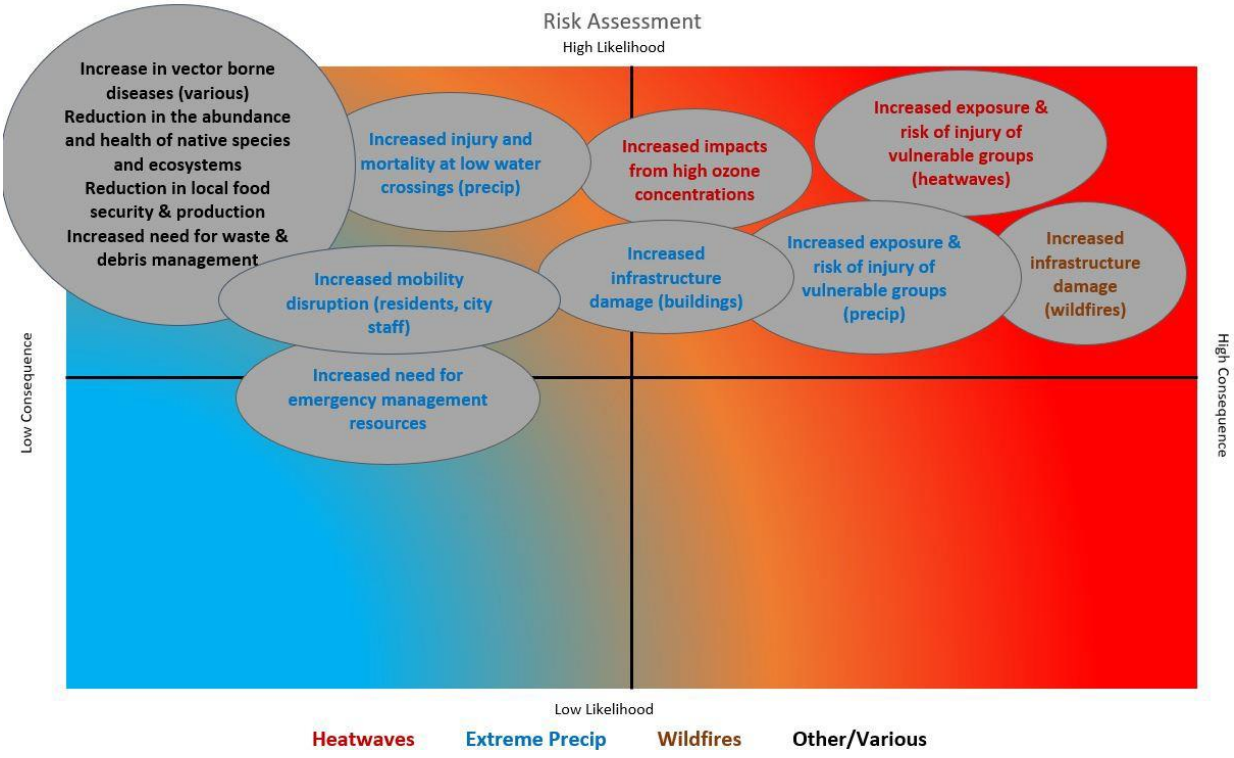
[30] Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation. http://www.icleicanada.org/images/icleicanada/pdfs/GuideWorkbookInfoAnnexes_WebsiteCombo.pdf

Impact	Risk Level
Increased infrastructure damage (precipitation)	Medium
Increase in vector-borne diseases	Medium
Increased need for waste & debris management	Medium
Reduction in local food security (production)	Medium
Reduction in health of native species & ecosystems	Medium
Increased mobility disruption (residents, city staff)	Medium
Increased need for emergency management resources	Medium

Risk assessment plot

Figure 3 indicates the level of risk for each impact.

Figure 3: Risk level for identified impacts



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1. High Risk: Increased exposure of injury of vulnerable groups (Heatwaves)

Vulnerable groups include populations that are disproportionately burdened by the impacts of climate change or face a greater number of risks associated with climate change and other stressors. This includes people of color, indigenous groups, low-income individuals and households, children, older adults, individuals with limited English proficiency, people with pre-existing or chronic medical conditions, pregnant women, people with disabilities, socially isolated individuals (homeless, homebound), and vulnerable occupational groups (e.g. outdoor workers).

As the population of San Antonio is set to grow by 1 million people by 2040, the needs of vulnerable groups will remain a key consideration in shaping municipal priorities and plans. Vulnerable groups are particularly liable to increased exposure to all types of weather (climate hazards) due to a combination of

- Lack of resources: where residents are renting or cannot afford to invest in resilient improvements in their homes
- Increased dependence on public transportation: people waiting outside at stops/pick-up points which lack shelter
- Increased distances to travel: traveling between stops/drop off/pick-up points, to and from shelters and cooling centers

Vulnerable groups are recognized as a priority area of action by San Antonio, and through the support of the Urban Sustainability Directors Network (USDN), the city hosted a Climate Equity Fellow in 2018 to identify engagement gaps, conduct a community scan of target areas, and engage community members. Results of the assessment indicate that districts 1-5 demonstrate higher levels of distress, high percentages of minority populations, lower ranges of life expectancy, and are situated in areas where there is higher risk of flooding, higher urban heat island (UHI) temperatures, and significant tree canopy gaps. Within these districts there was an added focus on ZIP codes 78207, 78204, 78221, 78201 and 78211, which were identified using multiple indicators of vulnerability.[31]

Vulnerable groups are at risk from:

- **Increased exposure to extreme heat:** In Bexar County, 13 people have suffered heat-related deaths and 29 were treated for heat-related illness since 2008. The most recent incident occurred in summer 2017, in which peak heat index values were estimated to be around 101°F and 105°F.[32]

[31] Final Climate Equity (CE) Fellowship Engagement Report, September 2018
[32] NOAA Storm Events Database, 2018. https://www.ncdc.noaa.gov/stormevents/

Suffering from extreme heat continues to remain a key impact which vulnerable populations are exposed to, as identified by the Climate Equity Fellow which assessed the indicators relevant to heat. Several ZIP codes come up repeatedly which experience:

- A high level of distressed communities
- Lower life expectancy
- Reduced tree canopy and
- The highest noted temperatures on the night of August 18th, 2014

Those ZIP codes which are associated with multiple indicators of heat-related vulnerability include 78208, 78207, 78220, 78204, 78201, 78210. However, this list is not exhaustive, and additional ZIP codes were identified across districts 1-5 and vulnerable populations are located across the city.

There is a citywide Heat Plan[33] in place, however outreach conducted by the Climate Equity Fellow indicated that some vulnerable groups are not aware of it or how they can benefit from it. Vulnerable people across San Antonio have cited many heat-related impacts which include a lack of air conditioning, lack of publicly available drinking water across the city, and lack of resources to keep cool.[34]

- **Increase in heat-related morbidity:** Those suffering chronic diseases such as diabetes and heart disease can be at greater risk during periods of extreme heat. The city's indicator to reduce the number of adults reporting diabetes diagnosis by 10% was met in 2015 and maintained in 2016, however the adult obesity rate was reported as flat/getting worse in 2016.[35] Furthermore, cardiovascular disease is the ranked first in the major causes of death in Bexar County and diabetes is ranked 7th in top ten causes of death in the county.[36]

In recognition of the specific needs of vulnerable populations, throughout 2018, staff from the San Antonio Office of Emergency Management (SAOEM) and the City of San Antonio Disability Access Office (DAO) worked on creating an emergency plan specific to people with disabilities and functional needs. The plan will serve as a guiding document for milestones and future projects regarding meeting the needs of people with disabilities during emergencies and will be released to the public for consultation in early 2019. In addition, the San Antonio Human Services Department works with partner agencies to provide homeless shelters in times of extreme heat and there are a number of programs that aim to support vulnerable populations, including the Under 1 Roof Program which replaces worn and damaged roofs with energy-efficient white roofs for senior, veteran, low-income, and disabled homeowners. Benefits include: improved home structure and stability, improved indoor comfort, reduced cooling needs and energy savings (for example, average reductions in Energy Use Intensity (EUI) of 7.3% can be achieved), reduced roof maintenance, and a reduction in UHI effect.[37]

[33] https://www.sanantonio.gov/Health/EmergencyManagement/HeatPlan
[34] EDI Fellowship Engagement Reflections 8/27/18
[35] SA2020 Impact Report 2017
[36] 2016 Bexar County Community Health Needs Assessment
[37] Cool Fixes for Hot Cities Part 1: San Antonio https://www.epa.gov/sites/production/files/2018-08/documents/3-heat-island-webcast-cool-fixes-part-1-2018-08-01.pdf

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Impacts of climate change
The projected impacts of climate change indicate that San Antonio can expect to see an increase in summer maximum temperatures, average summer daytime maximum temperatures, warm nights (min. temp.>80 °F), and hot days (max. temp. >100 °F) under all scenarios and timeframes. In addition, climate projections indicate that San Antonio will experience very hot days (max. temp.>110 °F) by the 2040s: these conditions will continue to significantly stress vulnerable groups as they live, work, and travel across the city, and stretch existing supporting systems such as emergency responders, social services, and partner agencies.

The cost of impact)
Current research has shown that the death rate for elderly populations with chronic health conditions could increase by 2.8% to 4.0% per 1.8°F (or 1°C) increase in summer temperature. Under the RCP8.5 scenario, temperature extremes are projected to cause 1,300 additional deaths per year and 6% losses in annual labor hours in the Southern Great Plains by 2100. These health risks are not specific to only vulnerable groups, but vulnerable groups are likely to be at greater risk, including outdoor agricultural workers, for example.[38]

[38] NCA4

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2. High Risk: Increased impacts from high ozone concentrations (Heatwaves)

As identified in a previous vulnerability assessment for the City of San Antonio, ground-level ozone exacerbates "*asthma, reduces lung function, creates lung inflammation… (and levels) increase when temperatures increase.*"[39] Ground-level ozone also increases due to emissions sources, such as vehicle use,[40] and increased energy production for cooling, such as air conditioning,[41] with consequences for the local economy, education, public health, and emergency services.

A 2015 report investigated the direct link between ozone, fine particulate matter, and chronic lower respiratory disease (CLRD) mortality in the U.S., and found that "*after controlling for selected demographic, socioeconomic, behavioral, and environmental risk factors, and other spatially unstructured and structured contextual influences, ozone is associated with increased CLRD mortality rates across U.S. counties.*"[42] CLRD is already ranked sixth in the top 10 leading causes of mortality in Bexar County in 2016.[43] Since the last vulnerability assessment, Bexar County has been designated as a nonattainment area as Bexar County exceeded the 2015 8-hour ozone NAAQS of 0.070 parts per million (ppm).[44]

The cost of impact
In the Southern Great Plains region, the RCP8.5 scenario is likely to lead to climate conditions more favorable for ground-level ozone formation than RCP4.5. Ozone-related premature deaths are expected to increase by 3.2 on average and cost about $40 million by 2050 under the RCP8.5 scenario. In contrast, the RCP4.5 scenario is projected to avoid 4.2 deaths and save $53 million in the region due to reduced ozone levels by 2050. Ozone-related incidents, hospital visits, and school absence due to acute respiratory symptoms are also projected to decrease significantly under RCP4.5.

In Bexar County, an increase in ozone levels by 1 to 2 parts per billion would lead to 19 additional deaths with $170 million in costs.[45] The current nonattainment ozone level in the San

[39] City of San Antonio Sustainability Plans: Climate Vulnerability Assessment 2016
[40] SA Climate Vulnerability Assessment 2018
[41] Air-quality-related health impacts from climate change and from adaptation of cooling demand for buildings in the eastern United States: An interdisciplinary modeling study. Note: study was limited in that it only modeled a single month, based on 1 model-year of future climate simulations. https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1002599
[42] Ozone, Fine Particulate Matter, and Chronic Lower Respiratory Disease Mortality in the United States https://www.atsjournals.org/doi/full/10.1164/rccm.201410-1852OC
[43] Leading Causes of Mortality, Bexar County, 2016 https://www.sanantonio.gov/Portals/0/Files/health/News/Reports/2016EpiReportLeadingCausesofMortality.pdf?ver=2018-04-03-110852-477
[44] EPA designates Bexar County Air Quality in Nonattainment https://www.sanantonio.gov/gpa/News/ArtMID/24373/ArticleID/13419/EPA-designates-Bexar-County-Air-Quality-in-Nonattainment
[45] How Ozone Pollution Affects Public Health in San Antonio: An Analysis Commissioned by the City of San Antonio, 2017

Antonio metropolitan area is estimated to cost the area $3 to $36 billion from impacts of expansion/relocation of companies, conformity costs, inspection and repair costs, etc.[46]

This risk was classified as "Almost Certain" because San Antonio was recently designated as a nonattainment area and needs to achieve significant reductions in ozone levels within the next year in order to meet the three-year average standard of 70 ppb and avoid more severe regulations. CoSA's ozone attainment plan is being led by the Metropolitan Health District.

[46] Potential Cost of Nonattainment in the San Antonio Metropolitan Area, 2017

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3. High Risk: Increased infrastructure damage (Wildfires)

Impacts of future climate change
Climate change is expected to increase the frequency and intensity of wildfires in the region, with hot and dry conditions conducive to wildfires becoming more common.[47] The Fourth National Climate Assessment projects an increase in wildfire risk throughout the Southern Great Plains as temperatures continue to rise and the duration of the fire season increases.[48]

Coupled with rapid population growth and continued development in the Wildland-Urban Interface (WUI), an increase in the hot and dry conditions favorable to wildfires is expected to cause an increase in the risk of wildfire-related damage to infrastructure and buildings in San Antonio.[49]

The cost of impact
Rising temperatures are very likely to increase wildfire risk and the duration of the fire season in the Southern Great Plains region.[50] A major outbreak has already happened in Texas – the Bastrop Complex Fire in 2011, which caused the destruction of over 1,500 homes, death of thousands of cattle, several human fatalities, and community displacement.[51]

Several wildfires in the Bexar County caused multiple power outages and mandatory evacuations in 2011. Between 2007 and 2014, the City of San Antonio experienced 83 wildfire events.[52] Two recent wildfires in 2011 and 2014 resulted in approximately $250,000 (2014 USD) in property damage.[53]

There are an estimated 15,649 homes in areas of high wildfire risk in the WUI and an additional 117,409 homes in areas of medium wildfire risk in the San Antonio region.[54] This represents an estimated $16.6 billion of property values in areas of significant wildfire risk.

[47] NCA4
[48] NCA4
[49] City of San Antonio Community Wildfire Protection Plan, 2016, Texas A&M Forest Service
[50] NCA4
[51] NCA4
[52] SA HMAP 2017
[53] SA HMAP 2017
[54] SA CWPP 2016

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4. Medium Risk: Increased injury & mortality at low water crossings (Precipitation)

San Antonio is located in the most flash flood-prone region in the country and has become known as "Flash Flood Alley." Since 1996, in Bexar County there have been 310 flood events reported, including 29 deaths and 852 injuries.[55] Furthermore, according to the National Weather Service, "*the City of San Antonio and Bexar County area hold the highest number of fatalities resulting from flash flooding in Texas.*"[56]

San Antonio's flood mitigation efforts have included reducing the number of low water crossings through municipal bond projects,[57] yearly budget projects, as well as partnering with Bexar County, and the positive efforts of private development. However, the floodplain is changing all the time, as new drainage projects are planned and new developments are put in place to accommodate future population growth. Furthermore, NOAA's Atlas 14, Volume 11 – the most recent study of rainfall intensities across Texas – shows rainfall depths for a 100-year storm in Bexar County are 1"-3" greater than identified in previously accepted studies. The Bexar Regional Watershed Management (BRWM) partnership has been working internally and with stakeholders to review and adopt the Atlas 14 data. The San Antonio River Authority is undertaking a multiyear study incorporating the new rainfall data and updating the regulatory floodplain in coordination with FEMA. This may mean that roadways that previously were considered lower risk may show being at risk once again.

Impacts of future climate change
The updates to the regulatory floodplain and the City of San Antonio's Ultimate Development floodplain do not take future climate change projections into account. Based on the findings of the 2018 UTSA climate projections report,[58] future climate projections for precipitation in 24-hr design storms indicate that depths are projected to increase up to 13 inches (100-year event) and 17.7 inches (500-year event) by the 2040s.

While the San Antonio community has become more resilient and fewer people are injured or die during flooding events each year, communicating the dangers to the public in real time will become an increasingly challenging issue as flooding events become more severe. The addition of new populations moving into San Antonio who may be unfamiliar with the dangers of low water crossings (as well as potential new low water crossing sites being identified as the floodplain changes) requires the dangers of low water crossings to be considered on an ongoing basis into the future.

[55] SA Hazard Mitigation Plan (HMAP), Section 7: Flood, 2017
[56] SA HMAP 2017
[57] Examples of current projects at low water crossings include Paso Del Norte Street & Vance Jackson Road; https://www.sanantonio.gov/TCI/Projects
[58] Climate Projections for the City of San Antonio. UTSA, June 2018

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5. Medium Risk: Increased exposure & risk of injury of vulnerable groups (Precipitation)

As described in previous sections, the Climate Equity Fellow identified high priority areas that are affected by factors that exacerbate vulnerability and reduce adaptive capacity to cope with extreme weather. These same ZIP codes also score highly in the case of distressed communities, life expectancy, flood risk, and race. While vulnerable residents live throughout the city, "*Council Districts: 1, 2, 3, 4 and 5 were identified as the most vulnerable areas as they demonstrate higher levels of distress, high percentages of minority populations, lower ranges of life expectancy and are situated in areas where there is higher risk of flooding…within these districts there was an added focus on ZIP codes 78207, 78204, 78221, 78201 and 78211 that were identified in multiple indicators.*"[59]

The floodplain is also set to change as NOAA's Atlas 14 shows rainfall depths for a 100-year storm in Bexar County are 1"-3" greater than identified in previously accepted studies. The BRWM partnership has been working internally and with stakeholders to review and adopt the Atlas 14 data. The River Authority is undertaking a multiyear study incorporating the new rainfall data and updating the regulatory floodplain in coordination with FEMA.

Impacts on vulnerable groups in transit
Vulnerable groups may lack means for private transportation, in which case they are more likely to use public transportation on a regular basis. This requires walking or cycling to and from pick-up and drop-off points, and possibly spending significant amounts of time waiting at bus stops and pick-up points, during which they can become exposed to rainfall events.

Some areas of the city are classified as somewhat walkable/bikeable with higher bike or walk scores,[60] which are also within the identified zones of vulnerability. However, these areas also lack high levels of tree canopy, which provide an important water management function. Furthermore, it is recognized that a "*significant portion of roadways… do not have sidewalks or have gaps between sidewalks…many sidewalks are 4 feet wide and located at the back-of-curb with no separation or buffer between the pedestrian and the traffic lane.*"[61]

Impacts on the homeless
The homeless are particularly vulnerable to the dangers of extreme precipitation as anecdotal evidence suggest that they often sleep and live in drainage ditches. In advance of an extreme precipitation event occurring, the Human Services Department increase their outreach to the homeless to move them out of danger and provide free public transportation.

Impacts of future climate change
Climate projections for San Antonio indicate that there will be high variability in the time-periods with consecutive dry and wet days especially during end-of-century. Projected maximum rainfall

[59] Final CE Fellowship Engagement Report, September 2018
[60] Maps indicating areas of walk and bike scores feature in SA Tomorrow 2016 https://www.sasustainabilityplan.com
[61] SA Tomorrow Multi Modal Transportation Plan, 2016

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depths associated with 24-hour duration storms will increase compared to the past in all scenarios and San Antonio will experience a greater depth of rainfall occurring during these events. These extreme precipitation events will continue to pose a challenge to San Antonio's vulnerable populations in particular, as they lack permanent shelter and spend more time in transit across the city.

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6. Increased infrastructure damage (Precipitation)

Severe rainfall events in the San Antonio area underscore the damaging impacts of flooding on buildings and infrastructure. Since 1998, in Bexar County there have been 267 flood events reported, including 29 deaths and 642 injuries. Financial losses are estimated at $24.7 million in property damage. In recent years, since 2015 alone, Bexar County has experienced 91 flash flood events, seven of which occurred within San Antonio city limits.[62] While this report does not cover damage from high winds as there is a lack of confidence in models projecting the impacts of climate change on wind and tornado patterns for San Antonio, it is important to note that extreme precipitation events often accompany high winds and thunderstorms. In this case the wind can also blow precipitation directly into cracks and crevasses in buildings, increasing damage and raising moisture levels of buildings.

Analyzes conducted by the SAOEM (2014) reveal a total of 11,937 structures in Bexar County are located within the FEMA 100-year floodplain, and 8,406 of those structures are in the City of San Antonio.[63] However, since that analysis, the floodplain is set to change as NOAA's Atlas 14, Volume 11, the most recent study of rainfall intensities across Texas, shows rainfall depths for a 100-year storm in Bexar County are 1"-3" greater than identified in previously accepted studies. The BRWM partnership has been working internally and with stakeholders to review and adopt the Atlas 14 data. The River Authority is undertaking a multiyear study incorporating the new rainfall data and updating the regulatory floodplain in coordination with FEMA.

The top 10 most costly flash floods for Bexar County, including San Antonio, all occurred between 1998-2007; damages incurred were most significant in 1998.[64] However, the reduction in affected properties should be interpreted with caution as the intensity, duration, and location of each flood may vary and therefore the events are not directly comparable. Impacts can be multiple, depending on building type, age, location, and occupancy levels. Older buildings can be at risk of increased incidence of flooding due to undersized drainage. In the case of manufactured homes, even damage considered as 'minor damage' according to the FEMA standards[65] can have major long-term consequences for residents. For example, in May 2013, residents in a mobile home park in southwest San Antonio were forced to evacuate after flooding led to water being contaminated with E. coli and Coliform bacteria. The area was then condemned and residents had to relocate.[66]

[62] NOAA National Centers for Environmental Information: Storm Events Database https://www.ncdc.noaa.gov/stormevents/
[63] SA HMAP 2017
[64] NOAA National Centers for Environmental Information: Storm Events Database https://www.ncdc.noaa.gov/stormevents/
[65] https://www.fema.gov/media-library-data/1459972926996-a31eb90a2741e86699ef34ce2069663a/PDAManualFinal6.pdf
[66] https://www.ksat.com/news/san-antonio-residents-told-to-evacuate-due-to-bacteria-in-water

Ensuring the resiliency of building stock to the impacts of climate change throughout its lifetime will be vital in light of future projections of the growth of buildings stock in San Antonio. Total building stock projections for San Antonio (existing and new/redeveloped) are estimated to be 1,153,899 residential homes and 139,648,147 m^2 of commercial space by 2050.[67]

SA Tomorrow has several priority strategies[68] focusing on reducing the impacts of flooding to buildings; initiatives include San Antonio River Basin Low Impact Development Technical Guidance Manual for both new and older developments which are due to be revitalized or redeveloped, to "*plan and design stormwater best management practices.*"[69] The Build San Antonio Green program[70] implements some measures focused on resilience to managing stormwater and water efficiency; it has certified 15.8 million square feet over 7013 green buildings (7004 of which are single family homes). The Vacant Building Registration Program[71] encourages redevelopment of vacant properties and minimum maintenance requirements. The Transportation & Capital Improvements (TCI) Bond Project 2017-2022 also aims to reduce flooding from approximately 263 properties.[72]

Impacts of future climate change
Climate projections for San Antonio indicate that there will be high variability in the time-periods with consecutive dry and wet days especially during end-of-century. Projected maximum rainfall depths associated with 24-hour duration storms will increase compared to the past in all scenarios, this indicates that San Antonio can expect to experience a greater depth of rainfall occurring during these events.

With regards to strong winds, the current scientific understanding of the relationship between climate change and the frequency and intensity of tornados and severe thunderstorms is not developed enough to confidently project future trends in these phenomena. There is evidence supporting an increase in the number of days with conditions that favor severe thunderstorm development, indicating a possible relationship between climate change and severe thunderstorm events. National figures for damages related to severe thunderstorm events have increased the most since 1980 compared to other disasters;[73] severe thunderstorm activity and high winds can bring heavy precipitation events to the San Antonio region, which is already liable to flash flooding. As a result, an increase in infrastructure damage related to extreme precipitation is considered a priority risk for San Antonio.

[67] Building Projections from the CURB Tool http://www.worldbank.org/en/topic/urbandevelopment/brief/the-curb-tool-climate-action-for-urban-sustainability
[68] Priorities GB 11, 12, 13 listed in SA Tomorrow 2016 https://www.sasustainabilityplan.com
[69] San Antonio River Basin Low Impact Development Technical Guidance Manual, 2015
[70] Build SA Green https://buildsagreen.org/about-us/
[71] Vacant Building Registration Program https://www.sanantonio.gov/Vacant-Building
[72] https://www.sanantonio.gov/TCI/Projects
[73] US 4th National Climate Assessment

The cost of impact

Inland flooding caused by precipitation is likely to increase damages to buildings in the Southern Great Plains region in the future. By 2040, the damage costs of buildings in the region are expected to be approximately $0.5 billion under RCP8.5 and close to $0.8 billion under RCP4.5.[74]

Since 1998, Bexar County has experienced 267 flood events in total, resulting in $24.7 million of property damages. Several thunderstorm events also led to $1.7 million of property damage in the City of San Antonio.[75] There are currently 8,406 structures located in the FEMA 100-year floodplain within San Antonio.[76] While there are several initiatives by the city to reduce impacts on buildings from flooding, the potential risks remain valid with future extreme precipitation.

[74] NCA4
[75] NOAA National Centers for Environmental Information: Storm Events Database https://www.ncdc.noaa.gov/stormevents/
[76] SA HMAP 2017

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7. Medium Risk: Increase in vector-borne diseases (Heatwaves, drought, precipitation)

Changes in climate affect the geographic and seasonal distribution of vector populations, which could lead to the introduction and spread of vector-borne diseases in areas that have historically not experienced significant impacts from certain infectious diseases.[77]

The San Antonio Metropolitan Health District has staff equipped to track, mitigate, and reduce the spread of vector-borne diseases in the San Antonio area. The Epidemiology Division investigates suspected cases of infectious diseases and analyzes disease surveillance data for Bexar County. Additionally, the Vector Control Program utilizes pest control measures on public property to reduce mosquito populations and the threat of disease spread from mosquitos.

Impacts of future climate change
In San Antonio, annual and seasonal average temperatures are expected to increase through the end of the century, altering vector habitats, breeding patterns, and behaviors.[78] Longer periods of warm temperatures will allow certain vectors, like mosquitos, ticks, and fleas, to breed and thrive for a longer period of time, and a decrease in the frequency of cold days will reduce the population control effects of cold environmental temperatures on these same vectors.[79]

Additionally, increasing variability in precipitation patterns coupled with other environmental factors could increase San Antonio's exposure to vector-borne diseases. Extreme rainfall events often lead to flooding in San Antonio, and these floodwaters can also result in the formation of pools of standing water. Standing water is an ideal breeding location for disease vectors, especially mosquitos. An increase in the frequency of extreme rainfall events in San Antonio has the potential to increase the number of favorable breeding habitats for mosquitos, leading to mosquito proliferation and the risk of exposure to mosquito-borne diseases.

During periods of prolonged drought, wild animals in search of other water sources are more likely to come in close contact with humans, increasing the risk of exposure to any diseases or disease-carrying insects they may be hosting.[80] Droughts can also reduce the size of water bodies, causing them to become stagnant. These stagnant water bodies also have the potential to become breeding grounds for disease-carrying mosquitos.[81]

The cost of impact
With rising temperatures, tropical diseases are likely to expand to a wider geographic range and experience a longer reproduction season.[82] Dengue, chikungunya and Zika viruses are already

[77] Climate and Health: Diseases Carried by Vectors. Centers for Disease Control and Prevention. https://www.cdc.gov/climateandhealth/effects/vectors.htm
[78] NCA4
[79] NCA4
[80] Health Implications of Drought: Diseases Transmitted by Insects and Animals. Centers for Disease Control and Prevention, 2012. https://www.cdc.gov/nceh/drought/animals.htm
[81] CDC 2012
[82]NCA4

occurring in Texas.[83] The State of Texas saw 59 cases of dengue virus in 2005 and a severe outbreak of West Nile Virus in 2012, as well as local transmission of chikungunya since 2014 and person-to-person transmission of Zika virus in 2016.[84]

Locally, the City of San Antonio has experienced local transmission of vector-borne diseases – such as West Nile Encephalitis, West Nile fever, and Typhus fever – since 2011.[85] The incidence of Typhus fever increased six fold between 2011 and 2017.[86] The incidence of vector-borne disease is expected to increase locally as higher annual and seasonal average temperatures allow vector populations to thrive for a longer period-of-time.

[83] NCA4
[84] NCA4
[85] SAMHD Epidemiologic Analysis
[86] SAMHD Epidemiologic Analysis

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8. Medium Risk: Increased need for waste & debris management (Drought, precipitation)

Severe weather events, particularly those involving heavy rains after a prolonged period of drought, have the potential to cause waste and debris management issues in San Antonio. Extreme precipitation events are often associated with severe thunderstorms, which can damage trees, homes, buildings, and other infrastructure and result in the accumulation of storm-related debris.

The City of San Antonio is also facing significant problems with illegal dumping; in the past year, there have been 3158 instances of illegal dumping[87] in San Antonio, and the problem of illegal dumping costs the city up to $359,000 every year.[88] While each instance is not tracked according to weather events, there have been examples of waste management issues arising after severe weather, and extreme rainfall events aggravate the problem of illegal dumping. During droughts, dried up waterways or canals turn into dumping hotspots, where waste can accumulate. Directly after a storm, dumped waste can be concealed by rising waters, making it harder to identify illegal dumping sites. The waste can also be washed away by floodwaters, causing further problems downstream.

Impacts of future climate change
While this report does not cover damage from high winds as there is a lack of confidence in model projections for wind and tornado patterns, it is important to note that extreme precipitation events often accompany high winds and thunderstorms. The impacts of climate change do indicate that drought conditions will last longer and be accompanied by extreme precipitation events which can occur throughout the year. Projected maximum rainfall depths associated with 24-hour duration storms will increase compared to the past in all scenarios, and San Antonio can expect to experience a greater depth of rainfall occurring during these events. These extreme conditions can increase the speed that water moves through the city, washing waste and debris with it. Extreme rainfall can also create new bodies of water, such as stock ponds, which could cover waste, making identifying sites and cleaning up debris more challenging.

[87] Number correct at the time of writing from November 2017, https://data.sanantonio.gov/dataset/service-calls/resource/20eb6d22-7eac-425a-85c1-fdb365fd3cd7
[88] https://news4sanantonio.com/news/local/illegal-dumping-thousands-of-complaints-made-to-the-city-over-the-last-3-years

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9. Medium Risk: Reduction in local food security & production (Heatwaves, drought, precipitation)

According to the USDA, 14.3% of Texas households were "food insecure" in 2016 *(struggled to afford a nutritionally adequate diet),* and 15.6% of the population lived below the poverty line.[89] The Supplemental Nutrition Assistance Program (SNAP) offers nutrition assistance to low-income individuals and families and reached 14% of the Texas population in 2017.[90]

The San Antonio Food Bank is an important resource to combat food insecurity and improve public health, especially for low-income groups. According to their 2018 annual report, the food bank harvested 200,000 pounds of produce from their farm and garden, served 1.68 million meals from their community kitchens, and distributed 29 million pounds of food through partner agencies.[91] SA Food Bank's ability to produce food locally has already been severely impacted by extreme heat, drought and precipitation patterns.

Impacts of future climate change
Climate projections for San Antonio include increases in maximum summer temperatures and increases in hot days and very hot days together with a reduction in annual precipitation. These projections risk pushing back planting times for local food production to the extent that the range of crops will become more limited, unless additional investment is made at some sites for irrigation. Furthermore, a dependence on manual harvesting will risk crops going to waste as temperatures become too hot to work outside.

Climate projections also suggest a pattern of more extreme precipitation events: this can make the land more difficult to access for planting and harvesting as well as leading to local explosions of some pests and diseases for particular crops. The ability to improve local food production levels in San Antonio will be threatened without additional measures being put in place to manage these risks. While food can be procured from outside the region, climate impacts will also negatively affect wider national and international supply chains in terms of price spikes and reductions in quality or quantity of food, which will affect the ability for San Antonio to reach its 2020 goal of having residents that are among the healthiest in the country.[92]

The cost of impact
During the multiyear drought in the Southern Great Plains region between 2010 and 2015, a shortage of irrigation water resulted in an over tenfold reduction in the total plantation area for rice in Matagorda County, Texas.[93] The shrinking of agricultural activities led to a 70% decline in

[89] Household Food Security in the United States in 2016, USDA https://www.ers.usda.gov/webdocs/publications/84973/err-237.pdf?v=0
[90] Texas Supplemental Nutrition Assistance Program Fact Sheet https://www.cbpp.org/sites/default/files/atoms/files/snap_factsheet_texas.pdf
[91] SA Food Bank Annual Report https://safoodbank.org/annual-report/
[92] SA 2020 Impact Report 2017
[93] NCA4

sales of farm equipment and supplies.[94] Food security in Texas is also greatly subject to the impacts of climate extremes in Arizona, from where it sources 25% of consumable food and 18% of animal feeds.[95]

Locally, there are areas identified as "food deserts" located in the Southwest, Southeast, West, and East regions of San Antonio.[96] Extreme weather events are likely to further harm food security by damaging crops and the region's ability to produce locally. Bexar County has suffered $320,000 of crop damage from flooding since 1998 – however, this is likely to be a significant underestimate.[97] In San Antonio, the SA Food Bank confirmed that heavy rainfall and warmer temperatures in September-October 2018 led to an outbreak of the American snout caterpillar, which devastated 3-acres of pumpkin and winter squashes over a 36-hour period.

[94] NCA4

[95] NCA4

[96] Food desert: Any urban area where (1) the nearest grocery store is over one mile away, and (2) the income of at least 20% of residents is at the federal poverty level.

[97] SA HMAP 2017

10. Medium Risk: Reduction in the abundance and health of native species and ecosystems (Heatwaves, drought, precipitation)

San Antonio recognizes the importance of protecting and enhancing native habitats and those of migratory and endangered species.[98] One example is the Edwards Aquifer Protection Program in which the City works with landowners to establish conservation easements that preserve sensitive lands that lie over the Edwards Aquifer Recharge and Contributing Zones.[99] Additionally, the City's tree planting policies require the planting of trees native to the region; as a result, the average survival rate of urban tree canopy plantings is about 80%. Currently, the impact of climate change on the population of native trees planted and managed by the city is not considered to be a high priority issue for city departments. However, given the observed impacts of the 2011 Texas drought on trees across the state (one estimate places the number of tree deaths in Texas resulting from the drought at 301 million), the citywide tree canopy is very much susceptible to the damaging effects of prolonged drought.[100]

Current situation
One endangered songbird native to San Antonio, the Golden-cheeked warbler, requires a mixed deciduous woodland habitat and certain deciduous trees that are not able to withstand droughts, such as the Escarpment Black Cherry tree. While the impacts of habitat degradation on the songbird are not yet known, climate change poses a significant threat to migratory bird populations, including the Golden-cheeked warbler, which are already stressed by habitat loss and environmental pollution.[101]

San Antonio is also home to two of the remaining 15 populations of the rare, nearly endangered bracted twistflower plant, and city staff has been monitoring them since 2000. Unpublished evidence[102] suggests that the plant is negatively impacted by higher temperatures and experiencing phenological changes, as it starts to flower earlier in the year.

Impacts of future climate change
Climate projections indicate that average daily maximum temperatures for San Antonio are set to increase, together with a reduction in annual levels of precipitation and increase in occurrence of droughts. Without intervention to protect it further, the bracted twistflower could be critically threatened by climate change. Deciduous trees may decline, further disrupting the habitats of migratory bird populations, including the Golden-cheeked warbler songbird.

[98] NR12, SA Tomorrow Sustainability Plan 2016
[99] City of San Antonio, Edwards Aquifer Protection Program
[100] Tree mortality from an exceptional drought spanning mesic to semiarid ecoregions. Ecological Applications, 26(2), 2016, https://agrilife.org/gmoore/files/2017/04/22-Moore-et-al-2016.pdf
[101] The State of the Birds: 2010 Report on Climate Change
[102] Unpublished observations cited by City of San Antonio

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11. Medium Risk: Increased mobility disruption (Precipitation)

As described in a previous section, Bexar County has experienced 91 flash flooding events since Jan 1, 2015. As identified in the previous vulnerability assessment, "*the VIA Transportation facility. It is located near the source of the San Pedro springs and built over the San Pedro creek. The facility is low lying, sometimes flooded, and central to VIA's ability to maintain its vehicles and offer transportation services to the region*." This is significant as the "*VIA service area is comparable to Houston's and almost twice the size of Dallas*" but VIA has substantially less funding than either. In addition, San Antonio is the largest city in the country without any type of light rail or commuter rail service.[103] As VIA Metro Transit operates out of one location and comprises the main public transportation facilities for San Antonio, significant disruption could occur if the location is damaged during an event. Disruption to the transportation network can exacerbate the problem of people being stranded either in their homes or at other locations across the city.

There may be additional key thoroughfare routes which become at risk of flooding as San Antonio's floodplain maps are being updated as part of NOAA's Atlas 14. The BRWM partnership has been working internally and with stakeholders to review and adopt the Atlas 14 data. The River Authority is undertaking a multiyear study incorporating the new rainfall data and updating the regulatory floodplain in coordination with FEMA.

A lack of mobility from flooding can lead to further cascading impacts such as reduced school attendance, disruption to children's learning, impacts on school budgets, and reduced ability for people to get to work. Furthermore, vulnerable populations can be more dependent on public transportation, therefore any disruption or delays to public transportation as a result of flooding will impact vulnerable groups in particular, as well as other transport users and regular commuters. Extreme precipitation events will increase the depth and speed of flash flooding events; therefore people may be required to stay put more frequently during extreme precipitation events as a safety precaution.

San Antonio's TCI Department oversees street and drainage maintenance and capital projects, which are funded by Bond Programs to reduce the risk of flooding to key sites.[104]

Impacts of future climate change
Climate projections for San Antonio indicate that there will be high variability in the time-periods with consecutive dry and wet days especially during end-of-century. Projected maximum rainfall depths associated with 24-hour duration storms will increase compared to the past in all scenarios; this indicates that San Antonio can expect to experience a greater depth of rainfall occurring during these events. As the San Antonio region is already liable to flash flooding

[103] SA Tomorrow Multi Modal Transportation Plan, 2016
[104] Examples of projects include SA River at Loop 410 is now protected from flooding by the San Antonio Mission Reach drainage project; Olmos Basin/ Creek inside Loop 410: the Barbara Drive project is the outfall needed to drain to Olmos Basin, see https://www.sanantonio.gov/TCI/Projects

historically, together with future climate projections and future population increases, the impact of reduced mobility is considered a priority risk for San Antonio.

The cost of impact

In 2015, severe flooding caused $2.6 billion worth of road damage in Texas and Oklahoma, and the U.S. Department of Transportation allocated $1 million of federal emergency relief funds for repair.[105] Road degradation in Texas leads to $5.7 billion of vehicle operating costs in addition per year, which is likely to be amplified with climate extremes and aging infrastructure.[106]

Extreme precipitation has caused detours and closures in various state and U.S. highways in the Southern Great Plain region.[107] Heavy rainfall could also lead to other disruptions, such as rockslides, which led to a close-down of part of interstate Highway 35 for weeks in 2015.[108]

Locally, seven out of the 91 flash flood events that occurred in Bexar County since 2015 took place in the City of San Antonio.[109] Several roads and transportation facilities, including SA River at Loop 410, Olmos Basin/Creek inside Loop 410, and the VIA transportation facility have been subject to flooding.[110] Without drainage and flood control improvement projects, mobility disruption in the city is likely to get worse with the increased intensity and frequency of flooding.

[105] NCA4
[106] NCA4
[107] NCA4
[108] NCA4
[109] NOAA National Centers for Environmental Information: Storm Events Database
[110] San Antonio Climate Vulnerability Assessment 2016

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12. Medium Risk: Increased need for emergency management resources (Precipitation)

The City of San Antonio's Office of Emergency Management is responsible for coordinating the efforts of city departments and first responders during emergencies, collaborating with regional, state, and federal agencies on emergency management issues, and providing information and resources around preparedness and response to San Antonio residents.

During emergency situations, the Office of Emergency Management may activate the Emergency Operations Center, which brings together city departments and regional partners to coordinate emergency response actions and the dissemination of public alerts and information. Services delivered by the City of San Antonio during and after emergencies could include rescues, road closures, evacuation support, shelter activation, building inspections, damage assessments, and debris cleanup.

While the City of San Antonio has not experienced a catastrophic flood in recent years, an extreme event such as Hurricane Harvey could place on pressure on city staff, resources, and response capabilities. An event of that magnitude would impact flood response and rescue times, involve significantly expanded volunteer coordination activities, and require additional resources and disaster response aid from unaffected communities. Additionally, other spillover effects related to climate hazards, such as a potential influx of coastal hurricane evacuees, could impact city services and the city's ability to respond to major events.

Impacts of future climate change
Climate projections for San Antonio indicate that by the 2040s, annual average rainfall, the number of dry days, and the longest annual dry period are likely to decrease, while precipitation events will become more intense as San Antonio will experience greater depths of rainfall during these events. The maximum rainfall depths associated with 24-hour duration storms will increase compared to the past in all future climate scenarios, leading to increased surface runoff and potential increase in flash flooding events.

With regards to other extreme weather events, the current scientific understanding of the relationship between climate change and the frequency and intensity of tornados and severe thunderstorms is not developed enough to confidently project future trends in these phenomena.[111] However, there is emerging evidence supporting an increase in the number of days with conditions favoring severe thunderstorm development, indicating a possible relationship between climate change and severe thunderstorm events.[112] When compared to other extreme weather events, national figures for damages related to severe thunderstorm events have increased the most since 1980.[113] Severe thunderstorm activity and high winds can bring heavy precipitation events to the San Antonio region, which is already liable to flash flooding. As a result, an increase in flooding could test the City of San Antonio's ability to provide critical services during emergencies and strain city resources.

[111] NCA4
.[112] NCA4
[113] NCA4

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Adaptation Actions and Recommendations

A range of adaptation actions have been developed to manage the priority risks identified in the vulnerability and risk assessment. These actions draw on the knowledge of local experts, including city staff and community members, best practices in climate adaptation, and relevant examples from the international urban adaptation community.
The actions are designed to address the specific risks the City of San Antonio is facing due to climate change, with near-term actions that will help the city mitigate immediate risks and long-term actions to help the city build resilience to future impacts.

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Table 5: Adaptation Actions

#		Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
Increase Infrastructure Resilience	1	**Utility Preparedness for Climate Impacts** Ensure processes are in place to regularly assess the impacts of climate change on water and energy utilities.	1, 3, 5, 6, 11, 12	Various (all)	Yes	**Office of Sustainability**, CPS Energy, SAWS	NT
	2	**Risk Assessment of Critical Infrastructure** Identify and undertake critical infrastructure (transportation, building, IT and telecoms, utilities sectors) risk assessment once updated flood plains are available (Atlas 14 to follow in Spring 2019) and incorporate additional future climate projections related to temperature and precipitation.	1, 3, 4, 5, 6, 11, 12	Various (all)	No	**Office of Sustainability**, Transportation & Capital Improvements, CPS Energy, SAWS, SARA, VIA, Neighborhood & Housing Services, Office of Emergency Management	NT
	3	**Heat Risk Assessment** Undertake risk assessment for managing the impacts of extreme heat on public housing and City-subsidized residential buildings and identify opportunities to implement UHI reduction measures (as outlined in mitigation strategies) with a focus on vulnerable populations.	1, 2	Heatwaves	Yes	**Office of Sustainability**, Office of Emergency Management, SA Metropolitan Health District, Neighborhood & Housing Services, SAHA	NT
	4	**Flood-Proof Roadways** After Atlas 14 floodplain maps are produced, undertake a prioritized assessment of flood resilience options for all low-lying roadways.	4	Extreme Precipitation	No	**Transportation & Capital Improvements**	NT
	5	**Protect Transit Riders** Ensure public transportation routes, stops, and associated infrastructure provide shelter from extreme weather.	1, 5	Extreme Precipitation	No	**VIA,** Transportation & Capital Improvements	NT
	6	**Building Retrofits for Vulnerable Populations** Prioritize retrofit program assistance for vulnerable populations according to risk level and building type once updated floodplains are available (Atlas 14 to follow Spring 2019) and consider future extreme precipitation levels.	5	Extreme Precipitation	Yes	**Neighborhood & Housing Services,** CPS Energy, Department of Human Services, Office of Historic Preservation	NT

#	Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
7	**Climate Risk in Development Review Process** Develop and pilot questionnaire in the building development review process to assess how climate change could impact new development and major renovations and provide support to developers to design their buildings to be resilient to climate impacts (SA Tomorrow, GB12).	1, 3, 5, 6	Various (all)	Yes	**Development Services Department**, Office of Sustainability, Office of Historic Preservation	NT
8	**FEMA Community Rating System** Join FEMA's Community Rating System (CRS) program (SA Tomorrow, GB13).	6	Extreme Precipitation	No	**Transportation & Capital Improvements**, Office of Emergency Management	NT
9	**Healthy by Design** Develop a "Healthy by Design" program for all new affordable housing projects (SA Tomorrow, PH8) to incorporate resilient design principles.	6	Various (all)	Yes	**Neighborhood & Housing Services,** San Antonio Metropolitan Health District, Office of Sustainability	NT
10	**Flood-Proof Critical Infrastructure** Identify and undertake prioritized retrofit programs for critical infrastructure (transportation, building, IT and telecoms, utilities sectors) to ensure resilience to flood impacts over the lifetime of the asset, once updated floodplains are available (Atlas 14 to follow Spring 2019) and also incorporating future climate projections.	4, 5, 6, 11, 12	Extreme Precipitation	Yes	**Office of Sustainability**, Transportation & Capital Improvements, CPS Energy, SAWS, SARA, VIA, Neighborhood & Housing Services	LT
11	**Resilience in Building Codes and Programs** Assess opportunities to integrate resilience measures (e.g. water and temperature regulation, resilient landscaping measures within Low Impact Development, Build SA Green, Under 1 Roof programs) into building codes, existing building programs and checklists to reduce impacts from projected climate change over the lifetime of developments.	1, 3, 5, 6	Various (all)	Yes	**Development Services Department**, Transportation & Capital Improvements, Office of Sustainability, Office of Historic Preservation	LT
12	**Produce a Climate Heritage Strategic Plan** Develop guidelines for determining the appropriate treatments of cultural sites and objects around climate change adaptation including: building an inventory of resources, developing methods for building adaptive capacity, providing input on climate policies affecting tangible and intangible heritage resources, and joining the Climate Heritage Network.	3, 6	Various (all)	No	**Office of Historic Preservation**, Office of Sustainability, Transportation and Capital Improvements	NT

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#		Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
Strengthen Public Health Systems	13	**Monitor and Track Public Health** Track admissions and health cases related to weather events within the newly created SA Metro Health Informatics Unit.	1, 2, 3, 4, 5, 6, 7, 11, 12	Various (all)	No	**SA Metropolitan Health District**, Office of Emergency Management	NT
	14	**Incorporate Climate Change into Heat Response Plan** Assess and revise Heat Response Plan to account for future climate projections.	1, 2	Heatwaves	No	**SA Metropolitan Health District**, Office of Emergency Management	NT
	15	**Public Drinking Fountains** Assess need to install additional public water fountains in areas of high vulnerability as identified by the CDC Social Vulnerability Index.	1	Heatwaves	No	**Parks & Recreation CCDO**, Transportation & Capital Improvements, SAWS	NT
	16	**Mobile Health Clinics** Enhance mobile health clinics to underserved areas of the community (SA Tomorrow, PH1).	7	Various (all)	No	**SA Metropolitan Health District**	NT
	17	**Integrate Climate Resilience into Public Health Practices** Actively participate in regional, national, and international public health peer groups and research networks (e.g. NACCHO Global Climate Change Workgroup) to continue identifying opportunities to integrate climate change considerations and best practices into local public health systems.	1, 2, 3, 4, 5, 6, 7, 11, 12	Various (all)	No	**SA Metropolitan Health District**	NT
Enhance Emergency Management and Community Preparedness	18	**Early Warning Systems** Assess and improve Early Warning System (EWS) communications to vulnerable groups around impacted routes and transportation modes.	4, 11	Extreme Precipitation	No	**Office of Emergency Management**, Transportation & Capital Improvements, Government & Public Affairs, Office of Equity, VIA	NT
	19	**Flood Awareness on Roadways** Evaluate the effectiveness of increased barriers and signage (electronic and physical) ahead of affected routes and transportation modes with deviation instructions.	4, 11	Extreme Precipitation	No	**Transportation & Capital Improvements**	NT
	20	**Community Wildfire Protection Plan** Conduct a resource gap assessment and identify and pursue new partnership opportunities and funding sources to implement the priority recommendations included in the San Antonio Community Wildfire Protection Plan.	3	Wildfires	No	**San Antonio Fire Department**	NT

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#	Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
21	**Damage Cost Assessment Protocols** Set up processes to systematically assess and document costs of extreme events across departments & partner agencies.	3, 6, 12	Various (all)	No	**Office of Emergency Management**, Office of Management & Budget	NT
22	**Assess Emergency Shelter Policies** Evaluate shelter policies & resources in light of future climate impacts to include provision of indoor shelter during periods of elevated nighttime temperatures (>80°F); expand cooling center open times (weekends, warm nights) and consider additional locations and extreme precipitation. Assess opportunities to integrate backup renewable and battery technology.	1, 5	Heatwaves; Extreme Precipitation	No	**Office of Emergency Management**, SA Metropolitan Health District, Department of Human Services	NT
23	**Emergency Planning for Vulnerable Groups** Review Emergency Planning procedures to ensure appropriate responses for vulnerable populations.	1, 5	Heatwaves; Extreme Precipitation	No	**Office of Emergency Management**, SA Metropolitan Health District, Department of Human Services	NT
24	**Emergency Planning for Climate-Related Evacuees and Displaced Populations** Periodically review the City's ability to provide for the needs of coastal hurricane evacuees and other populations displaced by extreme weather and climate events.	12	Extreme Precipitation	No	**Office of Emergency Management**	NT
25	**Complete Regular Updates to Vulnerability and Risk Assessment** Regularly update the Vulnerability and Risk Assessment, especially when new data or evidence of climate impacts to San Antonio become available or if climate impacts become more severe.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Various (all)	No	**Office of Sustainability**	NT
26	**Increase Capacity on Alternate Transportation Routes** Utilize emerging technologies to improve flow and Increase transportation capacity on alternative routes (and modes, where relevant) to absorb uptake during flood events.	11	Extreme Precipitation	No	**Transportation & Capital Improvements**	LT
27	**Wildfire Mitigation** Establish and maintain fire breaks, forest tracks, water supply points, and other blue infrastructure networks.	3	Wildfires	Yes	**San Antonio Fire Department**, Parks & Recreation	LT

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#		Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
	28	**Wildfire Simulation and Surveillance Tools** Consider using fire simulator tools and review surveillance mechanisms (watch towers, cameras).	3	Wildfires	Yes	**San Antonio Fire Department**	LT
	29	**Address Neighborhood Ingress/Egress Routes** Increased road network to access fire and flood-prone sites.	3	Wildfires; Extreme Precipitation	No	**Transportation & Capital Improvement,** San Antonio Fire Department	LT
	30	**Waste and Debris Surveillance and Response** Review waste surveillance and mitigation protocols in light of more frequent extreme weather events (frequency of surveillance, waste collection, problem site identification with partner agencies).	8	Various (Drought, Extreme Precipitation)	No	**Solid Waste Management Department**, Code Enforcement, SARA	LT
Promote, Restore, and Protect Green Infrastructure and Ecosystems	31	**Create an Integrated Green and Blue Infrastructure Plan** Assess opportunities for creating connected networks to manage water and regulate temperature through ecosystem-based adaptation measures. This could include connecting existing park & open space networks and adjacent areas to provide cooling corridors, stormwater management benefits.	1, 3, 4, 5, 6, 10	Various (Extreme Precipitation, Heatwaves)	Yes	**Transportation & Capital Improvements**, Parks & Recreation, SARA	LT
	32	**Tree Canopy Programs** Incentivize, expand, and fund tree planting/replacement programs to promote more drought and wildfire resistant native species, prioritizing the most effective locations for the plantings.	1	Various (all)	Yes	**Parks & Recreation,** Development Services Department	LT
	33	**Accelerate Protection of Sensitive Species** Assess options for active conservation (nurseries, seed banks), habitat restoration and regeneration or relocation of near-endangered species.	10	Various (all)	Yes	**Parks & Recreation,** SARA, Alamo Area Monarch Collaborative, Texas Parks & Wildlife	LT
Protect Local Food Security	34	**Local Crop Diversification** Work with agriculture experts to identify and test more drought and pest resistant crop options for local food production in San Antonio and support wildlife that provides ecosystem services that enhance agriculture production.	9	Various (Drought, Heatwaves, Extreme Precipitation)	Yes	**Food Policy Council of San Antonio,** Office of Sustainability, San Antonio Food Bank, the Nature Conservancy of Texas, Bat Conservation International	LT
	35	**State of the Food System** Fund and hire a Food Policy Coordinator to develop a State of the Food System Report to understand	9	Various (all)		**Office of Sustainability**	LT

#		Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
		extent food supply chain is resilient (SA Tomorrow, FS5, F6).					
	36	**Pursue Urban Agriculture Opportunities** Assess pilot urban agriculture projects, such as Mission San Juan Capistrano, for potential duplication on other properties and incentivize and provide resources to facilitate urban agricultural uses on vacant or underutilized land, including City-owned and other public land (SA Tomorrow, FS8).	9	Various (all)	Yes	**Food Policy Council of San Antonio,** Office of Sustainability, Parks & Recreation; San Antonio Food Bank, partner agencies	LT
	37	**Urban Agriculture Training Program** Develop an urban agriculture training program to train new urban farmers in climate resilient agriculture and business practices (including low-carbon food production and processing) (SA Tomorrow, FS9).	9	Various (all)	Yes	**Food Policy Council of San Antonio**, San Antonio Food Bank	LT
	38	**Controlled-Environment Agriculture** Consider opportunities for controlled-environment agriculture (hydroponics, aquaculture, etc.) to increase local production of food that is less energy and water intensive and protected from climate extremes.	9	Various (all)	Yes	**Food Policy Council of San Antonio,** Office of Sustainability, San Antonio Food Bank	LT
	39	**Incentivize Local Food Production** Increase local food production through various incentive programs, e.g. through provision of rebates for the purchasing of equipment to enable precision farming /machine harvesting resilient to extreme weather conditions, rebates for residential chicken keeping, etc.	9	Various (all)	Yes	**Food Policy Council of San Antonio**, Office of Sustainability	LT
	40	**Support and Enhance Community Garden Network** Provide resources to ensure the viability of neighborhood-based gardens that contribute to local food production and beneficial pollinator habitat.	9, 10	Various (all)	No	**Food Policy Council of San Antonio,** Office of Sustainability, Green Spaces Alliance of South Texas, Parks & Recreation, SAWS	LT
Increase Resiliency Awareness and Outreach	41	**Business Resiliency Assessment** Engage with the local business community to determine how to best undertake a vulnerability assessment (in a confidential, anonymous manner) to consider wide-ranging impacts of a changing climate to business continuity, economic growth, and unintended consequences.	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Various (all)	No	**Office of Sustainability**, Economic Development Department	NT

#		Strategies, Summary for Plan Document	Risk	Climate Hazard	Mitigation Benefit	Lead/Partner Agency	Phase
	42	**Climate Resilience Education and Outreach** Initiate a climate education campaign for businesses and property owners, including details about how to make built and natural infrastructure more resilient to existing and projected changes in climate (SA Tomorrow, GB11) for residents and businesses. Highlight successful projects through resiliency tours.	1, 3, 4, 5, 6, 10	Various (all)	No	**Office of Sustainability**, Office of Emergency Management, Economic Development Department, Development Services Department, Office of Historic Preservation, Transportation and Capital Improvement	LT
Ensure Equity in Adaptation	43	**Equity Assessment of Sustainability Programs** Work with the Office of Equity to ensure existing and future sustainability programs and initiatives prioritize vulnerable populations and equitable outcomes.	1, 5	Various (all)	No	**Office of Equity,** Office of Sustainability	NT
	44	**Prioritization of Vulnerable Residents** Work with partners to identify vulnerable individuals and groups, e.g. homebound individuals, disabled, elderly, etc. to prioritize adaptation actions.	1, 5	Various (all)	Yes	**Office of Emergency Management,** SA Metropolitan Health District, Department of Human Services, Office of Equity, SAHA	NT
	45	**Anti-Displacement Measures** Develop measures to prevent displacement to ensure vulnerable groups, small businesses, and existing residents can stay in their homes/districts and benefit from resilience measures.	1, 5	Various (all)	(Yes)	**Neighborhood & Housing Services**, Office of Equity, Office of Historic Preservation, Department Human Services	LT

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Appendix A: Full List of Vulnerabilities for the City of San Antonio

Vulnerability	Climate Hazard
Increase in vector-borne diseases	Various
Increased impacts from high ozone concentrations	Heatwaves
Increased exposure & risk of injury of vulnerable groups	Heatwaves
Increased need for waste & debris management	Various
Reduced access to parks & open spaces	Various
Increased exposure & risk of injury of vulnerable groups	Precipitation
Reduction in local food security production	Various
Increased injury and mortality at low water crossings	Precipitation
Increased mobility disruption (residents, city staff)	Precipitation
Increased need for emergency management resources	Precipitation
Increased infrastructure damage	Wildfires
Increased opening/operating hours for cooling centers	Heatwaves
Increased use of cooling centers	Heatwaves
Increased use of energy/water for cooling	Heatwaves
Increased need for cooling equipment	Heatwaves
Staff schedules move to avoid heat	Heatwaves
Increase outreach to homeless	Heatwaves
Equipment melting in heat	Heatwaves
Increased shading for public parks	Heatwaves
Reduction in the abundance and health of native species and ecosystems	Various
Infrastructure damage on clay soil (transportation)	Various
Increase in water main breaks due to clay soil shifting	Drought
Increased waste that comes from upstream sources during floods	Various

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Vulnerability	Climate Hazard
Sanitary sewer overflows	Precipitation
Creek erosion becomes aggravated, sewer lines relocated	Precipitation
Additional staff (transportation)	Precipitation
Creekways closed due to erosion	Precipitation
Brushfires burn into waste dumps	Wildfires
Increased operating hours (transportation)	Heatwaves
HVAC adjustments, mold remediation costs	Precipitation
Land-side flooding of roads to airport	Precipitation
Outdoor workers to take precautions in heat	Heatwaves
Increased water resource for cooling (energy production)	Heatwaves
More frequent implementation of efforts to moderate discretionary water use	Heatwaves

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Appendix B: List of Interviewees

Name	Department
Douglas Melnick	Sustainability
Nefi Garza	TCI Stormwater
Art Reinhardt	TCI Transportation, Road & Rail
James Mendoza	Office of Emergency Management
Colleen Bridger	Metro Health
Edward Gonzales	Department of Human Services
Carla De La Chapa	CPS Energy
Jeff Arndt	VIA
Steve Graham	SARA
Karen Guz	SAWS
Andy Winter	Bexar County - Public Works
Brad Davenport	Pre-K 4 SA
Lisa Lin	Sustainability
Julia Murphy	Sustainability
Lindsay Ratcliffe	CAAP Team Member
Iris Gonzalez	Climate Equity Fellow
Tom Bartlett	Aviation
Darron Gaus	SA Food Bank
Wendy Leonard	Parks and Recreation
Homer Garcia	Parks and Recreation
Grant Ellis	Parks and Recreation
Jenny Hay	Office of Historic Preservation
Stephanie Phillips	Office of Historic Preservation
Anita Ledbetter	Build SA Green
Lina Luque	Build SA Green
Brian Stanush	Fire Department
Mitchell Hagney	SA Food Policy Council