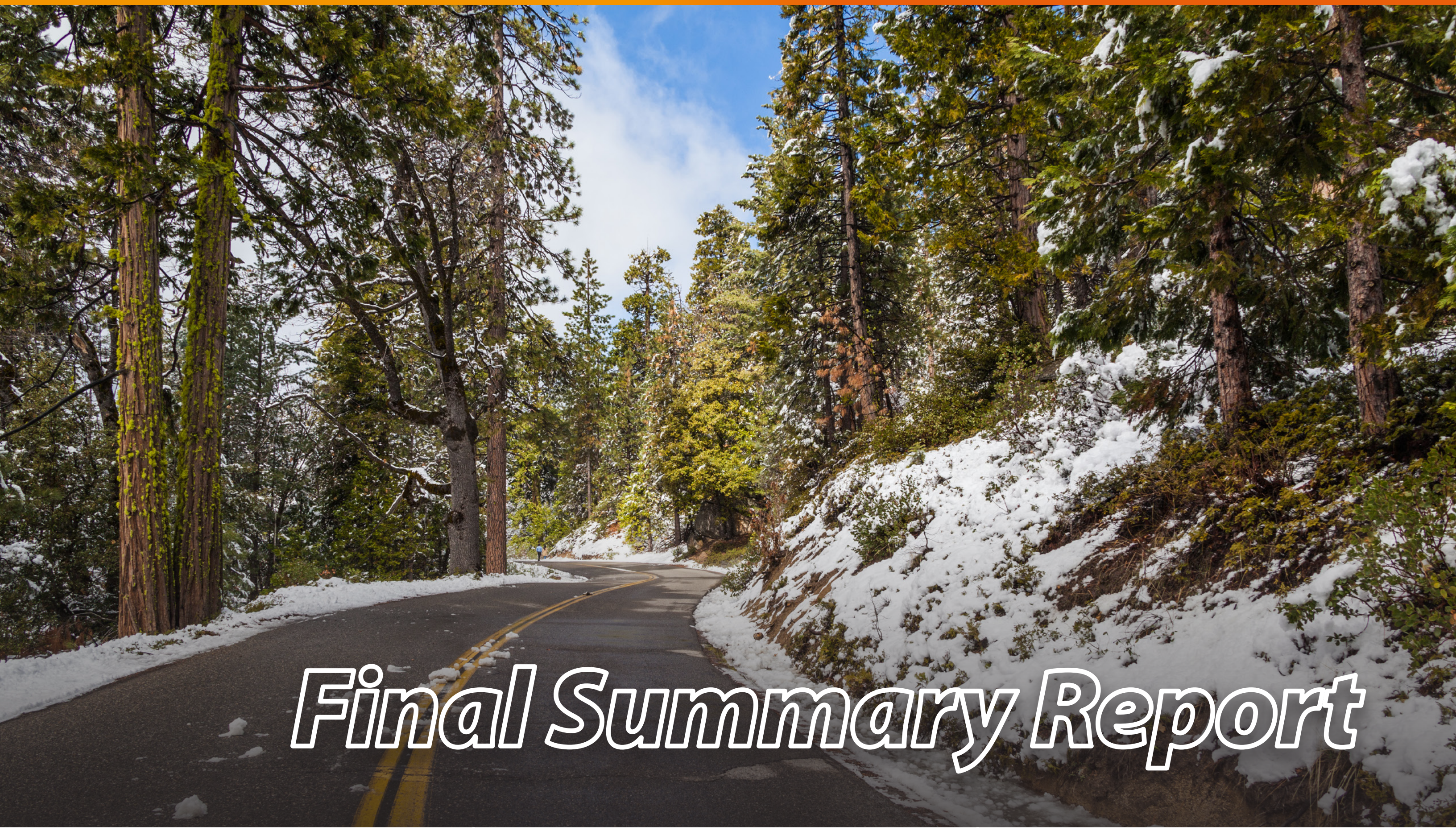
Fresno County Regional Transportation Network
Vulnerability Assessment



Final Summary Report

Fresno Council of Governments

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INTRODUCTION

The Fresno Council of Governments (Fresno COG) received grant funding from the California Department of Transportation (Caltrans) under the Senate Bill (SB) 1 Adaptation Planning Grants Program to conduct a Transportation Network Vulnerability Assessment (TNVA) for Fresno County. The TNVA aims to assist Fresno COG and their member agencies in understanding the potential impacts of climate change on the region's transportation infrastructure. Fresno COG wants to ensure that the region's multimodal transportation network continues to support the county's travelers and promote positive economic development. The information learned through the TNVA development process and summarized here will inform the next Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) update and can be integrated into local jurisdictions' General Plans.

TNVA Objectives

1. Convene regional partners and community members from across Fresno County. Gather feedback on their climate change-related concerns and priorities.
2. Identify climate change hazards and the risks they pose to the county's multi-modal transportation infrastructure.
3. Pinpoint specific transportation assets that are vulnerable to climate change impacts.
4. Develop adaptation strategies to prevent or remedy identified climate change-related vulnerabilities.

Senate Bill 379

One of the reasons Fresno COG decided to complete the TNVA was to help its member agencies meet the requirements set by SB 379. California's SB 379 requires that all cities and counties address climate adaptation and resiliency strategies in the next revision of the Safety Element of their General Plans. If cities and counties had a hazard mitigation plan when the bill was signed in October 2015, they can meet the requirements of the bill by updating their local hazard mitigation plan instead. SB 379 requires that the update include three core elements:

- **Vulnerability assessment** – Jurisdictions are expected to conduct and document a vulnerability assessment using data from sources including Cal-Adapt, California Adaptation Planning Guide, and relevant local, state and federal agencies, and considering historical materials and existing and planned development.
- **Adaptation and resilience goals, policies, and objectives –** These goals, policies, and objectives should be informed by the vulnerability assessment.
- **Feasible implementation measures** – The implementation measures should be designed to carry out the set of adaptation and resilience goals, policies, and objectives.

Additional information on the bill and the three primary requirements can be found in the Alliance of Regional Collaboratives for Climate Adaptation SB 379 guidance (ARCCA, 2016). The Fresno TNVA can help jurisdictions fulfill these core elements of the SB 379 requirements. The Vulnerability Assessment Summary Memorandum, completed earlier in the project, has information, maps, and data that can be used to help meet the first core obligation of SB 379. The Adaptation Strategies Summary Memorandum is a compendium of strategies that can be used to help meet the second core obligation of the policy. Identifying implementation measures is contingent on the needs and requirements of each jurisdiction, and they can draw on the portions of the TNVA that are most applicable to their local settings to complete this third obligation.

Background and Regional Context

The Fresno COG is a voluntary association of local governments that conducts regional planning for Fresno County. More specifically, the COG is a Regional Transportation Planning Agency and federally designated Metropolitan Planning Organization. Fresno COG identifies transportation needs for the county and prepares the county's RTP/SCS and the Regional Transportation Improvement Program. The COG also conducts additional regional studies, like the Fresno TNVA, when they are needed.

Fresno County lies in the southern portion of the California Central Valley, bordered by the Diablo Range to the southwest and the Sierra Nevada in the east. The Fresno-Clovis metropolitan area is situated in the center of the county and is made up of its two largest cities. The surrounding area has historically served as some of the nation's most productive farmland, producing over $7.8 billion in total gross production value in 2018 alone (Fresno County, 2018). The San Joaquin River runs along the northern border of the county from the Sierra Nevada where it eventually connects with the Fresno Slough near Mendota. The Kings River also runs from the eastern Sierra where it feeds Pine Flat Lake and continues into the valley floor neighboring Sanger, Parlier, and Reedley.

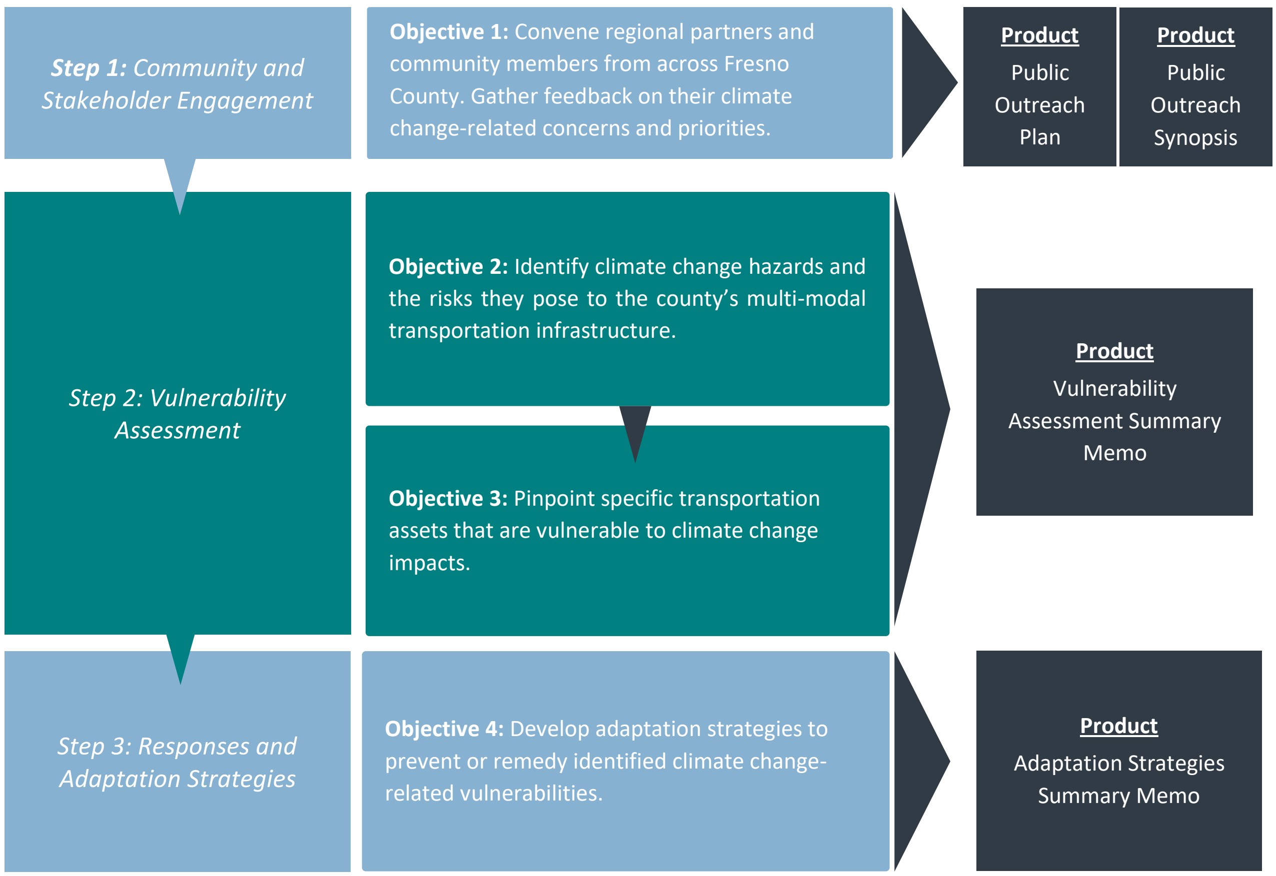
How to Use this Document

This Final Vulnerability Assessment Summary Report (Summary Report) summarizes the outputs of Fresno COG's TNVA, which had three main steps: 1) engage with the community and stakeholders, 2) conduct a vulnerability assessment of the transportation network's exposure to different climate hazards, 3) and develop responses to potential impacts and adaptation strategies that build the resiliency of the network. The following products were developed to summarize each step of the TNVA:

- Public Outreach Plan
- Public Outreach Synopsis
- Vulnerability Assessment Summary Memorandum
- Adaptation Strategies Summary Memorandum

The Summary Report provides a synopsis of each document listed above and is intended to act as an Executive Summary for the entire TNVA. Figure 1 provides an overview of the TNVA process, including its three main steps, the core TNVA objectives met through those steps, and final TNVA products. The Summary Report provides a snapshot of this entire process. See the Appendix to review the complete TNVA products and results.

Figure 1. TNVA Process and Products



PUBLIC OUTREACH SYNOPSIS

Community Engagement Goals & Strategy

Community engagement was an important element of the Fresno COG TNVA. It allowed the public and stakeholder agencies to effectively evaluate and comment on the TNVA. It also provided Fresno COG and consultant staff (the TNVA team) with additional information about local concerns related to climate change and what climate hazards already affect day-to-day life. In addition, the public and stakeholders provided helpful feedback about which adaptation strategies they would like to see in their community. Working with stakeholders and the public was a two-way street, where information and ideas were exchanged between parties, which helped to keep the public informed and guide the direction of the vulnerability assessment.

The following overarching outreach goals were identified when developing the Public Outreach Plan:

- Create public forums and materials that provide clear, concise project information.
- Allow the public and community members to inform the development of the vulnerability assessment.
- Seek opportunities to involve a broad range of community members.
- Engage minority, low-income, and disadvantaged communities.

Multiple strategies were used to generate interest and participation from the community. The TNVA team engaged with the public primarily through pop-up events, community surveys (both online and in person), and a public workshop. The team connected with stakeholders by establishing a Vulnerability Assessment Working Group (VAWG) of local agencies, who guided the development of the TNVA and ensured that the analysis represented and served Fresno County. Stakeholders were also invited to take part in interviews and provide their insight on what climate hazards will have the greatest impact to the Fresno County transportation network and its users. They were also asked about what they would like to see from the TNVA and how the results could benefit their own work.

Public Engagement Summary

Pop-ups

Pop-up events allowed the TNVA team to engage with the public at events of interest to them and ultimately reach a higher number of residents than traditional public workshops. The TNVA team worked with Fresno COG staff and the VAWG to identify high-volume community events throughout Fresno County. Pop-up events were held at the Kerman Almond Festival, Reedley Street Faire, San Joaquin Carnival, and the Fresno Grizzlies July 4th baseball game.

At the first three pop-up events, the TNVA team set-up an informational area, which included English and Spanish informational boards and study area mapping, informational flyers, comments cards, and a short survey consisting of seven questions. These materials can be found in the Appendix. All pop-up events were staffed with at least one bilingual TNVA Team member. A total of 178 surveys were completed by all pop-up event attendees over the course of the four pop-up events.

Online Survey

The TNVA team augmented the pop-up event surveys with an online community survey available in both English and Spanish. The survey was accessible through the Fresno COG webpage and distributed through social media, newsletters, and email. 63 completed surveys were submitted.

Workshop

The TNVA workshop was held at Fresno City College and followed an open house format to present the TNVA findings to-date and collect public feedback. Unfortunately, the workshop attendance was low and the TNVA team did not receive many comments at this event.

Stakeholder Summary

VAWG Members

The TNVA team assembled a working group of local organizations called the VAWG, which was made up of the following representatives:

- California Rural Legal Assistance
- Central California Asthma Collaborative
- City of San Joaquin - Public Works
- Fresno County Rural Transit Agency
- Fresno County Office of Emergency Services
- Fresno Metropolitan Flood Control District
- City of Fresno
- Fresno Area Express (FAX)
- California Department of Transportation (Caltrans)
- California Department of Forestry and Fire Protection (Cal Fire)

The VAWG were responsible for representing their organizations and Fresno County at large, providing both policy and technical guidance, shaping how the TNVA can serve the different communities of Fresno County, and informing their constituents about community engagement opportunities. VAWG members attended three meetings to review the progress of the TNVA, provided feedback on the direction of the project, and reviewed final products.

Interviews

The TNVA Team led stakeholder interviews to gather project-relevant information and stakeholder suggestions and concerns. Four interviews were conducted by telephone with key stakeholders who provided their knowledge and insight to better assist with the TNVA development process. Interviewees included representatives from the following agencies or organizations:

- California Rural Legal Assistance
- Central California Environmental Justice Network

- Central Valley Air Quality Coalition
- City of Fresno Engineering Department
- City of Reedley Community Development Department
- Fresno Area Express (FAX)
- Fresno County Department of Public Works and Planning
- Fresno County Office of Emergency Services
- Leadership Counsel for Justice and Accountability

Community Engagement Findings

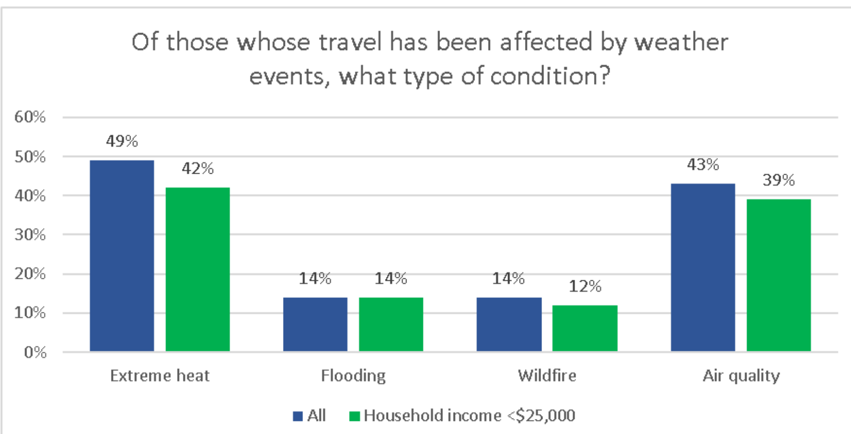
Public Outreach

Between the in-person and online surveys, the TNVA team gathered 243 responses from the public. 68 of these were from individuals who reported household income of less than $25,000.[1] The following provides a summary of three key questions from the pop-up and online surveys.

Have weather events or conditions ever affected your travel or required you to evacuate?

Of all survey respondents, 43% reported that weather events or conditions have either affected their travel or required them to evacuate. A higher share (57%) of those with household incomes under $25,000 reported that weather events or conditions have either affected their travel or required them to evacuate. For those whose travel has been affected, extreme heat and air quality were the two most frequently reported hazards. Figure 2 shows the breakdown by event type for all respondents and for those with household incomes below $25,000.

Figure 2. Travel Impacts



What impacts from climate change are you most concerned about?

Participants were asked to rank their level of concern about seven types of potential climate change impacts (see Table 1). 86% of all Fresno County respondents reported at least one concern about climate change. For all respondents, the highest average ranking was for extreme heat (2.4), followed closely by drought (2.6), and air quality (2.8). The top three average rankings were the same for individuals with household incomes less than $25,000 compared to the overall population.

[1] This is slightly below the U.S. Census Bureau's 2018 poverty threshold of $25,465 for a family of four with two children (https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html).

Table 1. Average Ranking for Level of Concern

Climate Change Impact	All Respondents	Household income <$25,000
Extreme Heat (highest concern)	2.4	2.2
Drought	2.6	2.8
Air Quality	2.8	3.0
Wildfires	4.1	4.1
Flooding	4.6	4.5
Subsidence	5.2	5.4
Landslides/Erosion (lowest concern)	5.7	5.7

Which of the following transportation improvements are most important for addressing extreme weather and climate change?

Participants responded to the question above about which transportation improvements are important for addressing extreme weather and climate change. They could select more than one option. Both the all respondent and low-income respondent groups listed "tree plantings along roadways and sidewalks" the most frequently (70% and 79%, respectively). Results were generally consistent across the two groups. However, a substantially higher percentage of low-income answered highlighted "comfortable and shaded transit stops" (75% versus 57%). Other popular options included "expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.), during high heat or other extreme weather events" and "public transit service to cooling centers on high heat days."

Vulnerability Assessment Working Group and Stakeholder Feedback

The VAWG and other stakeholders provided valuable input during working group meetings and interviews. Some of the more general feedback covered:

- Concerns regarding extreme heat and poor air quality, especially for outdoor workers.
- Difficulty navigating flooding in rural areas that have insufficient drainage.
- The need for shaded areas for active transportation and transit users.
- Concerns regarding increases in operations and maintenance costs from heavy rain events.
- The need to identify the highest priority threats to the transportation network.

In addition, the VAWG and other stakeholders provided specific locations around the county where flooding and wildfire have been recurring issues. This information directly fed into a portion of the vulnerability assessment where the TNVA team identified "problem areas" along the transportation network, where there have historically been issues along the roadway network from flood events and wildfires. See the Vulnerability Assessment Summary Memorandum for a complete list of feedback collected from Fresno COG stakeholders.

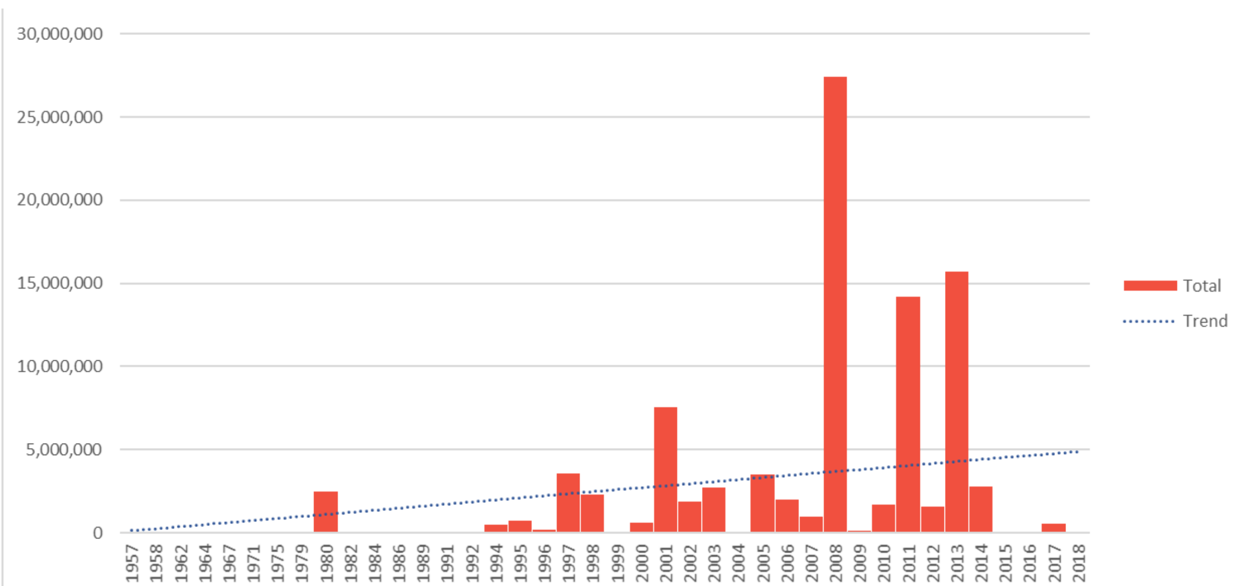
Fresno County Extreme Weather and Climate

Spanning across the Central Valley and reaching into two major mountain ranges, Fresno County experiences a variety of weather and climate conditions. Extreme heat, riverine flooding, wildfire, drought, dense fog, strong winds, and winter storms have affected the region in recent years. The impacts of climate change on the planet's natural systems are leading to observable changes in California's environment. Fresno County is likely to experience higher average temperatures and increases in extreme heat events, wildfires, storms, and droughts. The changes in climate are expected to exacerbate related issues, such as air pollution and water supply, and ultimately affect social equity as communities face disproportionate impacts from climate change.

Historical Context[2]

Storm-related property damage in Fresno County varies highly between years, but has experienced a recent, upward trend (Figure 3)[3]. Over the past 5 years, wildfires caused the greatest direct threat to people. Wildfires were also responsible for the largest amount of non-agricultural property damage, followed by strong winds and winds from thunderstorms. According to the database, crops in Fresno County have been damaged the most by frost/freeze events and strong wind events.

Figure 3. Fresno County Property Damage ($) by Year, NOAA Storm Events Database

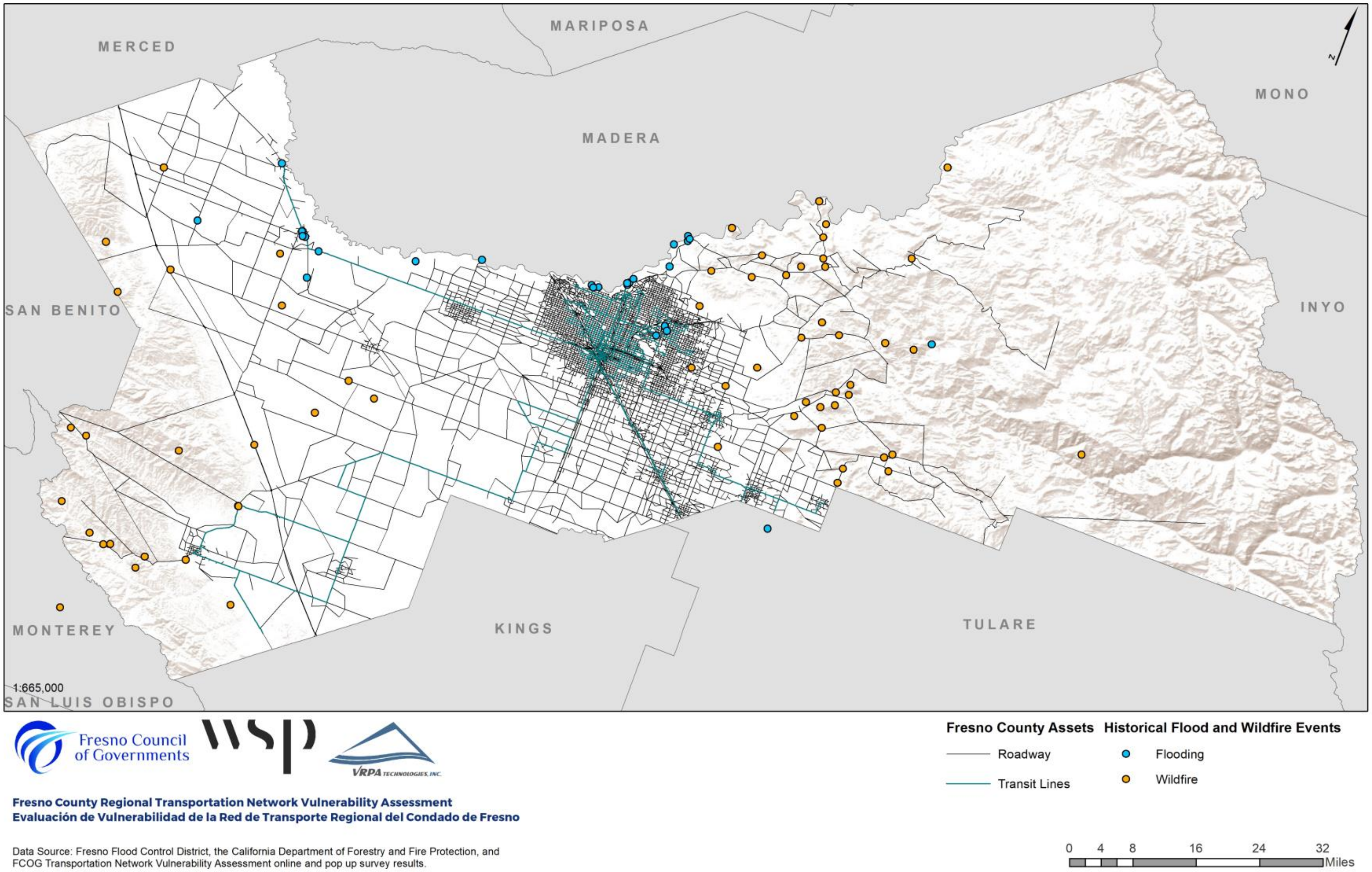


Source: NOAA Storm Events Database

The TNVA team reviewed news archives and incident reports for information about the location, type, and year of historical flooding and wildfire in Fresno County. Figure 4 shows the locations of these events.

[2] Fresno County's recent Multi-Hazard Mitigation Plan thoroughly summarizes past weather-related events and risks in the region: https://www.co.fresno.ca.us/home/showdocument?id=24743
3 National Oceanic and Atmospheric Administration (NOAA) Storm Events Database

Figure 4. Fresno County Historical Flood and Wildfire Events



Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

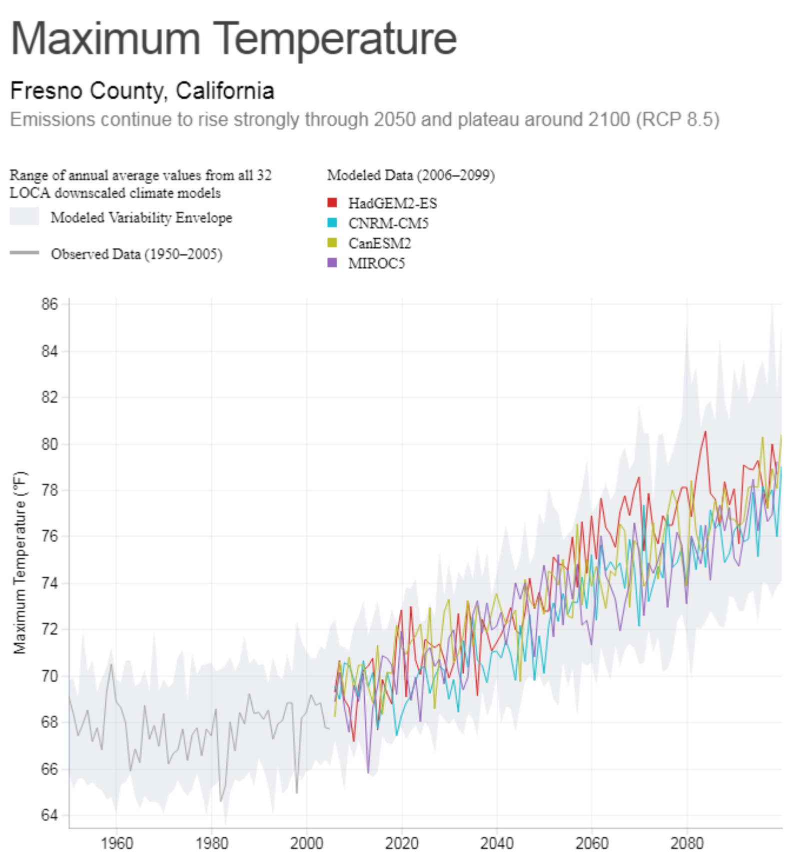
Data Source: Fresno Flood Control District, the California Department of Forestry and Fire Protection, and FCOG Transportation Network Vulnerability Assessment online and pop up survey results.

Future Projections Overview[4]

This study looked at the available projections from climate models and other sources to understand how Fresno County's climate is likely to change in the future. Global Climate Models (GCM) simulate climate over time, drawing on physics, climatology, and historical climate observations. They use assumptions about greenhouse gas emissions and other factors to forecast future climate conditions.

For this study, we used projections from 10 models by state agencies as being most representative of climate change across the state.[5] In general, we used two greenhouse gas emissions concentrations scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), a major international research institution that provides scientific research on climate change to help policy and decision makers. The scenarios are called Representative Concentration Pathways (RCPs). RCP 4.5 assumes that global annual GHG emissions peak around 2040 and then decline. RCP 8.5 corresponds more closely to the current status quo; it assumes that emissions continue to rise until the end of the century.[6]

Figure 5. Fresno County Average Daily Maximum Temperature Projections, RCP 8.5, Cal-Adapt



There is high agreement between the models that temperatures will rise considerably over the rest of the century (Figure 5). This pattern is consistent across Fresno County.

There is much less agreement between the models regarding future precipitation patterns. The model average shows an increase in annual precipitation, but the variability between models and between years within the models is high. Figure 6 shows Cal-Adapt extreme precipitation projections for the City of Fresno under four

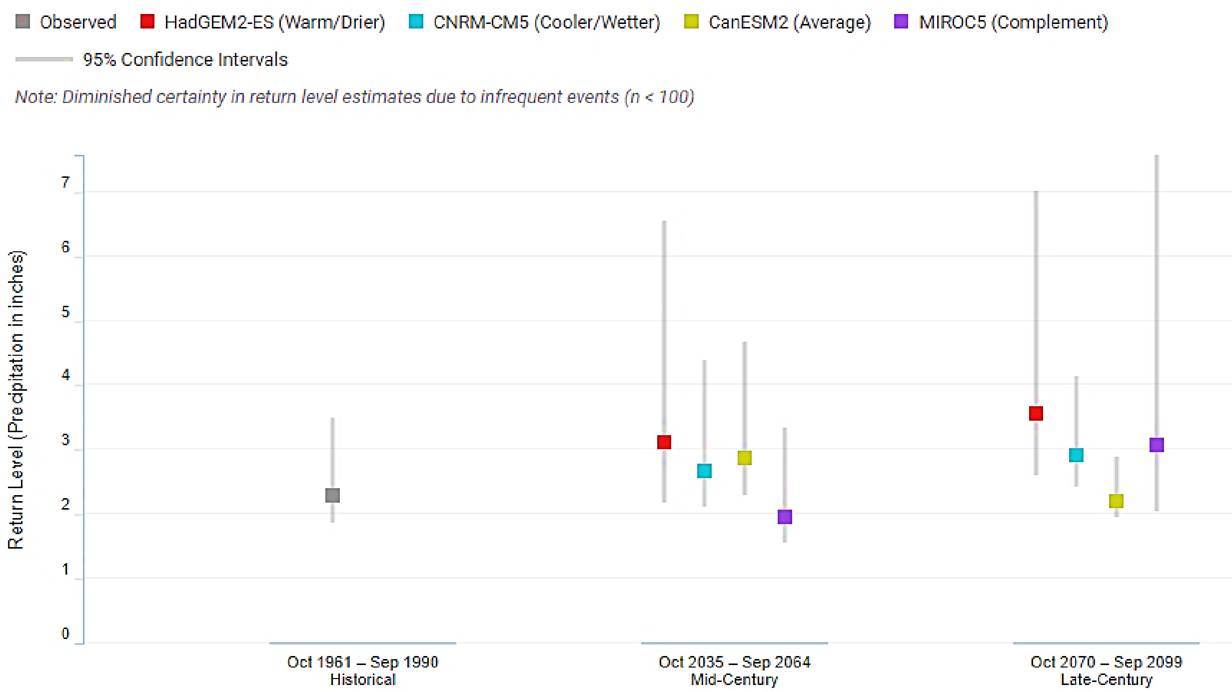
4 California's Fourth Climate Change Assessment provides a thorough overview of the expected effects of climate change in the state: https://www.energy.ca.gov/sites/default/files/2019-07/Statewide%20Reports-%20SUM-CCCA4-2018-013%20Statewide%20Summary%20Report.pdf

5 http://www.water.ca.gov/climatechange/docs/2015/Perspectives_Guidance_Climate_Change_Analysis.pdf

6 Meinshausen, M.; et al. (November 2011), "The RCP greenhouse gas concentrations and their extensions from 1765 to 2300 (open access)", Climatic Change, 109 (1-2): 213–241.

models. It shows the 100-year/24-hour[7] event for the historical timeframe and two future timeframes. The gray lines show the 95% confidence intervals for the projections. Most of the models show increases in the 100-year event, though the confidence intervals are very wide, indicating the uncertainty of future heavy precipitation conditions in the area.

Figure 6. City of Fresno 100-Year/24-Hour Precipitation Event Projections, RCP 8.5, Cal-Adapt



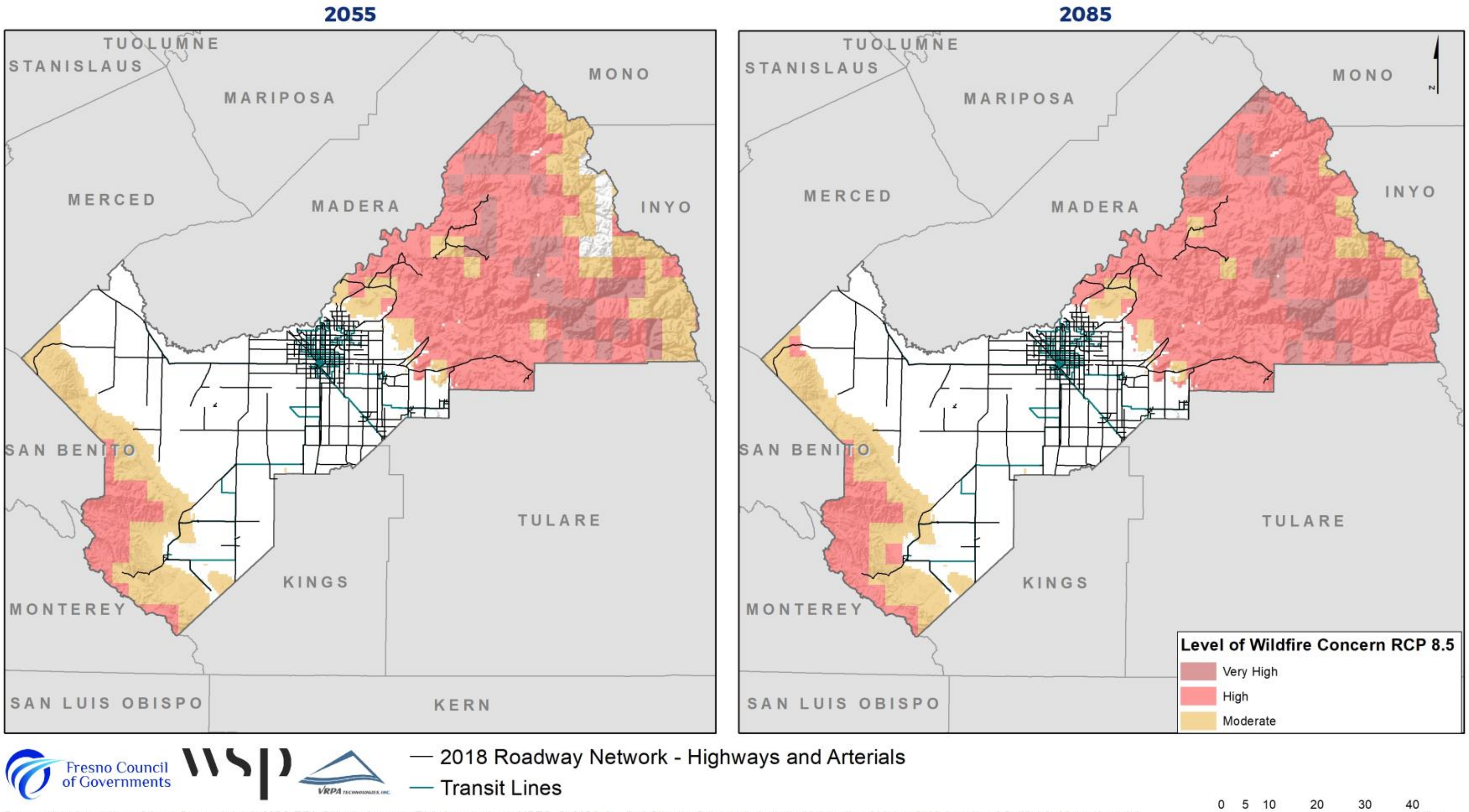
Rising temperatures dry out soils and vegetation, which increases wildfire risk in Fresno County. Figure 7 shows the relative level of wildfire concern for a composite of GCMs and wildfire models, with high or very high levels of concern in the Sierra Nevada and foothills and moderate or high levels of concern for the Coastal Range at the western edge of the county.

The project team also identified and assessed locations of deep-seated landslide risk around Fresno County. Deep-seated landslides are slow-moving slides where most of the moving earth is deep under the ground, by anywhere from ten to several hundred feet. The assessment paired existing, deep-seated landslide susceptible locations with future precipitation projections to identify areas where there is an existing risk of landslides that may be exacerbated or triggered by heavier precipitation events in the future (see Figure 8).[8]

7 The 100-year event has a 1% chance of occurring in a given year. 24-hour is the duration of the period for which the precipitation event is measured.

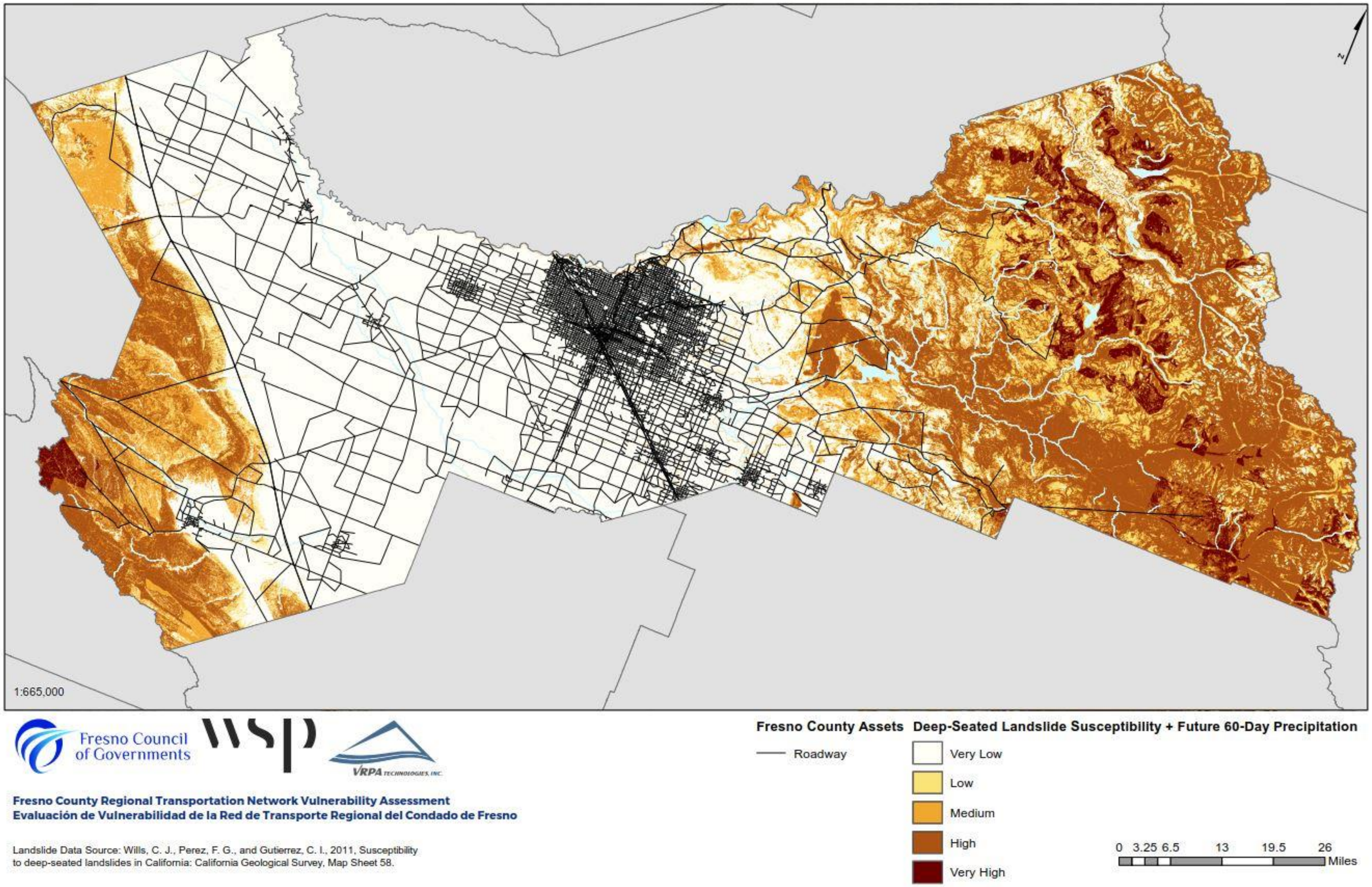
8 For this assessment, existing deep-seated landslide risk was based upon the California Geological Survey's (CGS) deep-seated landslide susceptibility dataset. Future precipitation projections were included by calculating the change in the 60-day duration, 100-year depth precipitation values between historical observations and future projections for 2085. The 60-day precipitation totals were used as an indicator for heavy soil saturation conditions that can trigger deep-seated landslides.

Figure 7. Fresno County Levels of Wildfire Concern, RCP 8.5, Multi-Model Ensemble



Source: Amalgamation of three fire models: 1) MC2-EPA Climate Impacts Risk Assessment, USFS, 2) MC2-Applied Climate Science Lab at the University of Idaho, 3) University of California Merced model.

Figure 8. Future Landslide Concern across Fresno County



Transportation System Analysis Findings

Much of the Fresno County transportation system and its users are likely to be affected by changing climate conditions. Primary climate-related hazards affecting the region's transportation include flooding, wildfire, extreme temperatures, and precipitation-induced landslides. Higher maximum temperatures can pose health threats for transit passengers and damage pavement and bridges. More frequent wildfires can disrupt the transportation system and hinder or cut off evacuation routes. Heavy rain events and runoff can lead to flooding, washouts, and erosion. Broader effects on the hydrologic and agricultural systems could affect regional travel patterns.

Vulnerability Scoring

A major component of the analysis was a risk indicator scoring exercise. The scoring involved gathering relevant data on climate hazards and assets and combining this information into vulnerability scores representing the relative risks facing different assets. With these results, the TNVA team could identify relatively vulnerable assets on the Fresno County transportation network. These assets may need facility-level assessments of future climate threats to understand their physical risks in more detail.

With the indicators approach, various metrics were used to capture (1) the nature of the asset's exposure to each relevant hazard and (2) the consequences of that exposure. Example metrics include:

- Projected future wildfire level of concern
- Projected future heavy precipitation
- Projected future riverine flows
- Projected future 7-day maximum temperature (metric used in pavement design)
- Projected future maximum annual temperature
- Projected future heat health events
- Current floodplain location (100-year, 500-year, or none)
- Recurring damage (whether location has experienced flooding or fire in the past)
- Condition ratings (e.g., bridge scour or substructure rating)
- Facility Level of Service (LOS)
- Traffic and truck traffic volumes
- Detour length around asset in case of disruption
- Household and employment density near asset
- Percentage of households with no vehicle access near asset
- Facility within or overlaps environmental justice areas identified by Fresno COG
- CalEnviroScreen score at asset location

These metrics were compiled into a score for each individual asset, that can be ranked to show the assets that should be prioritized for detailed study under each hazard. For example, this scoring identified which bridges are the most vulnerable to riverine flooding hazards out of all the bridges in the region. The Vulnerability Assessment Summary Memorandum describes each metric used in the analysis along with a rationale for inclusion, the data source, and other metadata. The following full-page maps show some of the results of the vulnerability scoring. Larger numbers (shown in red) are assigned to more vulnerable assets, whereas smaller numbers (shown in green) are assigned to less vulnerable assets. The Synthesis section discusses results of the scoring along with other elements of the Vulnerability Assessment.

Figure 9. Vulnerability Scoring: Bridges & Future Flooding

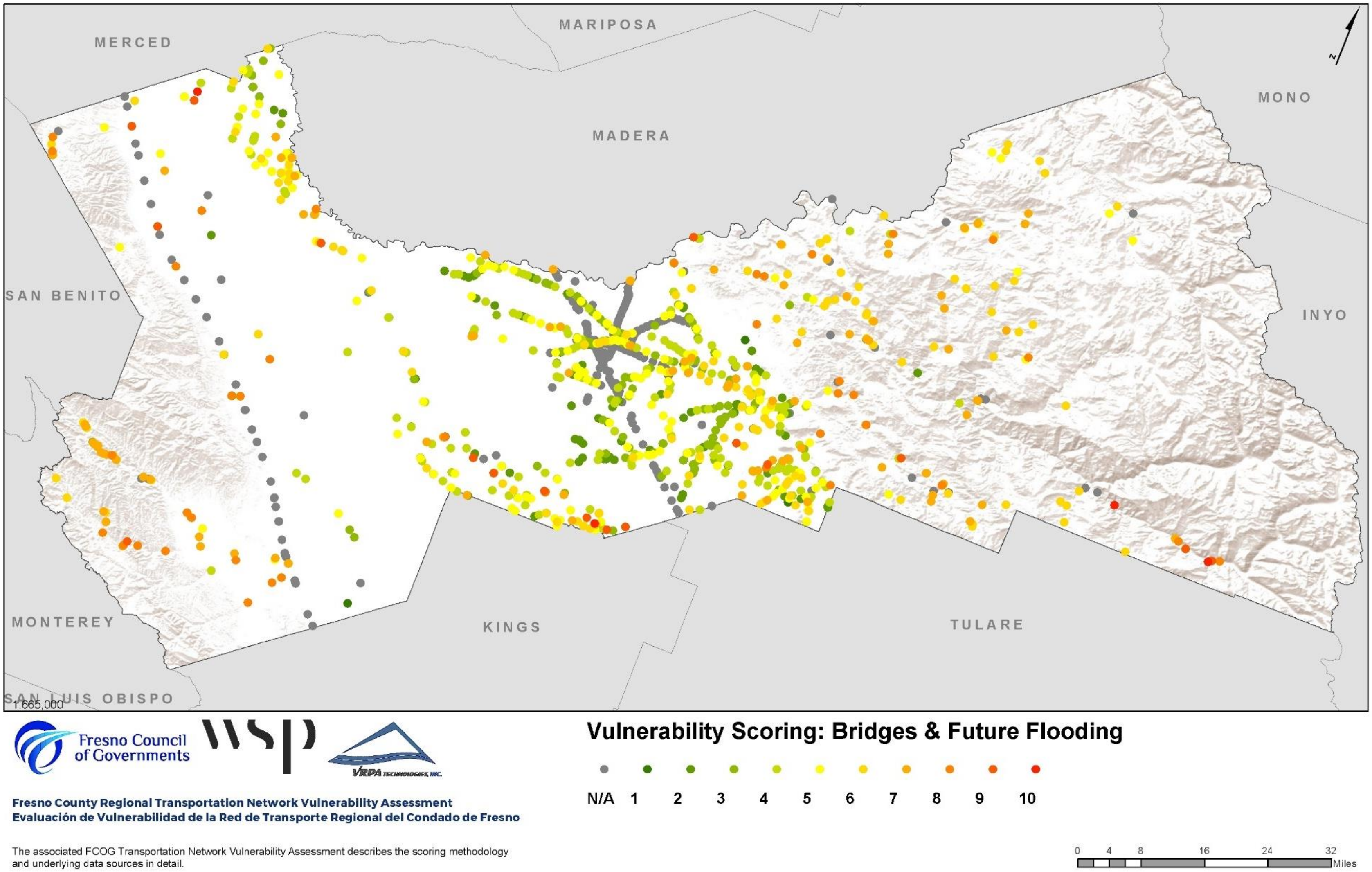


Figure 10. Vulnerability Scoring: Roadways and Future Wildfire

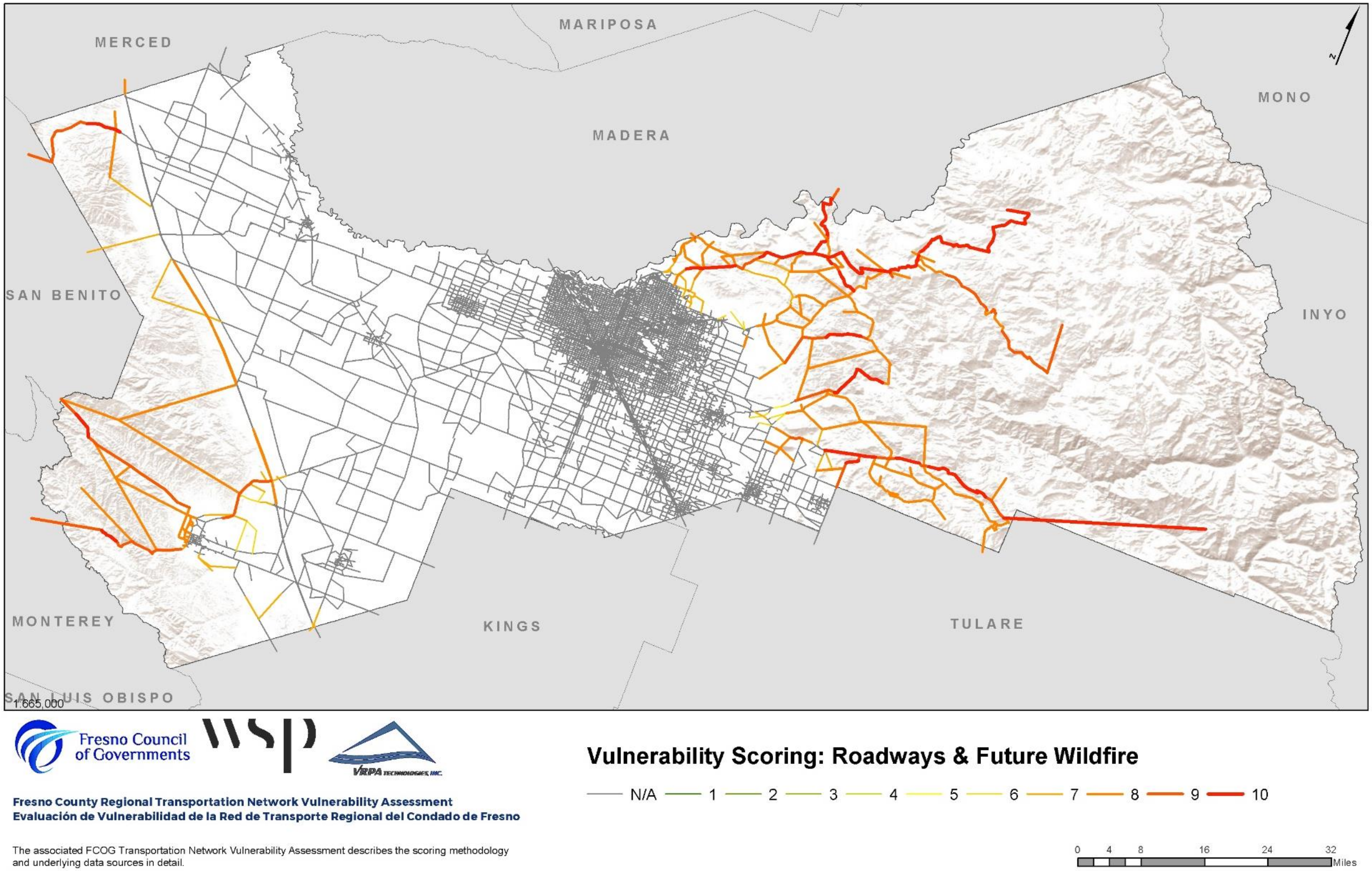
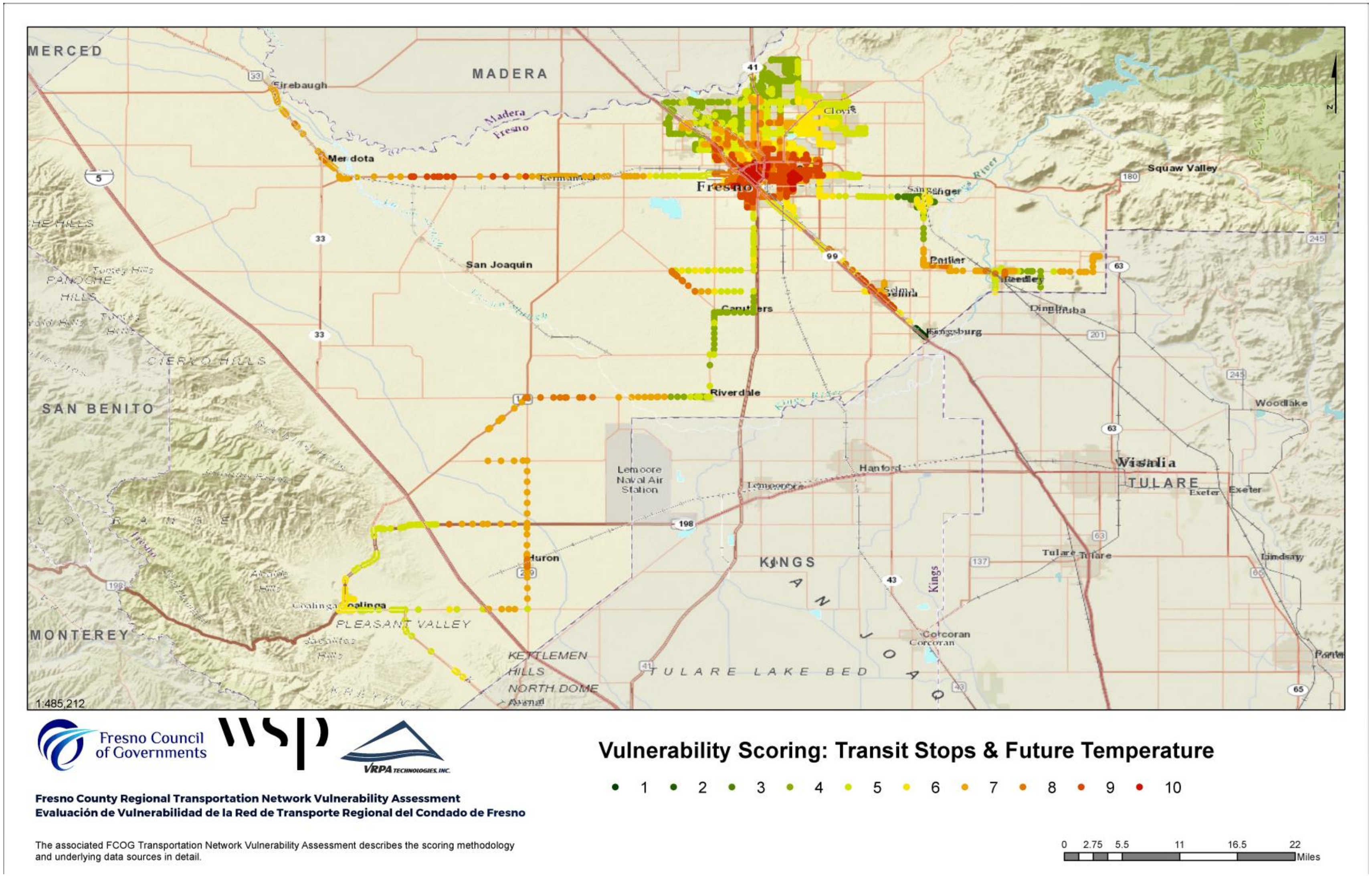


Figure 11. Vulnerability Scoring: Transit Stops & Future Temperature



This scoring is a helpful tool given the number of different assets, hazard types, and information sources needed to assess relative vulnerability. But it should not be mistaken as a complete understanding of risks facing those assets. It's a tool for system-level analysis that needs to be accompanied with professional judgement and on-the-ground context. It is useful in that it can help identify at-risk assets that should be examined individually at a facility-level.

Synthesis

Extreme heat, riverine flooding, wildfire, and other weather-related conditions events have affected Fresno County's transportation system in the past. Going forward, the county is likely to experience a future that holds substantially more high heat events and associated air quality issues; more frequent wildfires; more uncertain precipitation patterns with the potential for heavier high precipitation events; and strains on water supply. The following are some of the key takeaways and results from the vulnerability assessment. See the Vulnerability Assessment Summary Memorandum for more findings.

- Socially vulnerable residents, such as those with low incomes, without English fluency, or with asthma or other respiratory issues, are disproportionately at risk. Many of these individuals are transit dependent and more exposed to high heat and poor air quality.
- The projected future high temperatures are relatively uniform in the Central Valley portion of Fresno County, where virtually all the transit stops are located. In the FAX system, bus ridership tends to be lower on hotter summer days. Transit agencies also face operational challenges due to increased energy demand in higher temperatures.
- While wildfire and riverine flooding affect a smaller portion of the population, they pose substantial risks, especially to rural parts of the County with limited redundancy in the transportation network.
- Riverine peak flows are expected to increase under at least some of the future climate scenarios. The Kings River and San Joaquin River both pose threats to communities and associated transportation infrastructure. Failure of Friant Dam or Pine Flat Dam would be potentially catastrophic.
- Many bridges and roadways were identified as vulnerable to future riverine flooding. Most of these are lightly traveled roads in low-density areas, though network redundancy is limited in many of these areas, so detour routes are often long. Specific areas of flood vulnerability include:
  - Several of the most vulnerable bridges span the Kings River South Fork on the SR-180 or nearby roads in far eastern Fresno County. These roads are characterized by low travel volumes but significant detour lengths.
  - There are a few vulnerable bridges the I-5 over the Panoche Creek and Little Panoche Creek.
  - One of the most vulnerable bridges to future flooding was the North Fork Road bridge over the San Joaquin River in Friant. It has experienced flooding in the past, rates poorly for scour, and will likely experience high increases in flows many of the climate scenarios.
  - The SR-180 over the Fresno Slough near Mendota.
  - The SR-269 north of Huron.

  - Selma Airport ranked as the most vulnerable airport to future flooding
  - Some mobile home parks in river floodplains have experienced flooding in the past, including Wildwood Mobile Home Park and Woodward Bluffs Mobile Home Park in northern Fresno along the San Joaquin River and River Bend RV Park in Sanger.
- For wildfire, there are many small communities in the Sierra Nevada and foothills with limited routes for access and egress. The longest stretches of highly vulnerable roadway are the SR-180, Auberry Road, and the SR-168 in the Sierras. These have very low redundancy and relatively high volume compared to other rural roads in the county's exposed areas. Other highly vulnerable Sierra roadways include Lodge, Powerhouse, SR-63, Trimmer Springs, and Watts Valley. On the Diablo Range side, the most vulnerable roadways were the SR-198 west of Coalinga and Los Gatos Creek Road.
- Extreme heat and precipitation will have an impact the maintenance of roadways, causing potholes and other roadway degradations. This can ultimately lead to an increase in road maintenance costs.
- Landslide susceptibility already exists around Fresno County and this susceptibility is expected to increase over time as more precipitation falls during heavy events. Some areas are higher concern than others, but this risk exists throughout the Diablo Range and Sierra Nevada.
- From an organizational resiliency perspective, smaller cities often face the same hazards as larger cities but have less funding and fewer staff to address them. Funding constraints were mentioned repeatedly and make addressing vulnerabilities to climate change particularly challenging.

ADAPTATION STRATEGIES SYNOPSIS

The term adaptation refers to an action taken to address a risk related to climate change. The final step of the TNVA was to identify adaptation strategies that can be implemented around the county to prepare for climate change impacts. The resulting list of strategies is intended to act as a toolkit or menu of various response options, which Fresno COG and their stakeholders can pull from as needed. It is not intended to provide prescriptive recommendations for the county and its infrastructure.

There are a wide range of responses for Fresno County to consider, including changes to planning, policy, design, operations, and maintenance. Some strategies are more focused on natural or green infrastructure as opposed to gray infrastructure responses. The responses are context-dependent and should be considered and weighed individually depending upon the stressor of concern, location, budget, timing, and other considerations. See the Adaptation Strategies Summary Memorandum for further discussion of the adaptation responses available to Fresno County.

More important than the strategies themselves are the change in principles and approaches needed to make the transportation system resilient to climate change.

General Principles and Approaches

Transportation infrastructure has always interacted with the natural environment and its potential hazards, including flooding, high temperature, wildfire, and landslides. Infrastructure managers, operators, planners, and designers already have an arsenal of strategies for addressing these hazards. Thus, an adaptation is often simply an application of one of these traditional strategies. But the principles behind adaptations and adaptation decision making are different. This section describes the principles and strategies that can be used to inform adaptation decision-making as depicted in Figure 12.

Figure 12. Factors to Inform Adaptation Decision-Making

Processes and Resources

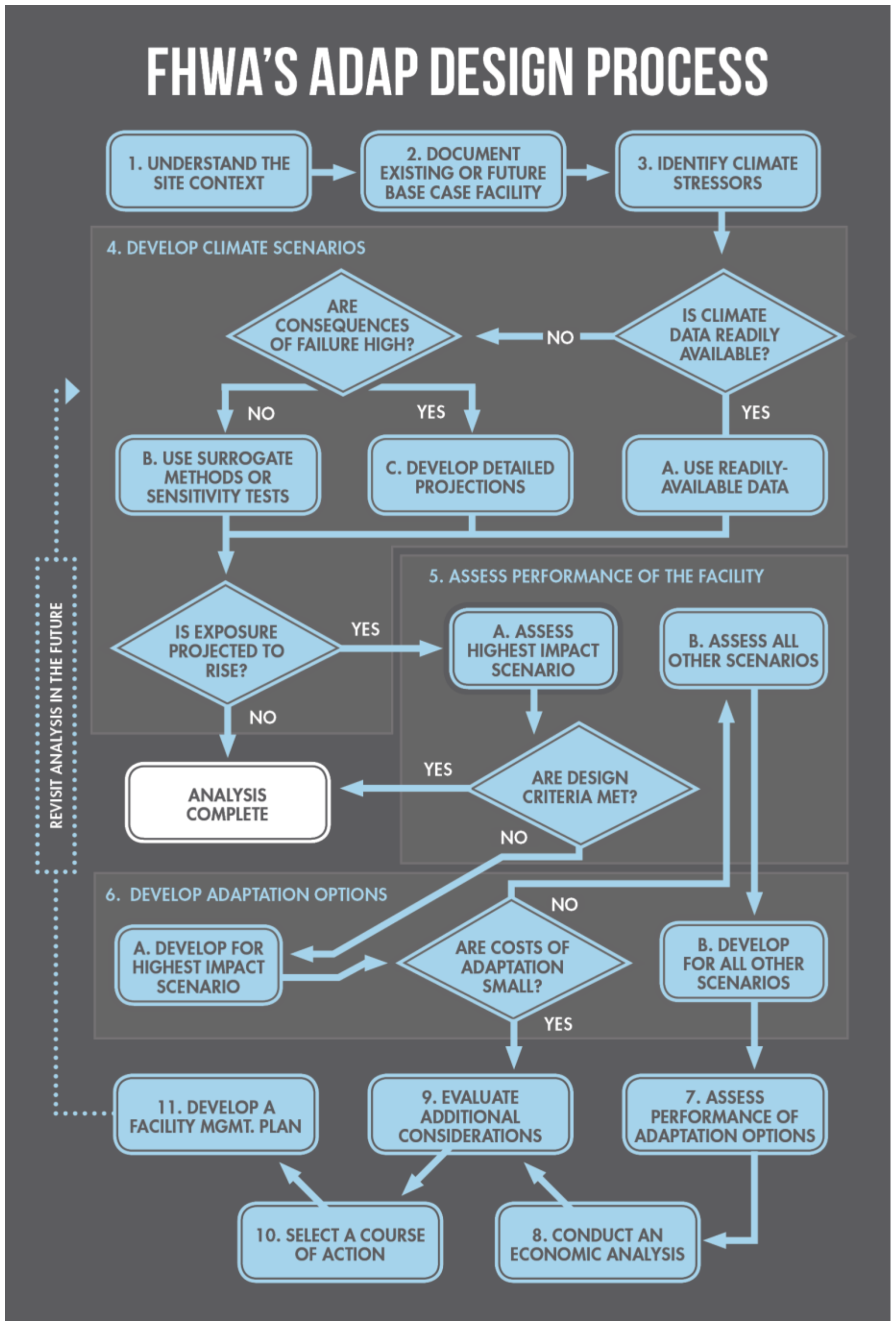
There are numerous resources and guidance documents on adaptation strategy approaches and evaluations. For this study, we highlighted a few key frameworks. The California Governor's Office of Planning and Research (OPR) guidebook entitled *Planning and Investing for a Resilient California* aims to "inform planning and investment processes to address the two primary elements of resilience – planning for future conditions and doing planning itself differently" (Governor's Office of Planning and Research, 2018). Figure 13 shows the OPR guidebook's high-level process for adaptation planning.

Figure 13. OPR's Process for State Agencies to Integrate Climate Change into Decisions

The Federal Highway Administration (FHWA) Adaptation Decision-Making Assessment Process (ADAP) is a facility-level framework that helps transportation practitioners analyze climate hazards and evaluate adaptation options (see Figure 14) (FHWA, 2019). ADAP addresses some of the key challenges associated with climate change and transportation systems, including assumptions about how historical climate conditions will remain the same in the future, the certainty of climate conditions, and the lack of account for the full consequences of infrastructure failures. The ADAP process is a risk-based approach that addresses these challenges through several features:

- It uses climate scenario analysis to understand how an asset would perform under different future conditions.
- It assesses benefits and costs of different action alternatives across the lifecycle of the facility, accounting for how climate conditions could change over time.
- It includes a consideration of socioeconomic benefits and costs in addition to damage repair and lost revenue estimates.

Figure 14. FHWA'S Adaptation Decision-Making Assessment Process



At the local level, the Vulnerability Assessment memo for this study (the Fresno COG Transportation Network Vulnerability Assessment) references other tools and resources that can be used for adaptation planning. These include the Fresno County Multi-Hazard Mitigation Plan.

Policy and Funding

Aside from SB 379, there are other policies and programs that are relevant for adaptation planning in the Fresno region.

California Executive Order (EO) B-30-15, signed in 2015, requires that state agencies (and, therefore, the infrastructure they fund) "take climate change into account in their planning and investment decisions" (Office of Governor Edmund G.

Brown Jr., 2015). It requires them to use "full life-cycle cost accounting to evaluate and compare infrastructure investments and alternatives." Assembly Bill 2800, approved in 2016, codifies EO B-30-15. It requires state agencies to account for "current and future impacts of climate change when planning, designing, building, operating, maintaining and investing in state infrastructure (California Legislature, 2016)."

Most current practice in Fresno County, the State of California, and the US assumes that the properties of the climate and its associated hazards will remain constant over time. As research and experience show that this assumption is unwarranted, different principles and methods are needed to address the risks associated with climate change and enable the transportation system to fulfill its objectives related to mobility, economic activity, public health, social equity, and the environment.

The implication of these policies is that local agencies that understand their climate-related risks and seek to make their systems more resilient will be better positioned to obtain state funding for these projects and activities. They may also be better positioned for federal funding. The Federal Emergency Management Agency (FEMA) will soon increase its pre-disaster funding, which aims to protect infrastructure and communities from hazards before they occur. Its new pre-disaster program is called Building Resilient Infrastructure and Communities (BRIC). BRIC authorizes a "National Public Infrastructure Pre-Disaster Mitigation fund, which will be funded through the Disaster Relief Fund as a six-percent set aside from estimated disaster grant expenditures" (FEMA, 2019). This six percent set aside will likely represent a larger, more reliable source of funding (Holdeman, 2019). In addition to public programs, private lenders, insurers and credit rating agencies have demonstrated more concern about climate-related risks embedded in financial instruments and insurance policies.

While this document does not provide background on potential funding sources for each adaptation strategy presented, there are some helpful general resources for identifying funding sources. The State Adaptation Planning Clearinghouse has a page on funding opportunities organized by sector. The U.S. Climate Resilience Toolkit also lists potential funding sources. Funding sources can vary considerably by strategy type. Furthermore, many investments with a resilience element need not seek funding solely from resilience-specific sources. Demonstrating that a potential investment can make an asset or system more resilient can help it obtain funding from traditional transportation funding sources.

Co-Benefits

Co-benefits are other key considerations of adaptation planning. These are the additional benefits that may stem from a single adaptation strategy, which positively influence the surrounding community and social equity, natural resources, greenhouse gas mitigation, and/or the local economy. Natural infrastructure solutions can provide a variety of different co-benefits.

For example, project landscaping can be designed so that it is an adaptation strategy that reduces risks from temperature rise, flooding, and wildfire, and it also provides co-benefits by reducing greenhouse gas emissions, providing habitat and green space, and even recreational activities.

The benefits that are generated by an adaptation strategy depend on the factors such as the local geography, environment, and community. What is most beneficial depends upon location. For example, planting shade trees to reduce Urban Heat Island (UHI) would be more beneficial along a roadway in a low-income neighborhood then along a highway with no pedestrian access.

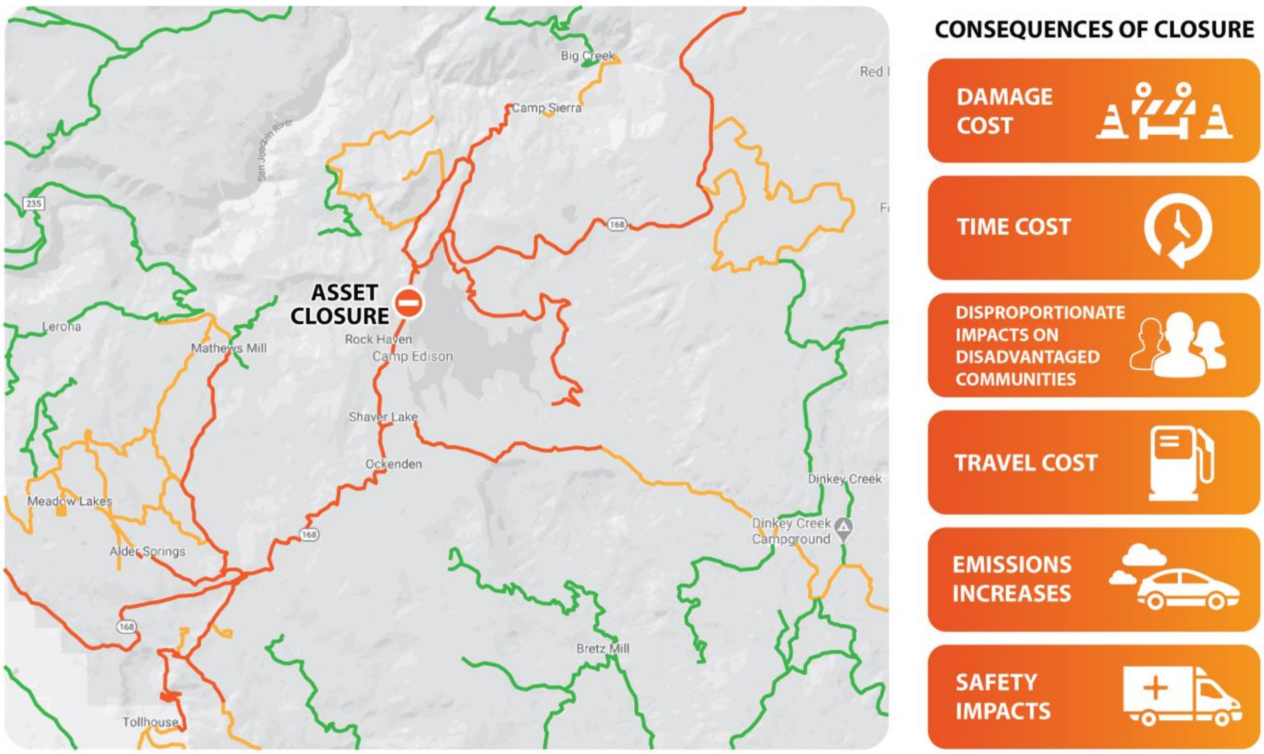
Where applicable, the adaptation strategies summarized in this memo will outline relevant co-benefits associated with that response.

Understanding Consequences of Design Criteria Exceedance

Transportation assets are often engineered to withstand certain design events or similar standards. For instance, a critical roadway might be designed to remain in service during a 50- or 100-year storm (i.e., a storm that has a 2% or 1% chance of occurring each year). A design event is selected based on the risk tolerance for the facility. An agency with a relatively low risk tolerance for an asset would typically use a relatively low probability (and therefore higher magnitude) design event.

Practitioners can make the system more resilient by understanding the consequences of exceeding an asset's design event. This includes information about what magnitudes of hazards could substantially affect an asset (e.g., flood elevation, discharge rate, temperature threshold). It also includes information about how the asset itself could be affected, including damage and disruption costs associated with those magnitudes (West Riverside Council of Governments, 2019). Consequence information can be used during the design process and later in an asset's lifecycle to improve performance from an operations and maintenance perspective.

Figure 15. Consequences of a Road Closure



A simple way to examine consequences is to require that designers assess and document the consequences of a "check event," which refers to an event whose magnitude exceeds the design event.[9] For example, an asset with a design storm recurrence interval of 100 years could have a check storm recurrence interval of 500 years. For higher risk facilities, a more comprehensive analysis may be warranted.

Other Principles

Decision-making timing is another important factor in climate adaptation. Adaptation can require increased capital spending depending on the facility and applicable strategies. In these cases, there can be opportunities for agencies to incorporate adaptation into their other projects and planning activities. For instance, whereas modifying a bridge to withstand higher magnitude floods might be a costly effort, if the asset is to be replaced or repaired anyway, it could be a cost-effective opportunity to adapt it to higher flood levels. Furthermore, because climate change is a relatively long-term trend, there is a temptation to delay response and take a reactive approach. This may be enough in some cases, but in others it might be cost effective to be more proactive. By assessing the lifecycle costs and benefits of adaptation and no action options (see "Processes and Resources" above), practitioners can better understand how best to time their adaptation-related activities.

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[9] For example, see https://flh.fhwa.dot.gov/resources/design/pddm/Chapter_07.pdf

Community engagement is another crucial component to adaptation planning. With knowledge of the challenges facing the communities they represent; agencies can better prepare adaptation responses. This is particularly important in disadvantaged communities, where members may not have access to resources necessary to respond to extreme events or changing climate conditions. The resources can include funding to address damaged property or infrastructure or equipment such as vehicles that can be used for evacuation or for avoiding extreme weather conditions. There is also a need for stakeholder and public education regarding climate change risks and adaptation options. Increased awareness can enhance the capacity of communities to respond to hazards. This could include knowledge of evacuation best practices or who to contact when extreme events do occur.

Summary of Potential Strategies

This section describes possible strategies that can be employed by jurisdictions in Fresno County in response to climate change-related temperature rise, precipitation and flooding, wildfire risk, and landslides. Table 2 lists the climate hazards discussed in this assessment and the corresponding adaptation strategies. Again, these are intended to act as a menu of options rather than prescriptive recommendations.

Table 2. Adaptation Strategies by Climate Hazard

Hazard	Response Type	Response
Temperature	Health & Community	Shades Bus Stops
		Vegetation Cover (Urban Forestry)
		Cooling Centers
		Mitigating Air Quality Impacts
		Multilingual Notification During Poor Air Quality Events
	Pavements	Pavement Design
		Asset Management
	Bus Operations	Power Redundancy
		High Heat Event Response Planning
Precipitation & Flooding	Engineered Responses	Adjust Precipitation/Discharge Projections Used in Design
		Enhance Drainage Capacity
		Increase Scour Prevention
		Elevate Infrastructure
		Channelization
		Install Permeable Pavement
		Install Tree Wells

Hazard	Response Type	Response
	Natural Responses	Install Bioretention Areas and Bioswales
		Bank Vegetation/Seeding
	Land Use Responses	Designate Future Floodplains
		Minimize and Avoid Development in Flood Hazard Area
		Land Acquisition/Exchange
		Wetland Conservation/Restoration Areas
Wildfire	Responses to Direct Infrastructure Damage	Maintain Defensible Space and Protect Critical Assets
		Remove Post-Wildfire Debris
		Size Culverts, Bridges, and Drainage Infrastructure to Account for Wildfire Exposure
		Choose Appropriate Materials for Wildfire Prone Areas (For Drainage, Signage, etc.)
	Evacuation Response: Emergency & Communication Responses	Maintain and Update Community Emergency Response and Communication Plan
		Identify Key Evacuation Corridors and Bottlenecks
		Transit Services to Help Facilitate Evacuation
		Community Engagement and Public Education
	Evacuation Responses: Operations & Design Responses	Implement Transportation Design Strategies for Evacuation Events
		Implement Transportation Operations Strategies for Evacuation Events
		Implement General Plan Safety Elements Through Zoning and Subdivision Practices that Provide Adequate and Redundant Evacuation Routes in Wildfire Hazard Areas
		In-Place Shelters for Areas Without Redundant Evacuation Routes
Landslides	Responses to Direct Infrastructure Damage	Implement Zoning and Subdivision Practices that Restrict Development in Landslide Hazard Areas
		Slope Stability Monitoring
		Asset Design Changes in At-Risk Areas
		Natural Infrastructure Solutions
		Maintain and Update a Clean-Up/Debris Management Plan

Application

Fresno COG and its stakeholders can use these adaptation principles and strategies to identify implementable and beneficial responses to climate change impacts across the region. They can be applied to planned or current projects or as standalone projects. More broadly, Fresno County jurisdictions can incorporate the findings of this study into the Safety Elements of their General Plans to satisfy the requirements of SB 379, utilize this study as a foundation to identify the need for future asset-level and site-specific assessments, and to inform adaptation investments in the county.

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APPENDIX

Vulnerability Assessment Summary Memorandum

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

Vulnerability Assessment Summary Memorandum

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March 31, 2020

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Introduction

Project Background

The Fresno Council of Governments (Fresno COG) received grant funding from the California Department of Transportation (Caltrans) under the Senate Bill (SB) 1 Adaptation Planning Grants Program to conduct a Transportation Network Vulnerability Assessment (TNVA) for Fresno County. The TNVA aims to assist Fresno COG and other local agencies in understanding the potential impacts of climate change on the region's transportation infrastructure, identify specific locations that may be affected, and identify strategies to ensure the stability and resiliency of the infrastructure moving into the future. Fresno COG wants to ensure that the region's multimodal transportation network continues to support the area's strong communities and promote positive economic development. Information learned through the TNVA development process will inform not only the next Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) update, but will also provide data for local partner jurisdictions to integrate into their respective General Plans.

Objectives of the Fresno County Regional TNVA development process include:

- ✓ Convene regional partners from multiple jurisdictions.
- ✓ Identify climate change impact risks to multi-modal transportation infrastructure in the project area.
- ✓ Identify specific transportation infrastructure vulnerable to climate change impacts.
- ✓ Develop adaptation strategies and specific actions to remedy identified climate related vulnerabilities.

The development process for the TNVA is guided by a diverse Vulnerability Assessment Working Group (VAWG). The VAWG is responsible for providing both policy and technical guidance and shaping how the TNVA can serve the different communities of Fresno County, and adapt to the potential impacts of climate change.

Document Purpose and Structure

The project's Vulnerability Assessment task focuses on identifying climate change impacts to the transportation system in Fresno County. This memorandum documents the Vulnerability Assessment methodology and results.

The Fresno County Extreme Weather and Climate section discusses historical climate and weather impacts in Fresno County. It broadly summarizes projected changes in the county's climate.

The Engagement and Collaboration Findings section reviews information from the VAWG, stakeholder interviews, and public outreach. The separate Public Outreach Synopsis summarizes the community engagement activities and findings from this project. This Vulnerability Assessment memo draws on the engagement findings, but readers should refer to the Public Outreach Synopsis for detail on the project's community engagement and collaboration process.

The Transportation System Analysis Findings section summarizes the analysis of projected climate impacts on the transportation system in Fresno County. A major component of the analysis was a risk indicator scoring process. The process involved gathering relevant data on climate and assets and combining this information into scores representing the relative risks facing different assets. With these results, one can identify individual assets needing facility-level assessments of future climate threats and responses. Aside from the scoring process, the Additional Analysis section presents analyses of the relationship between high temperature events and transit ridership, and of potential areas of future deep-seated landslide risk in the County.

The Summary section synthesizes the findings from the TNVA and concludes with a discussion of next steps in the project how to use the findings.

Fresno County Extreme Weather and Climate

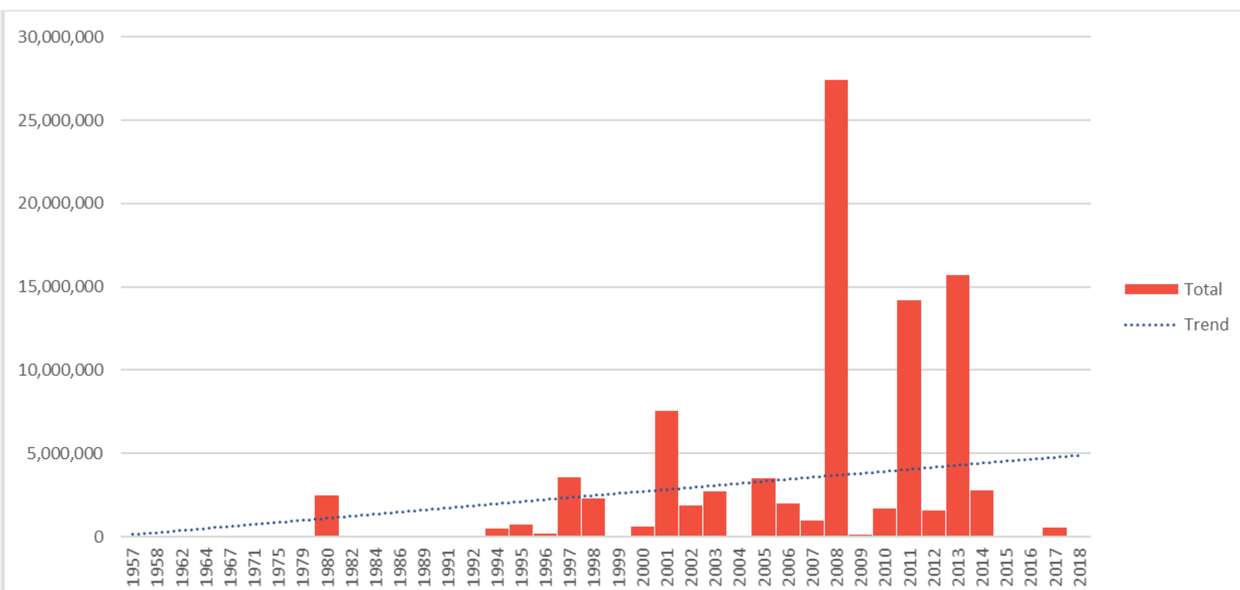
Spanning across the Central Valley and reaching into two major mountain ranges, Fresno County experiences a variety of weather and climate conditions. Extreme heat, riverine flooding, wildfire, drought, dense fog, strong winds and winter storms have affected human activity in different parts of the region in recent years. The impacts of climate change on the planet's natural systems are leading to observable changes in California's environment. Fresno County is likely to experience a future with higher average temperatures and increases in extreme heat events, wildfires, storms, and droughts. The changes in climate are expected to exacerbate related issues, such as air pollution and water supply, and ultimately affect social equity as communities face disproportionate impacts from climate change.

Historical Context

Fresno County's recent Multi-Hazard Mitigation Plan[1] thoroughly summarizes past weather-related events and risks in the region.

For this project, we also reviewed the National Oceanic and Atmospheric Administration (NOAA) Storm Events Database for recent years. Figure 1. Fresno County Property Damage ($) by Year shows storm-related property damage in Fresno County[2] by year, starting in 1957 and ending in 2018. There is a high variation in damages between years. There has also been an upward trend in damages over time. While this study did not review the storm event data collection methodology, it Is possible that there have been changes in methodology over the relatively long period shown on the graph.

Figure 1. Fresno County Property Damage ($) by Year, NOAA Storm Events Database



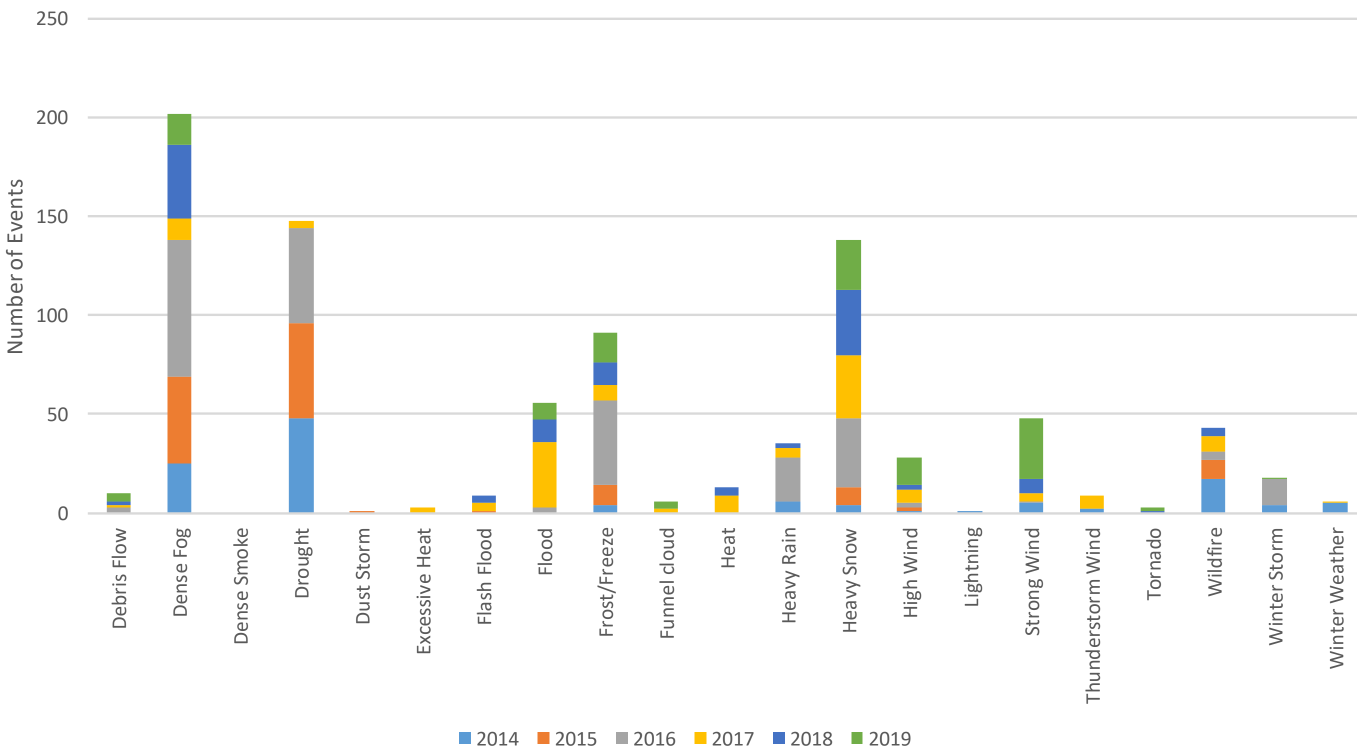
Source: NOAA Storm Events Database

[1] https://www.co.fresno.ca.us/home/showdocument?id=24743

[2] For the NOAA Storm Events Database, Fresno County is defined as: West-Central San Joaquin Valley, East-Central San Joaquin Valley, Mariposa Madera and Fresno County foothills, Sierra Nevada from Yosemite to Kings Canyon, West Side hills, Western San Joaquin Valley, Foggy Bottom, Fresno, Central Sierra Foothills, Central Sierra, North Kings River, and Sequoia Kings.

We analyzed a subset of the most recent NOAA storm event data in greater detail. From January 2014 to April 2019, Fresno County experienced more than 800 storm events that caused a total of 5 deaths, 69 injuries, over $4 million in property damage, and over $50 million in crop damage.[3] These storm events ranged from debris flow to winter weather events (see Figure 2. Number of Events from January 2014 to April 2019 for Fresno County). The county experienced the greatest number of events in 2016 (243 events) and the lowest number of events in 2018 (118 events).

Figure 2. Number of Events from January 2014 to April 2019 for Fresno County, NOAA Storm Events Database



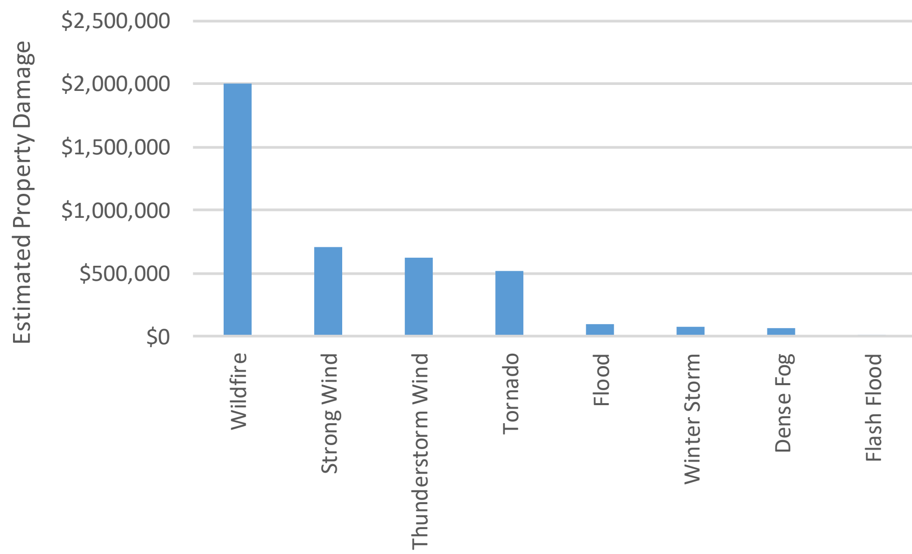
Assuming the events from 2014 to 2018 are a representative sample, the frequency of events occurring in any given year varies on average from 0 to 37 events. The frequencies suggest there is a high probability for occurrences of dense fog, drought, floods, frost/freeze, heavy snow, and wildfire within the county.

Of these storms, a strong wind event on March 5, 2017 was responsible for 1 death, and a wildfire event on July 13, 2018 was responsible for 4 deaths. Injuries were caused by lightning (February 28, 2014) and wildfires (July 13, 2018 and August 8, 2018). Overall, wildfires caused the greatest direct threat in terms of harm to people.

[3] We further reviewed the FEMA disaster declarations and did not identify any major disaster declarations in Fresno County from January 2014 to April 2019. Another type of event – an emergency declaration - can be declared by the President for an emergency for any occasion or instance when the President determines federal assistance is needed. There were 3 such events declared from January 2014 to April 2019.

Wildfires were also responsible for the largest amount of property damage ($2 million), followed by strong winds ($700 thousand) and winds from thunderstorms ($630) (See Figure 3. Property Damage for Fresno County per Storm Event Type from January 2014 through April 2019, NOAA Storm Events Database.

Figure 3. Property Damage for Fresno County per Storm Event Type from January 2014 through April 2019, NOAA Storm Events Database

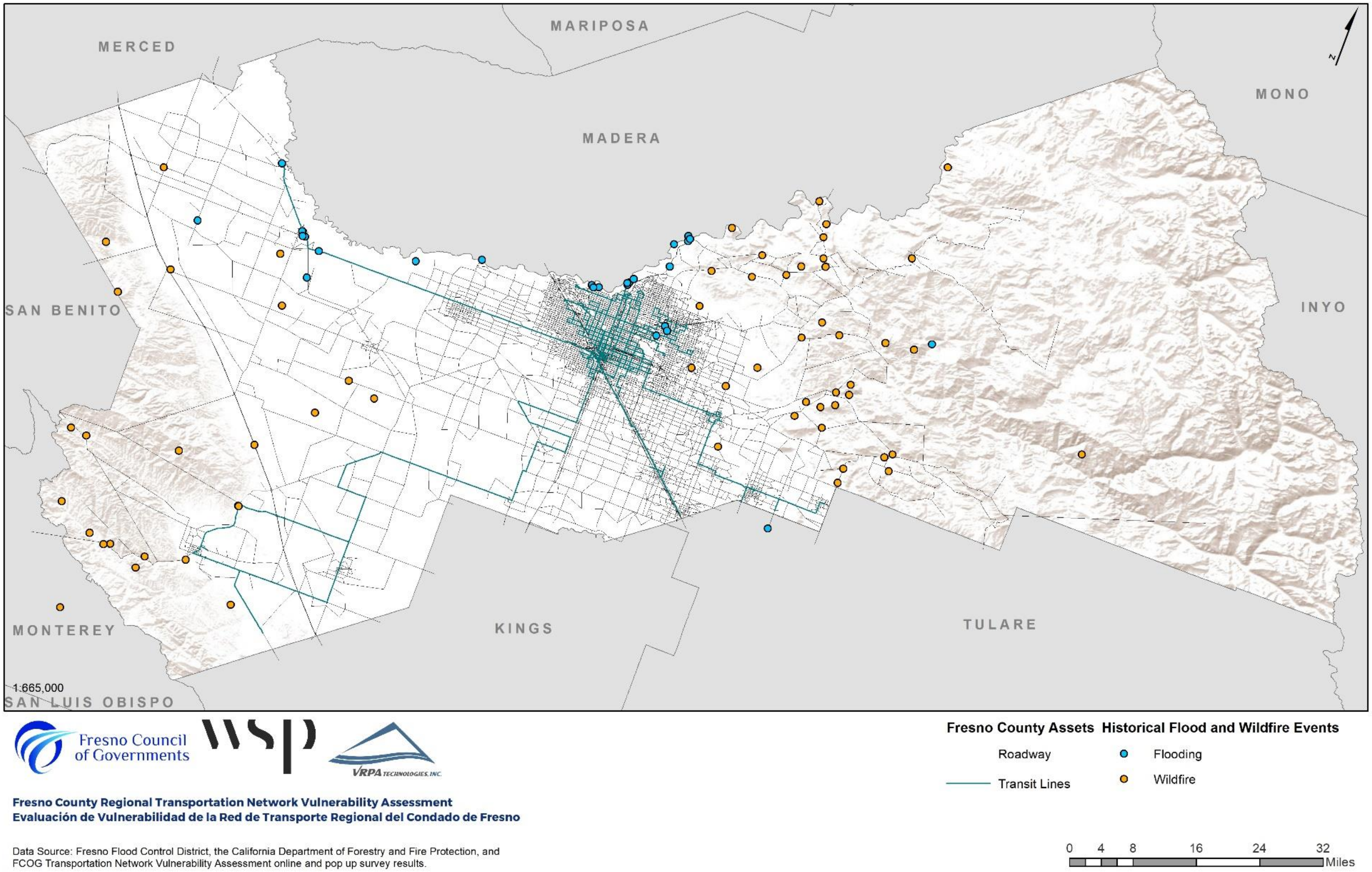


Crops in Fresno County have been damaged by frost/freeze events and strong wind events. A frost/freeze event on February 20, 2018 was responsible for $50M of crop damage, while a strong wind event on December 11, 2014 accounted for $500k of crop damage.

We also reviewed news archives and incident reports for information about the location, type, and year of historical storm events and damages in Fresno County. Historical flood event information was collected by reviewing archived newspapers compiled by the Fresno Metropolitan Flood Control District, which documented the major storms of 1996 to 1998. Past wildfire event information was collected by reviewing California Department of Forestry and Fire Protection (CalFire) incident reports that dated back to 2006. Using these sources, we identified 90 locations impacted by flooding and wildfire (see Figure 4. Fresno County Historical Flood and Wildfire Events).

We later combined this information with input on past events from community members and stakeholders. The Engagement and Collaboration Findings section presents these results.

Figure 4. Fresno County Historical Flood and Wildfire Events



Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Data Source: Fresno Flood Control District, the California Department of Forestry and Fire Protection, and FCOG Transportation Network Vulnerability Assessment online and pop up survey results.

Future Projections

California's Fourth Climate Change Assessment provides a thorough overview of the expected effects of climate change in the state.[4]

As part of this study, we obtained projections from climate models and other sources to better understand how Fresno County's climate is likely to change in the future. Global Climate Models (GCM) simulate climate over time, drawing on physics, climatology, and historical climate observations. They use assumptions about greenhouse gas emissions and other factors to forecast future climate conditions.

Downscaling is the process of enhancing the resolution of these GCMs, which are global in scale, for use at a regional scale. Scripps Institute of Oceanography used a process called Localized Constructed Analogs (LOCA) to downscale thirty-two GCMs for California.[5] In California, ten downscaled GCMs were assessed by state agencies as being most representative of climate change across the state.[6] Data from these models is housed on Cal-Adapt, which is a public web-based platform that provides downscaled GCM projections and other information on climate change in California.[7] We generally used these ten GCMs for this study.

In general, we used two greenhouse gas emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), a major international research institution that provides scientific research on climate change to help policy and decision makers. The scenarios are called Representative Concentration Pathways (RCPs). RCP 4.5 assumes that global annual GHG emissions peak around 2040 and then decline. RCP 8.5 corresponds more closely to the current status quo; it assumes that emissions continue to rise until the end of the century.[8]

We were generally consistent with Caltrans' use of GCMs, RCPs, and timeframes that it uses in its Climate Change Vulnerability Assessment. The Caltrans District 4 Climate Change Vulnerability Report describes the same timeframes used in this study:

> *For this study, analysis periods were defined as the beginning, middle, and end of century, and were represented by the out-years of 2025, 2055, and 2085, respectively. These years are chosen because some statistically-derived climate metrics used in this report (e.g. the 100-year precipitation event) are typically calculated over 30-year time periods centered on the year of interest. Because currently available climate projections are only available through the end of the century, the most distant 30-year window runs from 2070 to 2099. The year 2085 is the center point of this time range, and thus the last year in which statistically derived projections can defensibly be made. The 2025 and 2055 out-years follow from the same logic, but applied to each of the prior 30-year periods (2010 to 2039 and 2040 to 2069, respectively).*[9]

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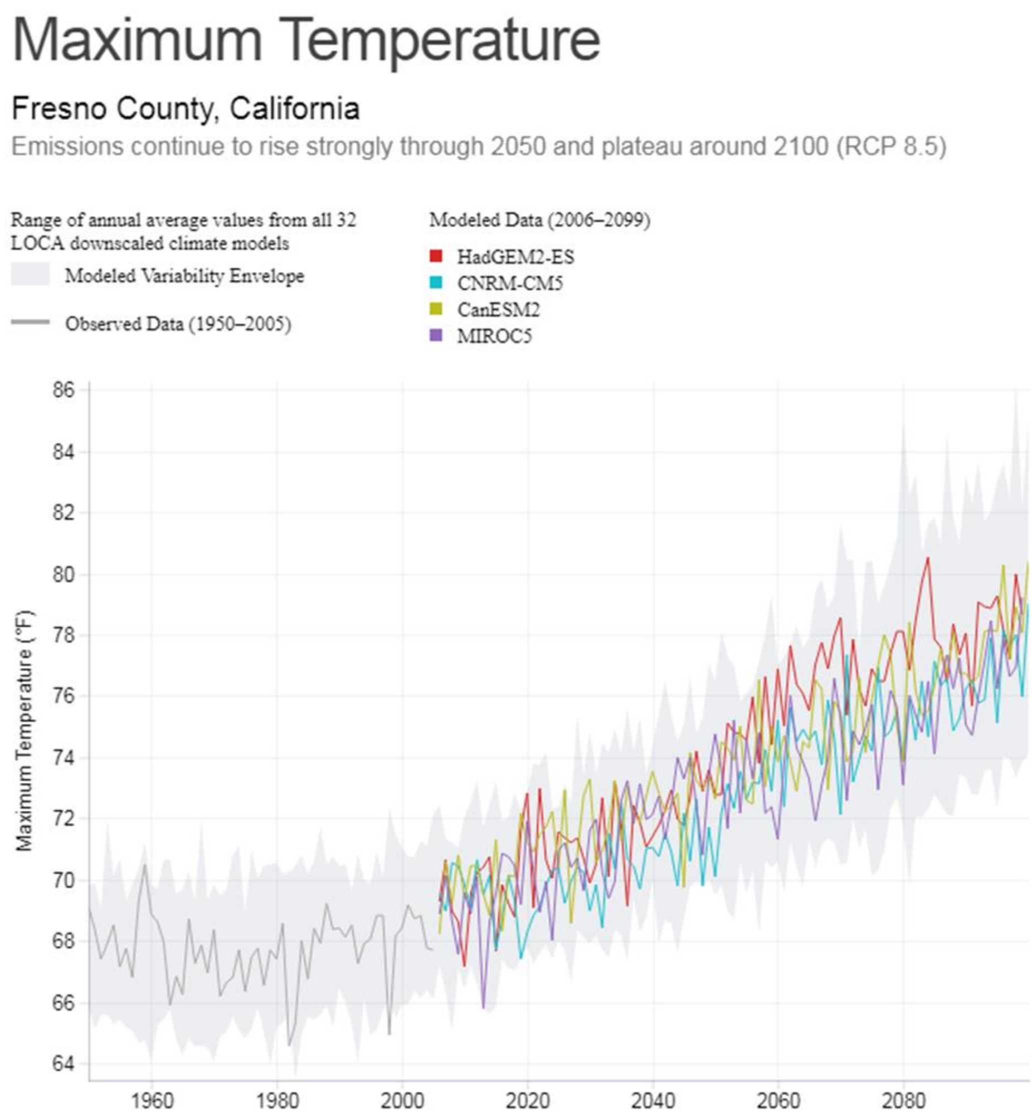
[4] The Statewide Summary Report is available here: https://www.energy.ca.gov/sites/default/files/2019-07/Statewide%20Reports-%20SUM-CCCA4-2018-013%20Statewide%20Summary%20Report.pdf
[5] http://loca.ucsd.edu/
[6] http://www.water.ca.gov/climatechange/docs/2015/Perspectives_Guidance_Climate_Change_Analysis.pdf. The models are: ACCESS 1-0, CanESM2, CCSM4, CESM1-BGC, CMCC-CMS, CNRM-CM5, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, and MIROC5.
[7] https://cal-adapt.org
[8] Meinshausen, M.; et al. (November 2011), "The RCP greenhouse gas concentrations and their extensions from 1765 to 2300 (open access)", Climatic Change, 109 (1-2): 213–241.
[9] Caltrans (2017), "*Climate Change Vulnerability Assessments, District 4 Technical Report*".

The following figures show future projections for Fresno County. The Transportation System Analysis Findings section relates the information from the climate projections to the transportation system.

Figure 5. Fresno County Maximum Temperature is from Cal-Adapt and shows the projected average daily maximum temperature in Fresno County under the RCP 8.5 ‘status quo’ emissions scenario for four of the ten GCMs used in this study. There is high agreement between the models that temperatures will rise considerably over the rest of the century.

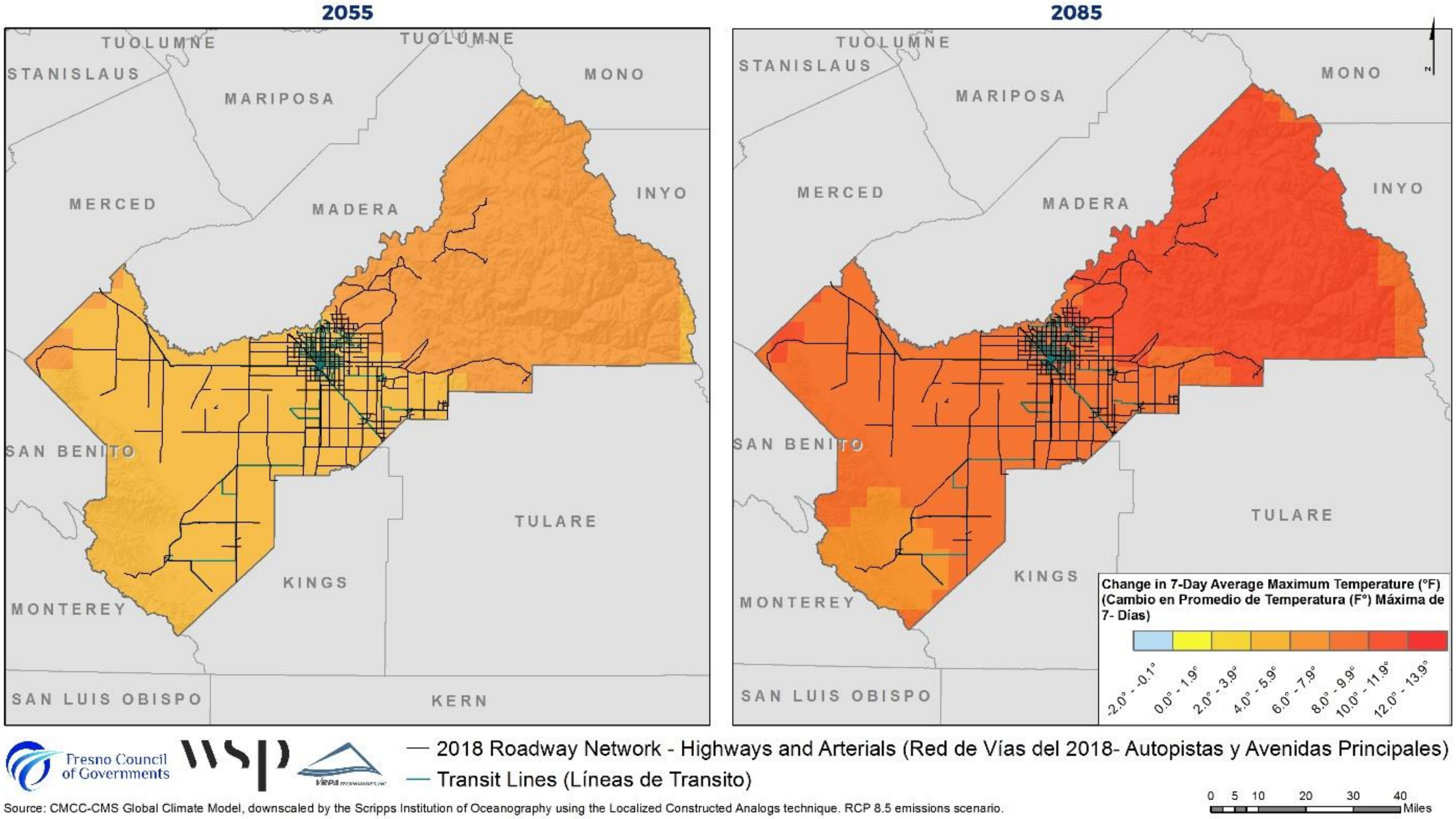
Figure 5. Fresno County Maximum Temperature Projections, RCP 8.5, Cal-Adapt



According to Cal-Adapt, the average daily maximum temperature for Fresno County is expected to increase from 67 °F to approximately 77 °F by end of century (RCP 8.5, model average, 1961-1990 baseline compared to 2070-2099). Also per Cal-Adapt, the average number of extreme heat days (>105.4°F, the 98th percentile daily maximum temperature) per year in the City of Fresno is expected to increase from 7 to approximately 66 by end of century (RCP 8.5, model average, 1961-1990 baseline compared to 2070-2099).

Figure 6. Fresno County Projected Change in 7-Day Average Maximum Temperatures spatially depicts the 7-day average maximum temperature for one of ten GCMs (CMCC-CMS) for two different future timeframes (2055 and 2085). The 7-day average maximum temperature is a parameter often used for pavement binder grades. The spatial pattern shows relatively consistent increases across Fresno County, with the northwestern portion of the county experiencing somewhat higher increases.

Figure 6. Fresno County Projected Change in 7-Day Average Maximum Temperatures, CMCC-CMS, RCP 8.5



Source: CMCC-CMS Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario.

There is much less agreement between the models regarding future precipitation patterns. Figure 7. from Cal-Adapt shows the projected annual precipitation for four of the ten GCMs under RCP 8.5. The model average shows an increase in annual precipitation, but the variability between models and between years within the models is high.

Figure 7. Fresno County Annual Precipitation Projections, RCP 8.5, Cal-Adapt

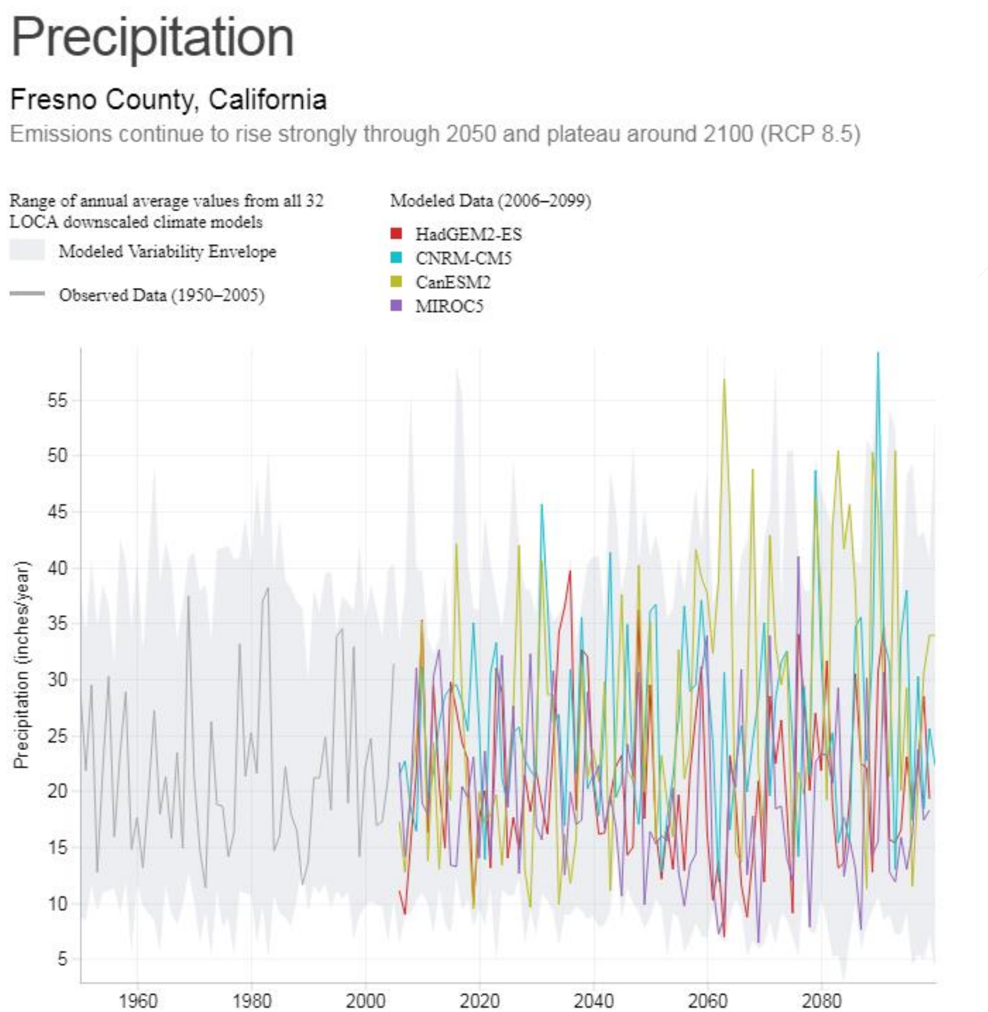


Figure 8. City of Fresno 100-Year/24-Hour Precipitation Event Projections, RCP 8.5, Cal-Adapt shows Cal-Adapt extreme precipitation projections for the City of Fresno under the same four GCMs. It shows the 100-year/24-hour[10] event for the historical timeframe and two future timeframes. The gray lines show the 95% confidence intervals for the projections. Most of the models show increases in the 100-year event, though the confidence intervals are very wide, indicating the uncertainty of future heavy precipitation conditions in the area.

[10] The 100-year event has a 1% chance of occurring in a given year. 24-hour is the duration of the period for which the precipitation event is measured.

Figure 8. City of Fresno 100-Year/24-Hour Precipitation Event Projections, RCP 8.5, Cal-Adapt

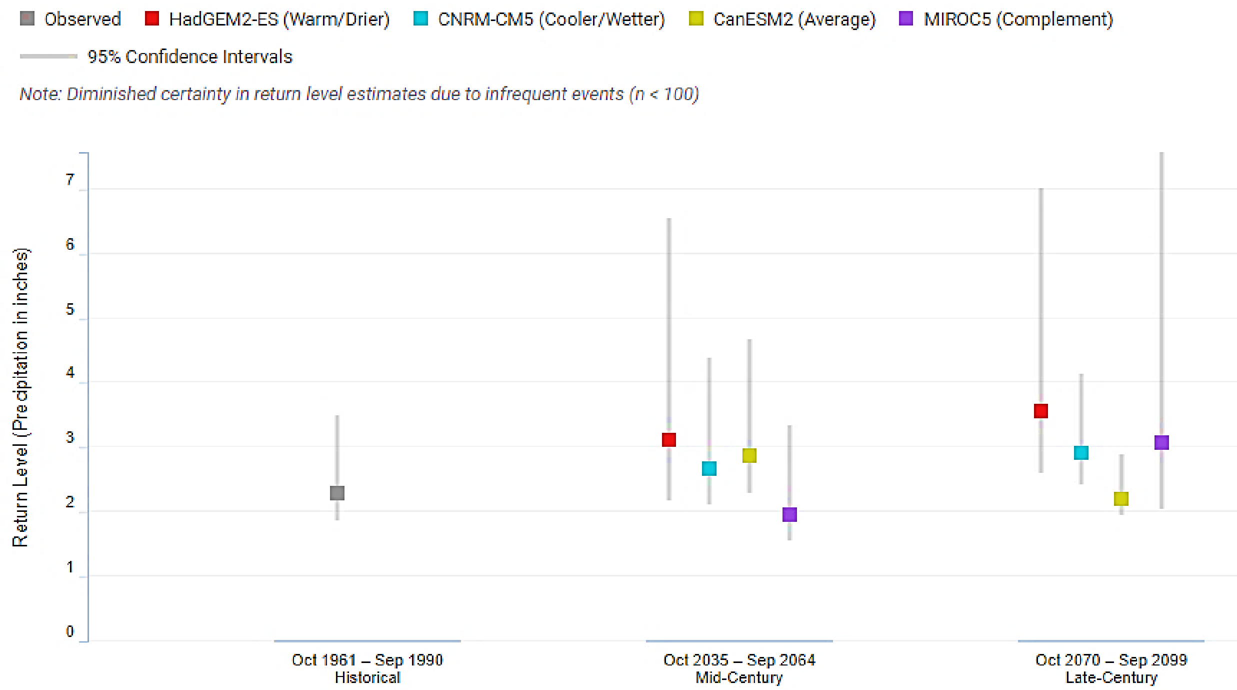
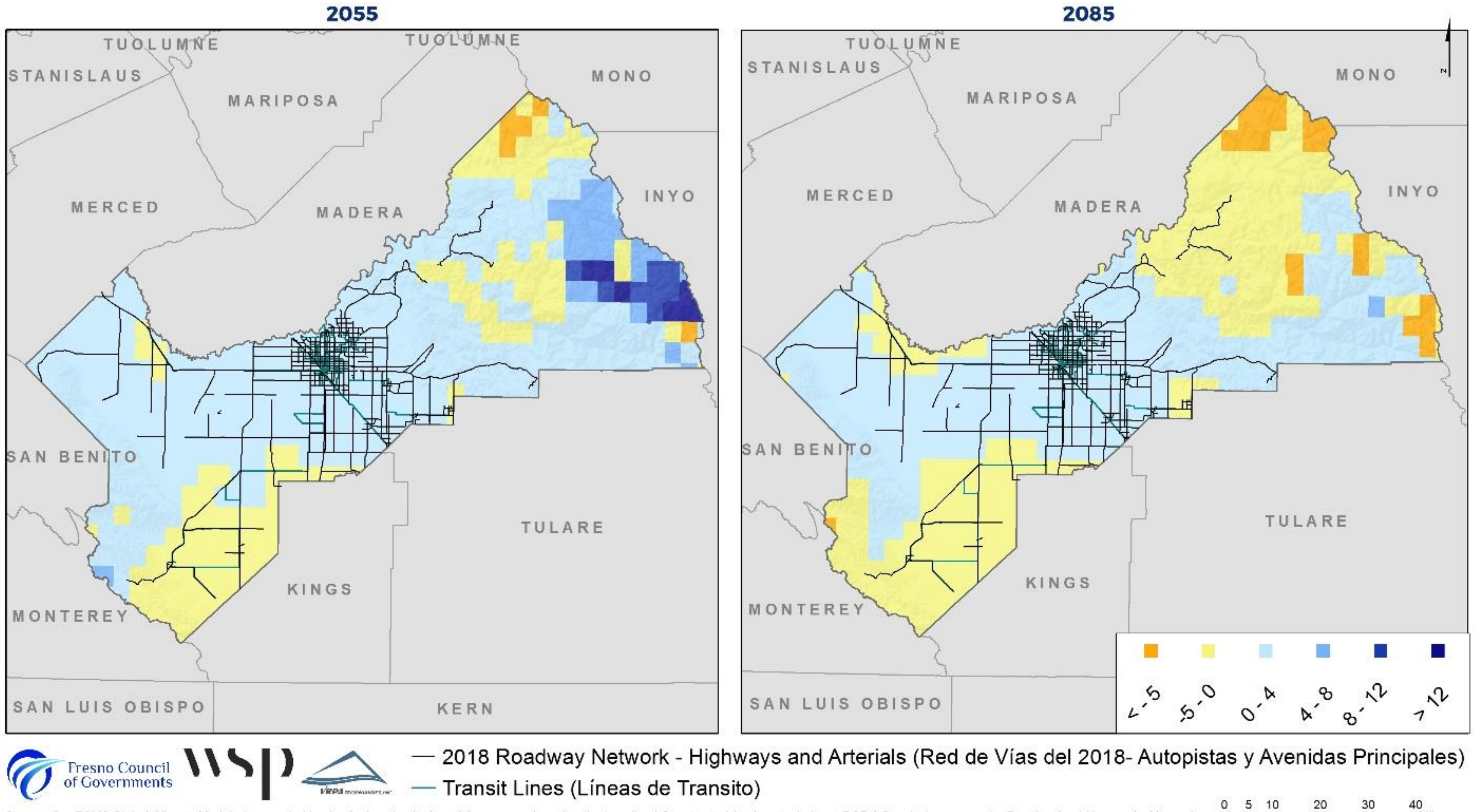


Figure 9. depicts spatially the projected change (in inches) of the 100-year precipitation event for one of the GCMs (CanESM2). For all climate projections, especially for precipitation, it is important to look at multiple models. For the model shown on this map, the largest increases and decreases in heavy precipitation occur in the Sierra Nevada, where precipitation levels are comparatively higher than the rest of the County.

Figure 9. Fresno County Projected Change in 100-Year Precipitation Event, CanESM2, RCP 8.5 (units: inches)



Source: CanESM2 Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario. Results should be used with caution.

Rising temperatures dry out soils and vegetation, which increases wildfire risk in Fresno County. Figure 10. Fresno County Area Burned Projections, RCP 8.5, Cal-Adapt from Cal-Adapt shows projections of area burned in the county from multiple climate models under RCP 8.5. Under that scenario, the historical average annual area burned is expected to increase from about 15,000 hectares historically to approximately 44,000 hectares at the end of century, with high variability between years within the models.

Figure 10. Fresno County Area Burned Projections, RCP 8.5, Cal-Adapt

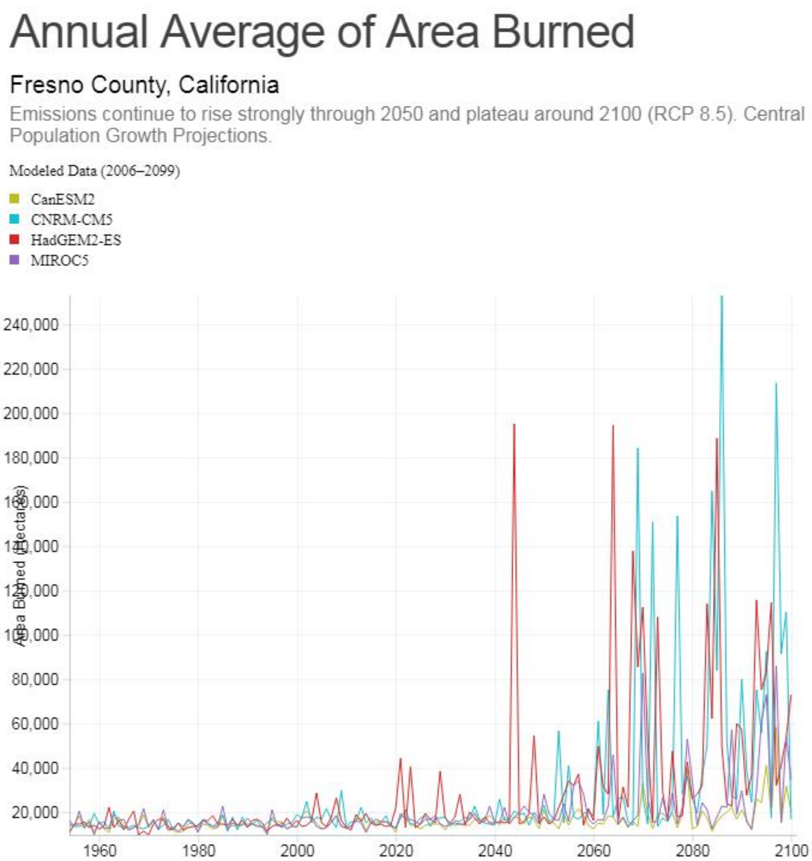
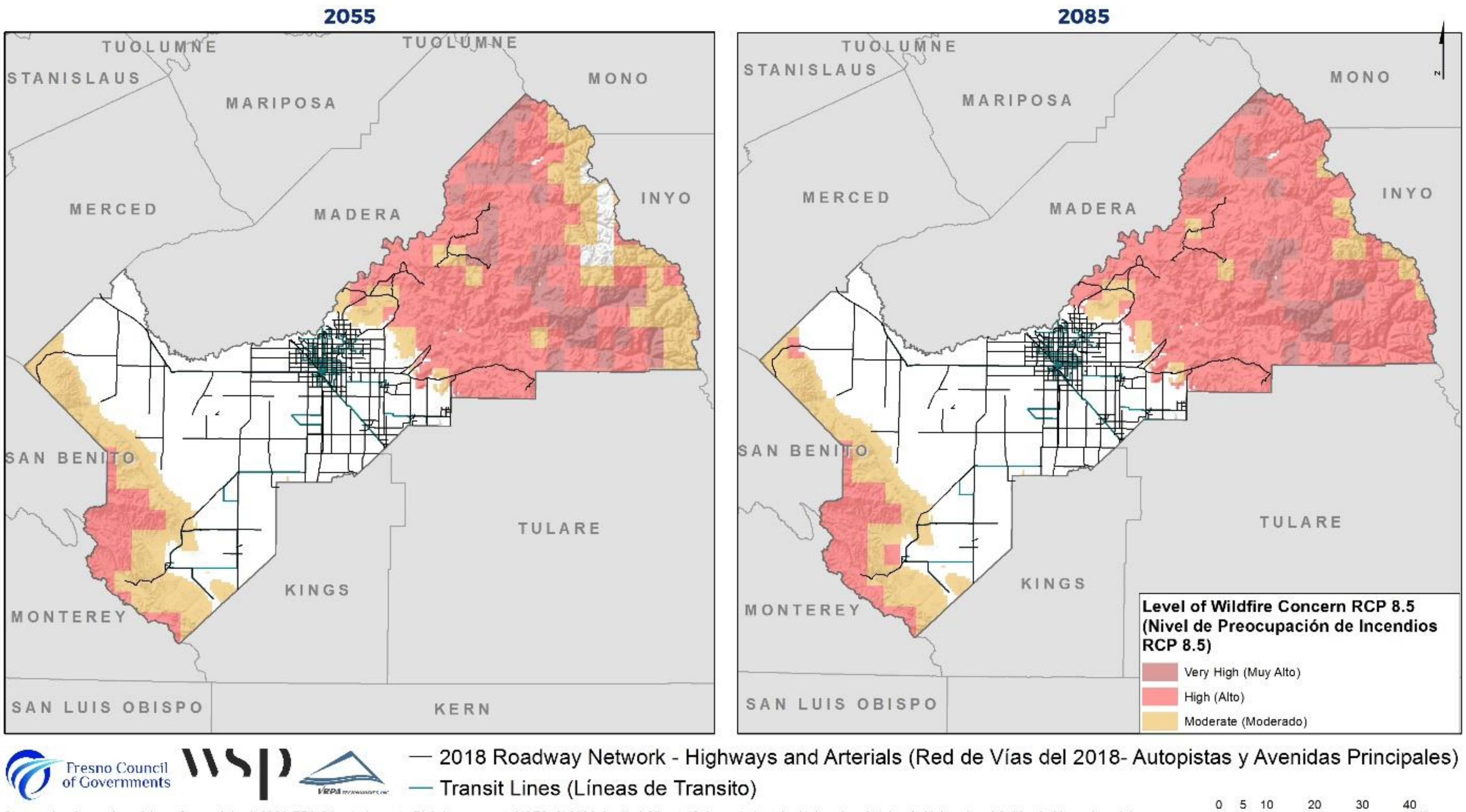


Figure 11. shows the relative level of wildfire concern for a composite of GCMs and wildfire models, with high or very high levels of concern in the Sierra Nevada and foothills and moderate or high levels of concern for the Coastal Range at the western edge of the county.[11]

[11] The fire model composite summaries shown are based on wildfire projections from three models: 1) MC2 – EPA Climate Impacts Risk Assessment, developed by John Kim, USFS; 2) MC2 – Applied Climate Science Lab at the University of Idaho, developed by Dominique Bachelet, University of Idaho; and 3) University of California Merced model, developed by Leroy Westerling, UC Merced. For each of these wildfire models, climate inputs were used from three Global Climate Models: 1) CAN ESM2, 2) Had_GEM2-ES, and 3) MIROC5. Data shows the multi-model maxima for each grid cell across the nine combinations of the three fire models and three GCMs. A classification was developed based on the expected percentage of cell burned. The classification is: 1) Very Low 0-5%, 2) Low 5-15%, 3) Moderate 15-50%, 4) High 50-100%, 5) Very High 100%+. Time periods are averages of 30-year periods. Projected increases in wildfire are compared to a historical backcasted period from 1975 to 2004. Emissions scenarios used are RCP 4.5 or RCP 8.5, representing low and high emissions, respectively.

Figure 11. Fresno County Levels of Wildfire Concern, Multi-Model Ensemble, RCP 8.5



Source: Amalgamation of three fire models: 1) MC2-EPA Climate Impacts Risk Assessment, USFS, 2) MC2-Applied Climate Science Lab at the University of Idaho, 3) University of California Merced model.

In addition to the projections analyzed for this study, which focus primarily on Fresno County's transportation system, there are other helpful resources for understanding the broader impacts of climate change on Fresno County, such as drought, groundwater depletion, and subsidence. These sources include:

- **California's Fourth Climate Change Assessment: Climate Change Risk Faced by the California Central Valley Water Resource System.** This paper reviews climate change risks to the integrated California Central Valley System (CCVS) and discusses specific vulnerabilities to this key water system.[12]
- **Central Valley Hydrologic Model.** The US Geological Survey (USGS) developed the Central Valley Hydrologic Model (CVHM) to understand how water use, precipitation, and land use changes will affect surface and groundwater flows in the Central Valley. The model's simulations based on a warmer, drier California show that stream flows may decline by up to 40%, which will increase groundwater demand across the region. The effects of increased groundwater draw-down include increased streamflow infiltration, reduced outflow to the Delta, and increased subsidence rates.[13]
- **Central Valley Flood Protection Plan.** This plan seeks to improve flood risk management in the Central Valley and develop strategies for reducing risk that provide multiple benefits, including transportation system protection. The most recent update was released in 2017 and includes climate change considerations such as more frequent extreme precipitation, changes in flood magnitudes and frequencies, sea level rise, and increased subsidence.[14]
- **California's Fourth Climate Change Assessment: Management of Groundwater and Drought Under Climate Change.** Climate change is projected to alter the natural recharge of groundwater. Decreased inflow from runoff, increased evaporative losses, and warmer and shorter winter seasons are expected to exacerbate existing groundwater overdraft in many basins. The surface water that can be delivered from the Central Valley Project (CVP) and State Water Project (SWP) to areas reliant on this water for groundwater recharge and consumptive use is projected to be less reliable and more expensive.[15]
- **California's Fourth Climate Change Assessment: Assessment of California Crop and Livestock Potential Adaptation to Climate Change.** This report discusses climate change challenges facing California agriculture and how it is likely to adapt to those challenges, focusing on Central Valley crops, the dairy industry, and the beef cattle grazing industry.[16]
- **California's Fourth Climate Change Assessment: Drought Impacts and Drought Vulnerability in Rural Communities of California's San Joaquin Valley.** This report examines the drought vulnerability of farmworkers both in the fields and in their communities by analyzing how changes in water resources and agricultural practices impact socioeconomic drought.[17]
- **California Department of Conservation, Summary and Compilation of Landslide Information for California.** This resource provides background on the history of landslide mapping, the types of landslides that occur in California, and landslide susceptibility mapping. The page also compiles a

[12] http://www.climateassessment.ca.gov/techreports/docs/20180827-Water_CCCA4-EXT-2018-001.pdf
[13] https://ca.water.usgs.gov/projects/central-valley/central-valley-hydrologic-model.html
[14] http://cvfpb.ca.gov/docs/2017CVFPPUpdateFinal/2017CVFPPUpdate-Final-20170828.pdf
[15] http://www.climateassessment.ca.gov/techreports/docs/20180827-Water_CCCA4-EXT-2018-006.pdf
[16] http://www.climateassessment.ca.gov/techreports/docs/20180827-Agriculture_CCCA4-CNRA-2018-018.pdf
[17] http://www.climateassessment.ca.gov/techreports/docs/20180928-PublicHealth_External_Greene.pdf

list of other relevant sources, such as the California Landslide Inventory, a summary of California's Susceptibility to Deep-Seated Landslides, and the USGS National Landslides Hazards Program.[18]

- **California Institute of Technology Jet Propulsion Laboratory, Subsidence in California, March 2015 - September 2016.** This study developed maps of subsidence in the San Joaquin Valley. The two main subsidence bowls in the Central Valley are settling north and south of Fresno. The western portion of the county is subsiding.[19]
- **Joint Center for Political and Economic Studies, Place Matters for Health in the San Joaquin Valley.** This study examines the relationships between place, race and ethnicity, and health in the San Joaquin Valley of California. Some key findings of the study are[20]:
    - The rate of premature deaths in the lowest-income zip codes of the San Joaquin Valley is nearly twice that of those in the highest-income zip codes.
    - Life expectancy varies by as much as 21 years in the San Joaquin Valley depending on zip code.
    - One in six children in the San Joaquin Valley is diagnosed with asthma before the age of 18, an epidemic level.
    - In the San Joaquin Valley, the communities with the highest levels of premature mortality are in San Joaquin County, central Stanislaus, western and central Fresno, north central Tulare, as well as central and eastern portions of Kern County.

[18] https://www.conservation.ca.gov/cgs/geohazards/landslides

[19] https://water.ca.gov/LegacyFiles/waterconditions/docs/2017/JPL%20subsidence%20report%20final%20for%20public%20dec%202016.pdf

[20] http://www.fresnostate.edu/chhs/cvhpi/documents/cvhpi-jointcenter-sanjoaquin.pdf

Engagement and Collaboration Findings

The vulnerability assessment included several community engagement and stakeholder collaboration activities. To engage with the community, the project team conducted several pop-up events, an in-person and online survey, and a 'hot spot' exercise where community members identified locations that have experienced past weather-related issues. To collaborate with stakeholders, the project team established and held meetings with a Vulnerability Assessment Working Group (VAWG) and interviewed key transportation stakeholders about vulnerabilities in the system.

The separate Public Outreach Synopsis summarizes the community engagement activities and findings from this project in detail. The following two subsections highlight key findings from the engagement and collaboration.

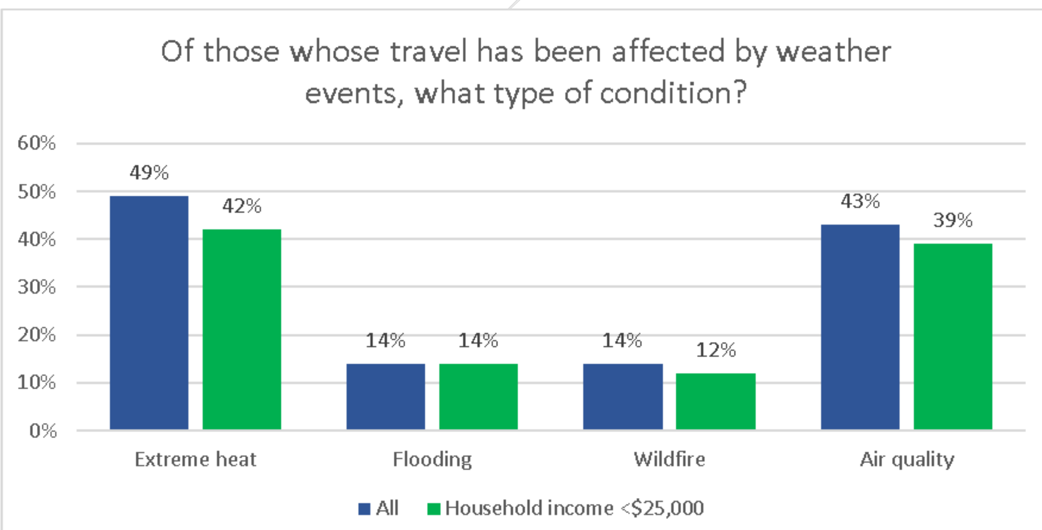
Public Outreach

Between the in-person and online surveys, we gathered 243 responses from the public. 68 of these were from individuals who reported household income of less than $25,000.[21]

Of all survey respondents, 43% reported that weather events or conditions have either affected their travel or required them to evacuate. A higher share, 57%, of those with household incomes under $25,000 reported that weather events or conditions have either affected their travel or required them to evacuate.

Of those whose travel has been affected, extreme heat and air quality were the two most frequently reported hazards. Figure 12. shows the breakdown by event type for both all respondents and for respondents with household incomes below $25,000.

Figure 12. Public Survey Result: Type of Event Affecting Travel



[21] This is slightly below the U.S. Census Bureau's 2018 poverty threshold of $25,465 for a family of four with two children (https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html).

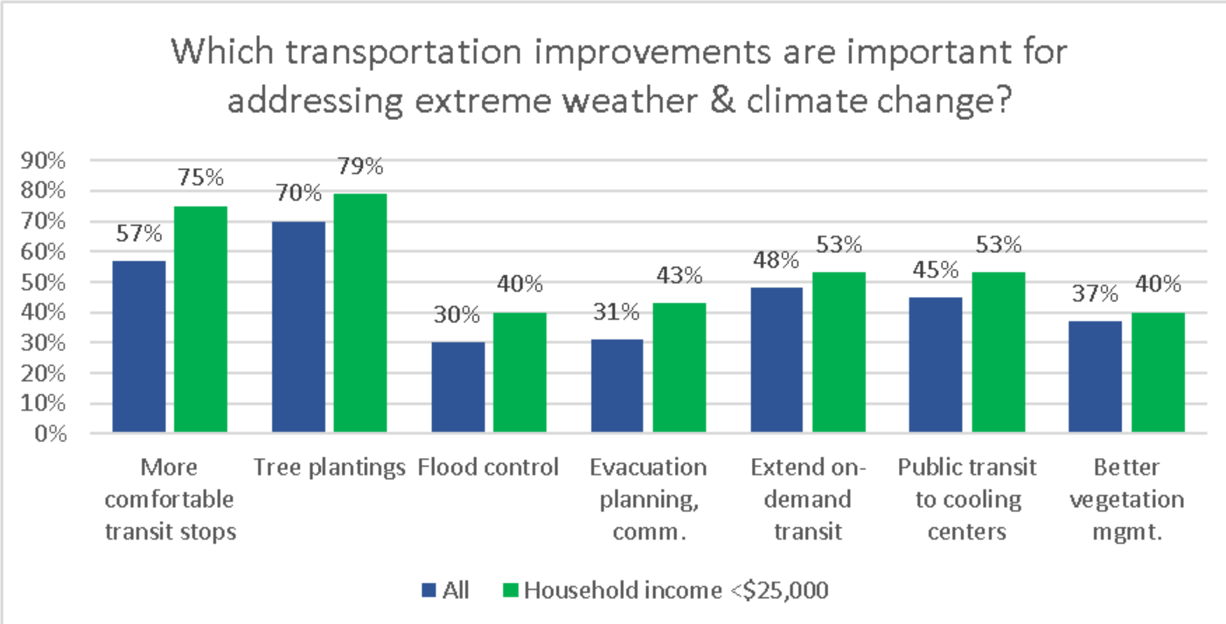
Participants were asked to rank their level of concern about seven types of potential climate change impacts (see Table 1. Public Survey Result: Average Ranking for Level of Concern). One was the highest level of concern, and seven was the lowest level of concern. For all respondents, the highest average ranking was for extreme heat (2.4), followed closely by drought (2.6), and air quality (2.8). The top three average rankings were the same for individuals with household incomes less than $25,000 compared to the overall population (extreme heat followed by drought and air quality). For both groups, wildfire had the fourth highest average ranking, followed by flooding, subsidence, and landslides/erosion. The lower average levels of concern for discrete events like wildfires, flooding, and landslides, are unsurprising because they are experienced in limited portions of the county. Extreme heat, drought, and air quality typically occur more frequently, in a wider geographic portion of the county, and in the most populous portions of the county.

Table 1. Public Survey Result: Average Ranking for Level of Concern

Climate Change Impact	All	Household income <$25,000
Extreme Heat	2.4	2.2
Drought	2.6	2.8
Air Quality	2.8	3.0
Wildfires	4.1	4.1
Flooding	4.6	4.5
Subsidence	5.2	5.4
Landslides/Erosion	5.7	5.7

Participants responded to a question about which transportation improvements are important for addressing extreme weather and climate change. They could select more than one option. Both the all respondent and low-income respondent groups listed “tree plantings along roadways and sidewalks” the most frequently (70% and 79%, respectively). Results were generally consistent across the two groups. However, a substantially higher percentage of low-income answered highlighted “comfortable and shaded transit stops” (75% versus 57%). Other popular options included “expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.), during high heat or other extreme weather events” and “public transit service to cooling centers on high heat days.”

Figure 13. Public Survey Result: Transportation Improvements to Address Climate Change



The next several pages show maps of some of the information obtained during the public engagement process. Figure 14. Fresno County Pop Up and Survey Results – Number of Responses by Zip Code maps the number of survey respondents by zip code. Pop-up events were held and well attended in Reedley and Kerman, so the respondent numbers from those zip codes are particularly high. Figure 15. Fresno County Pop Up and Survey Results – Percent of Responses that Reported an Income of Less than $15k shows the percentage of respondents within each zip code who reported household incomes of less than $15,000. Figure 16. Fresno County Pop Up and Survey Results – Percent of Responses that Reported a Travel Impact due to Weather shows the percentage of respondents within each zip code who reported a travel impact due to a weather condition or event. Figure 17. Fresno County Pop Up and Survey Results – Percent of Responses Indicating that Public Transit to Cooling Centers is an Important Response to Extreme Weather and Climate Change shows the percentage of respondents within each zip code who indicated that public transit to cooling centers is an important adaptation response to extreme weather and climate change.

Figure 14. Fresno County Pop Up and Survey Results – Number of Responses by Zip Code

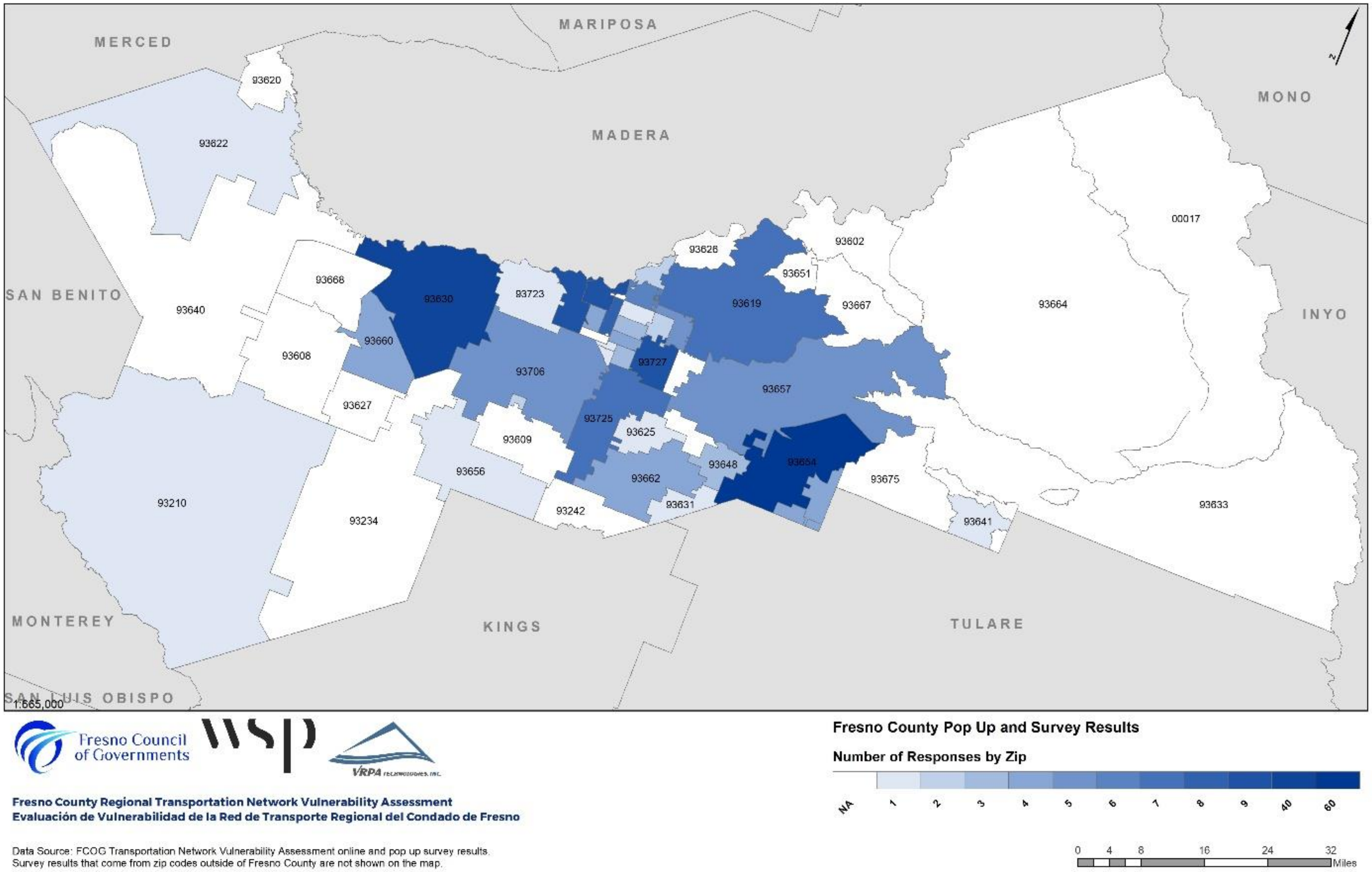


Figure 15. Fresno County Pop Up and Survey Results – Percent of Responses that Reported an Income of Less than $15k

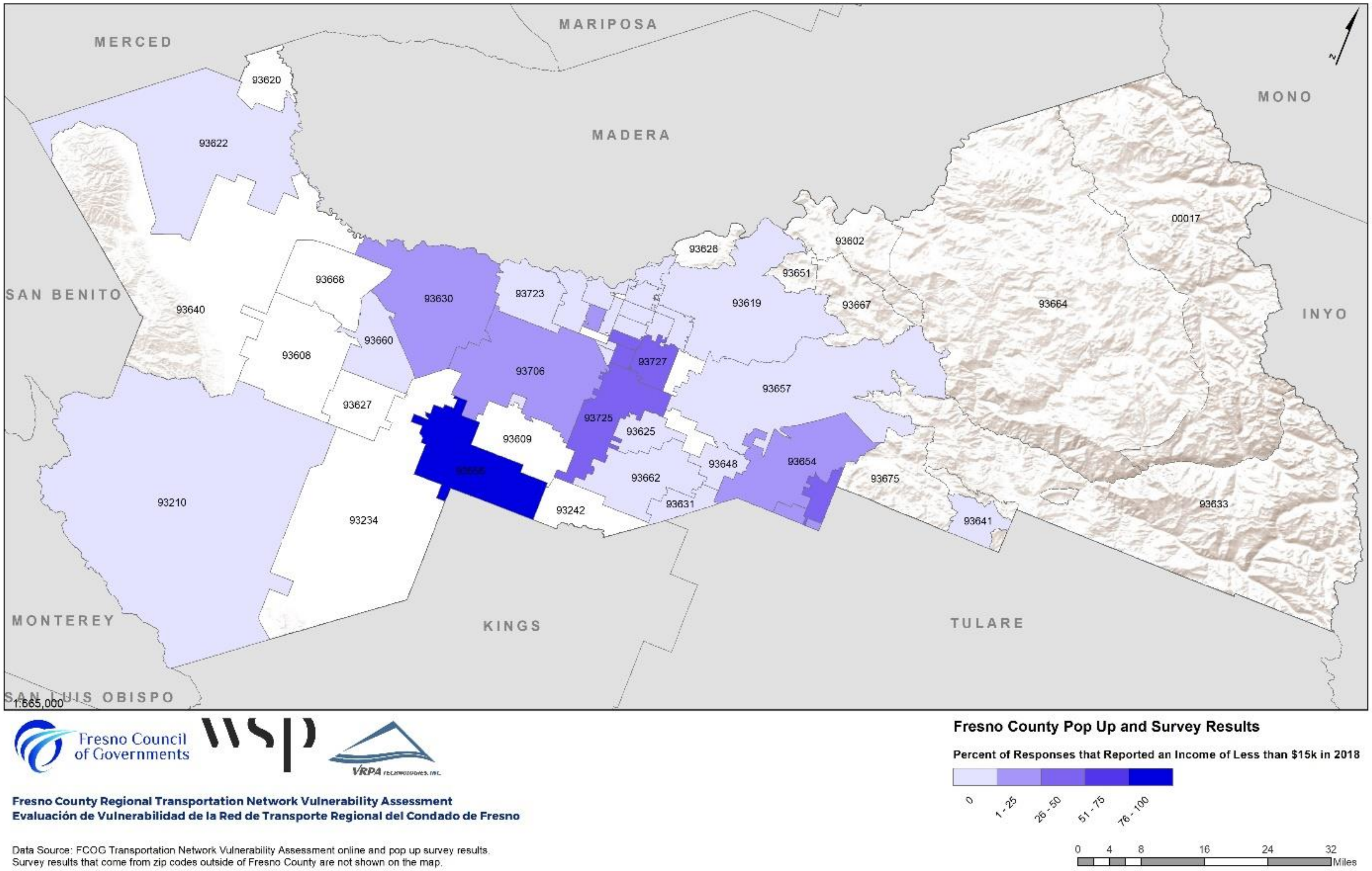


Figure 16. Fresno County Pop Up and Survey Results – Percent of Responses that Reported a Travel Impact due to Weather

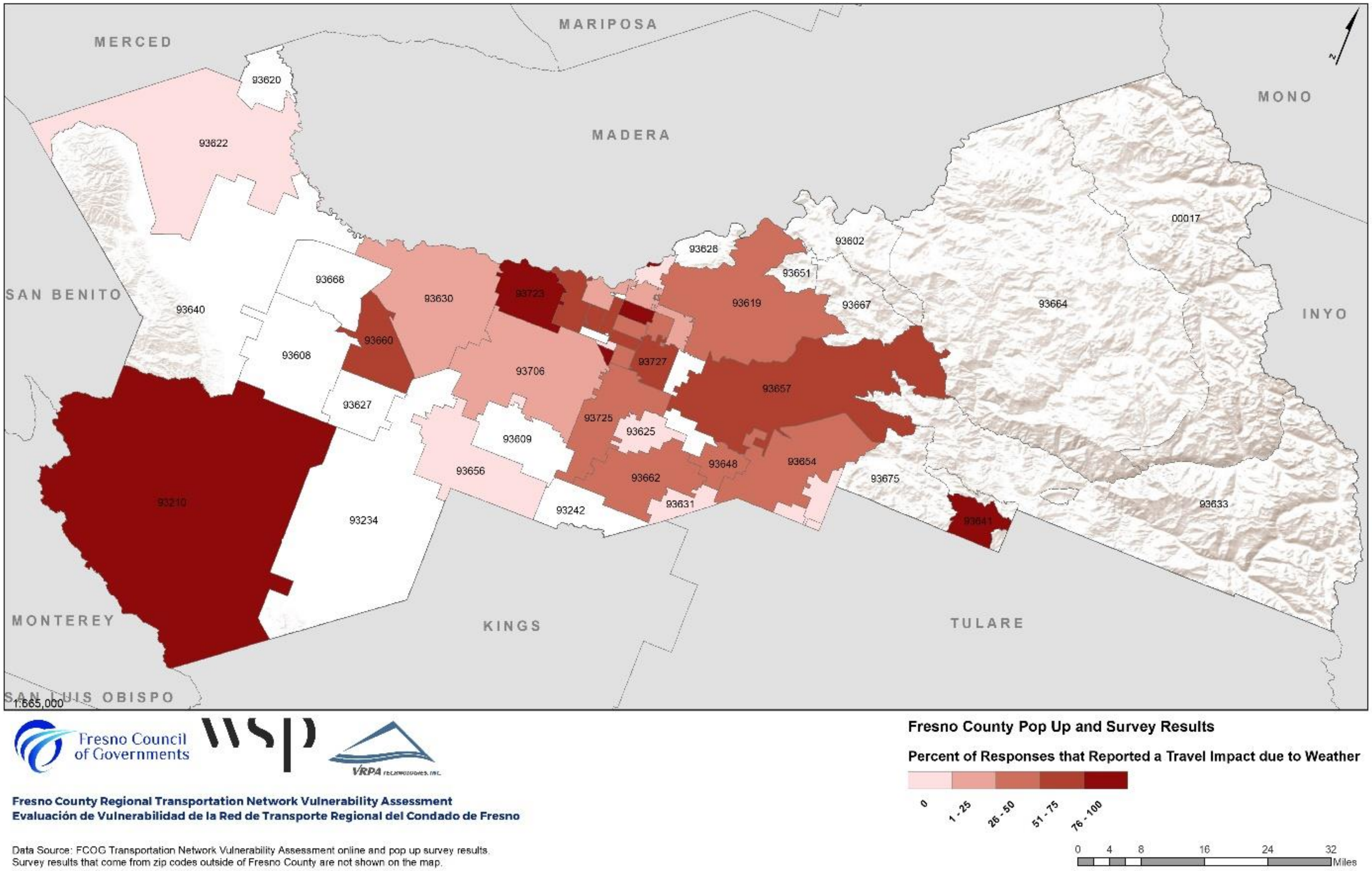
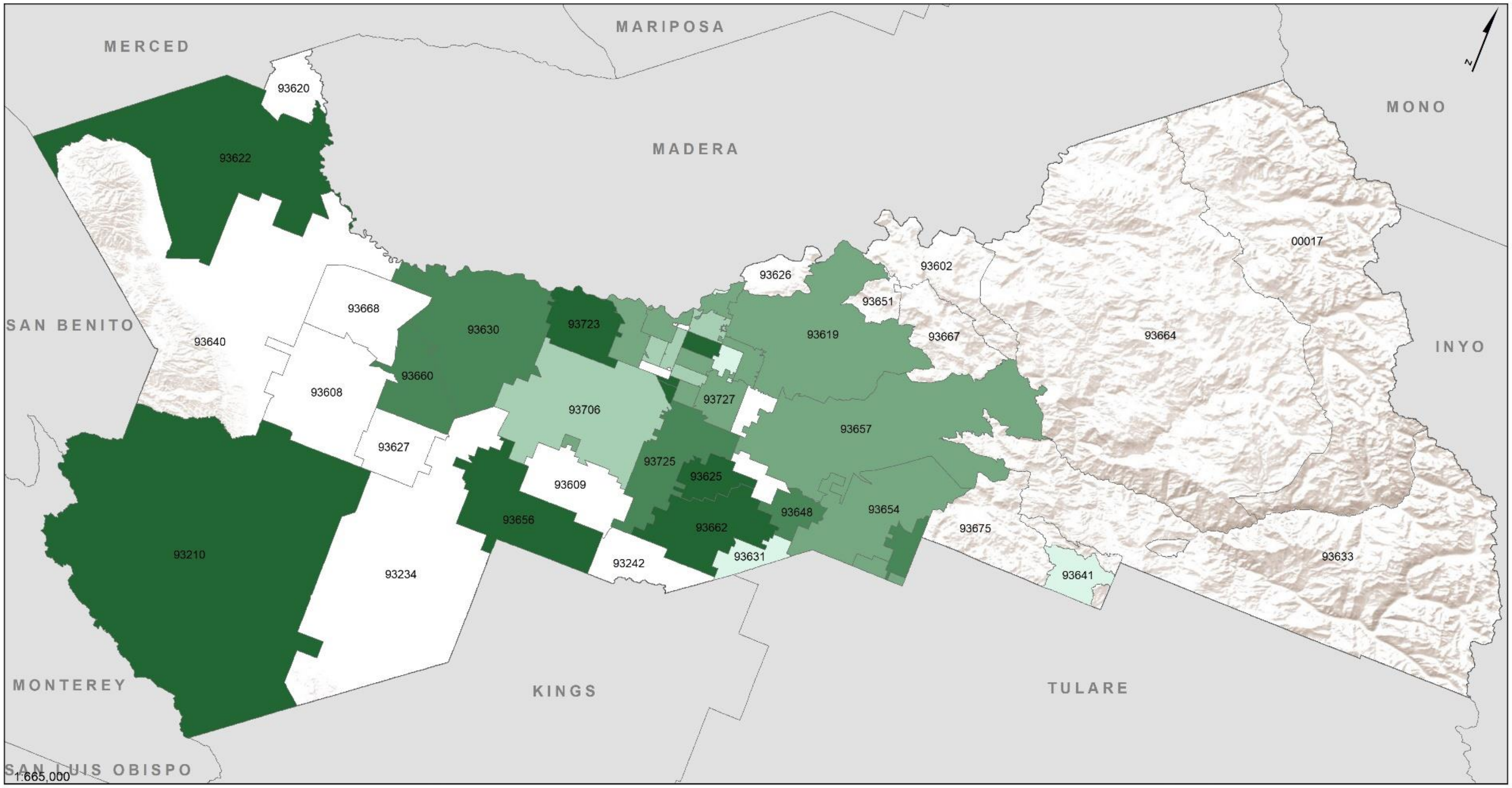
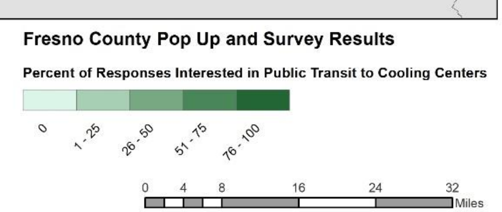


Figure 17. Fresno County Pop Up and Survey Results – Percent of Responses Indicating that Public Transit to Cooling Centers is an Important Response to Extreme Weather and Climate Change





Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Data Source: FCOG Transportation Network Vulnerability Assessment online and pop up survey results.
Survey results that come from zip codes outside of Fresno County are not shown on the map.

Vulnerability Assessment Working Group and Stakeholder Feedback

This section covers important input from the VAWG meetings and transportation stakeholder interviews. This input includes:

- General Information and Vulnerabilities
  - The County Multi-Hazard Mitigation considers what hazards will be most likely to affect the area and how to mitigate those risks.
  - Extreme heat and precipitation will have an impact on the roadways, such as potholes and other roadway degradations. This can ultimately lead to an increase in road maintenance costs. There are potential impacts to signage for transit and other modes as well.
  - Extreme heat can deter active transportation.
  - Rural roads surrounding schools often flood and make it hard to get to campus. Roads often designed to flood along edges.
  - There are potential impacts for maintenance and construction crews working outdoors. Work windows can also be affected by high heat and heavy rain. Also, for agricultural work, many outdoor workers cannot skip a day of work, because if they do not go to work then they cannot get paid.
  - Lots of people in the county do not have or cannot afford air conditioning.
  - Smaller cities often have the same problems as larger cities, but have less funding and fewer staff to address them.
  - The southern part of the county has less shade compared to the northern portion.
  - There is not a central dataset that tracks weather-related damage in the county.
  - Depending upon where an event occurs, the jurisdiction would be the first responders (e.g. City of Fresno). Depending upon how large the event is, and if an evacuation is needed, Fresno OES would be notified and law enforcement would facilitate evacuation. They would do so with partner agencies, such as the American Red Cross, County agencies and schools, to set up shelters and monitor impacts. Fresno County OES would then coordinate with local jurisdictions to provide updates to the state. For situations when there might be a detour, law enforcement is the primary responder. There are wildfire trainings for these types of events. The Sheriff's Office alerts citizens and gives them any specific instructions on road closures. They may use California Highway Patrol, Caltrans, or Fresno County Public Works to close roads. There is also coordination with fire responders or other first responders. There are so many variables that affect an event that instructions are given when the event happens, rather than having detailed evacuation plans laid ahead of time. Schools are often helpful as evacuation destinations.
  - On the roadway network, the low redundancy areas (i.e. limited alternative routes) are the highest concern.
  - Wildfire and flooding event seem to cause the most major and discrete impacts. These events cause roads to get cut off. Good routes enable resources to get in and people to get out. Some small communities built into mountain areas have single roads in, not necessarily a secondary route.
  - Air pollution is getting worse as the climate changes; ozone increases as temperatures rise; smoke from wildfires ends up back to the valley either from the Sierra's, Northern and Southern California; and longer wildfire seasons will cause increase in air pollution. Wildfires are increasing heat and letting off Nitrogen Oxide (NOx). There are attainment plans for air quality but do not consider climate change.

  - Often lower income people work outside and are exposed to air quality issues. Even at home many of these populations are still dealing with these air quality issues.
  - Being able to move around during poor air quality events is important. Active transit is not a viable option during poor air quality events.
  - The county typically will not put in sidewalks in a community that does not have a stormwater drainage plan, but there is limited funding to develop stormwater drainage plans.
  - Socially vulnerable populations are often in small, unincorporated communities with a limited number of English proficient individuals and non-traditional housing. They are hard to reach and often undercounted in the Census, and as a result are often underserved.
  - Flood zone mapping has lots of planning implications, but is based on historical data.
  - Unfunded mandates can create administrative burden for agencies and hinder the climate response.
  - More funding is needed across the board.
- Transit Impacts and Considerations
  - Bus riders are often affected the most by extreme heat and other weather events. There are many low-income, transit dependent riders in the County.
  - FAX is transitioning ahead toward a 100% electric vehicle fleet and is thinking about electricity demands in hotter weather, about resiliency of the grid, and how extreme temperatures affect battery storage
  - FAX and FCRTA both give free rides to cooling centers along their routes on days where temperature exceeds 105°F. The rider needs to know where the cooling center is. There are public service announcements on some of the local television channels for the cooling centers. Cooling centers, such as the mall, are often used for other purposes too. Fresno and Clovis have been the most active in terms of opening cooling centers. The Fresno-Madera Area Agency on Aging (FMAAA) targets the elderly and helps publicize cooling center opportunities.
  - There is some flooding in the rural parts of the county. Sometimes buses need to reroute because of this flooding.
  - Some bus stops in rural areas do not have sidewalks and therefore do not have covered areas.
  - Smaller communities often struggle to maintain sufficient ridership numbers to keep fixed-route services afloat. Therefore, extreme weather that decreases ridership has a potential impact on the long-term sustainability of transit options.
  - Flooding in many communities outside of Fresno metro area can prevent access to transit stops.
- Specific Locations: Flooding
  - Kings River and San Joaquin River are the two major rivers and can cause flooding. These two rivers come together near Mendota. The flows are not necessarily that high, but the confluence can cause flooding.
  - Some mobile home parks in river floodplains have experienced flooding in the past, including Wildwood Mobile Home Park and Woodward Bluffs Mobile Home Park in northern Fresno along the San Joaquin River, and River Bend RV Park in Sanger.
  - Tranquility, Mill Creek, and Hughes Creek flood frequently.
  - Sometimes there are issues in Kerman. Near the 145, there have been issues at the river crossing before. They are no levees in that area.

- Along the Kings River, there can be impacts near Centerville, Reedley and Laton, and as it moves through the west side there can be impacts to Tranquility. If there is a high enough flow it can overtop the banks and create flooding in Mendota/Firebaugh.
  - One of the roads that runs into Huron has flooded repeatedly. At times the road has been shut down for months. There are some areas where water can come out of the aqueduct near the Dorris and Lassen intersection.
  - In 2017, the rain and snow cut away at a lot of the mountain roads near Dinky Creek and Huntington Lake.
  - City of Fresno has relatively good drainage with water basins throughout the city to recharge aquifer and help limit flooding.
  - Dam failure at Pine Flat Lake would have catastrophic impacts.
- Specific Locations: Wildfire and Other Hazards
  - Sierra wildfires affect SR-180 and SR-168 (especially near Shaver Lake and Big Creek).
  - Many fires in the County are higher up in the mountains and do not affect people.
  - The Big Creek roadway is an important response and evacuation route during wildfires. It has experienced slides, rockfall, and weather-related impacts before.
  - There are some fires near Coalinga but these are often grass fires that pose less danger.
  - Subsidence has been a major issue on the west side of the county and affects levees.
  - When the drought occurred and the bark beetle took over, many trees were killed in the Sierra. Many of these have been removed to mitigate risk. The work that is needed to remove these trees (impact from trucks) is damaging roadways. There are also erosion/landslide impacts because the trees have been removed.
  - Many areas, such as Humphrey Station, Cold Springs Rancheria, Big Sandy Rancheria, Pine Ridge, have limited routes in and out.
- Adaptation Options[22]
  - Addressing vulnerabilities will cost money, so it is helpful to prioritize where to spend.
  - More shade or other cooling is needed at transit stops.
  - Cool pavements have been considered for parking lots, but not as much for roadways.
  - The County is building more pump stations to pump floodwater into canal system.
  - Advice on pavement - permeable, cool, pavement mixes - would be helpful.
  - Tree planting was mentioned several times.
  - There may be an opportunity to increase the messaging about transit to cooling centers. Also, providing demand responsive transit to these centers is another potential adaptation option.
  - An evacuation plan for a specific area that has been coordinated between all communities and agencies can be very helpful. Trainings and educational outreach helps people learn about their options and prevents panic.
  - Care should be taken when determining where and how development is built. One suggestion was requiring new developments in the mountains to provide multiple routes in/out.
  - Infrastructure should be designed with future climate projections as an input.
  - Some communities would like to have a secondary route but face funding challenges. Many roads are owned and maintained by property owners which can complicate evacuation planning. For some areas, having a shelter in place might be a critical option when evacuation is not feasible.

[22] Adaptation options will be addressed in the project's next task.

- Vulnerable people in rural communities often do not have access to cars. Bus services or other assistance during evacuation events could be beneficial.
- Public notification during poor air quality events is crucial. Working with the Air District, who does have a notification system, but this system is not tailored to the San Joaquin Valley. Last year was the first year this notification was translated into Spanish, but notifications were opt-in.
- There is a need for more education about the impacts of climate change.
- Electric Vehicle (EV) rideshares like those in Cantua Creek and Huron are good examples of options on the climate change mitigation side.
- More rural access to transit would make Fresno County more resilient.

Figure 18. Fresno County Survey and Interview Problem Spots shows past problem spots by hazard type that were identified in both the stakeholder interviews and the public survey. As noted in the previous section, the best-attended pop-up events occurred in Reedley and Kerman, which likely contributed to the disproportionate clusters of problem spots identified in those areas. Figure 19. Fresno County Survey, Interview, and Historical Event Problem Spots combines the problem spots from the survey and interviews with the historical events newspaper review described in the Historical Context subsection.

Figure 18. Fresno County Survey and Interview Problem Spots

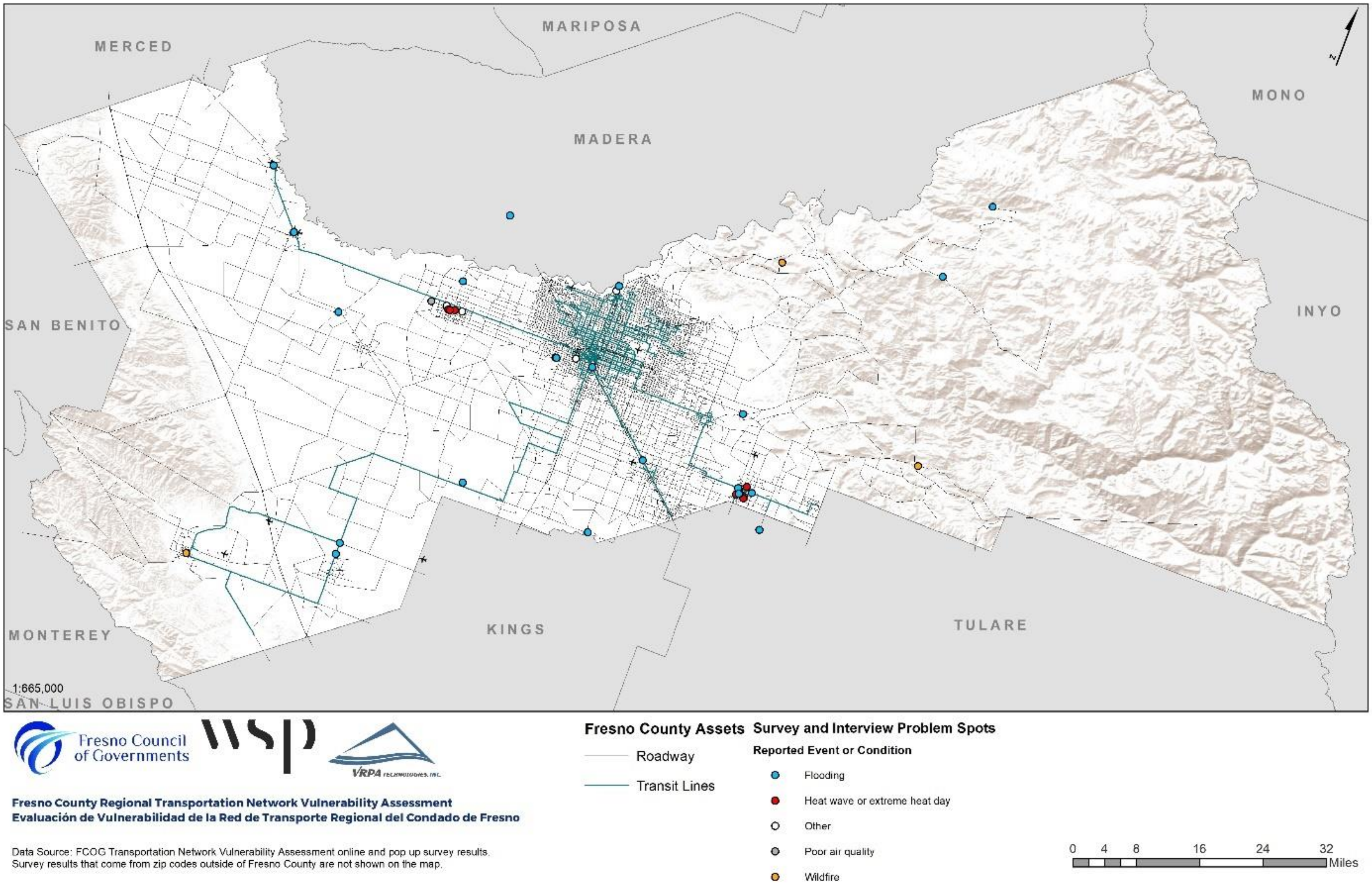
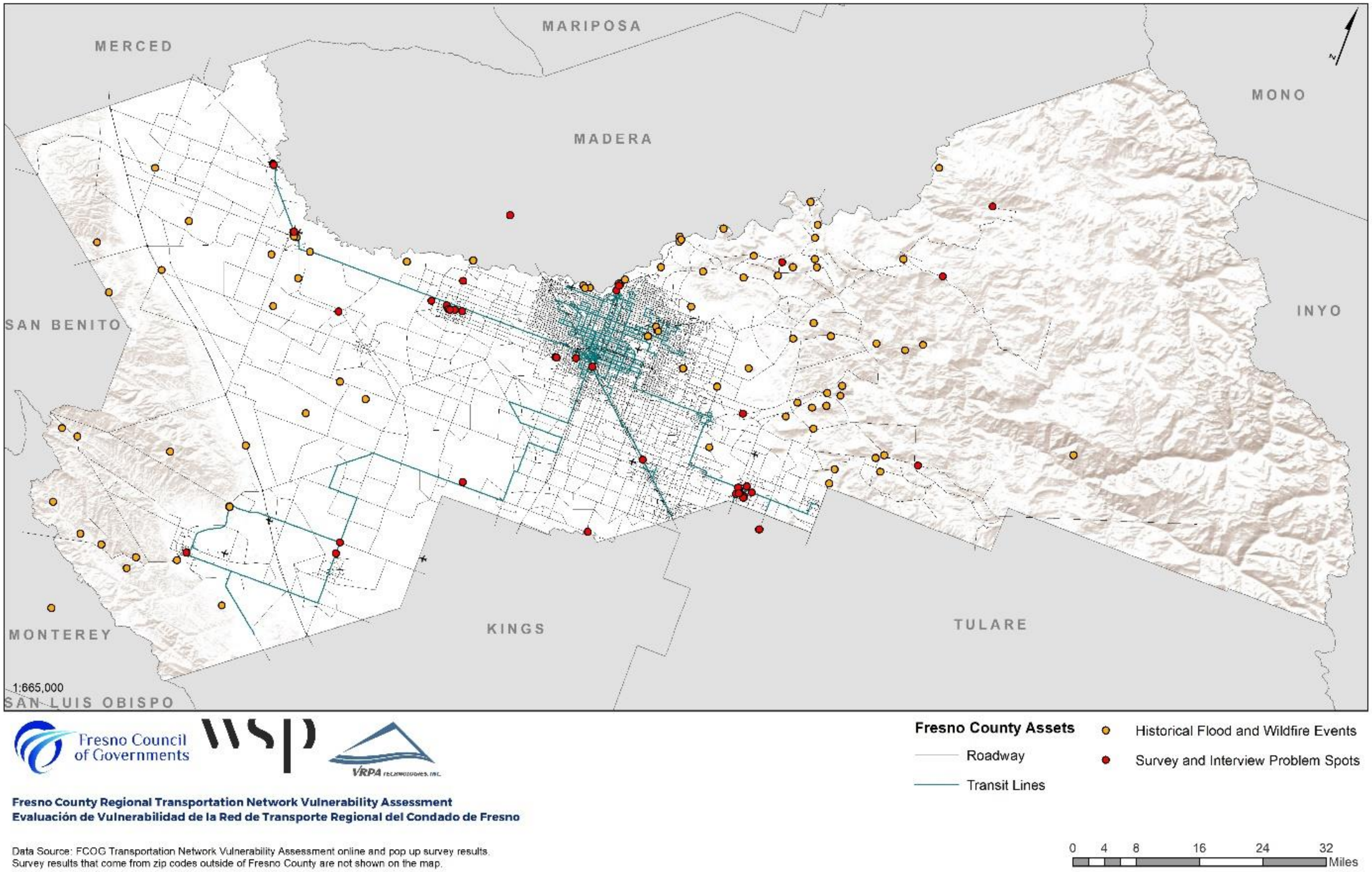


Figure 19. Fresno County Survey, Interview, and Historical Event Problem Spots



Transportation System Analysis Findings

Much of the transportation system, including its infrastructure and users, are expected to be affected by changing climate conditions in the Fresno COG region. The primary transportation and climate-related hazards include flooding, wildfire, extreme temperatures, and precipitation-induced landslides. Higher maximum temperatures can pose health threats for transit passengers and damage pavement and bridges. More frequent wildfires can disrupt the transportation system and hinder or cut off evacuation routes. Heavy rain events and runoff can lead to flooding, washouts, and erosion. Broader effects on the hydrologic and agricultural systems could affect regional travel patterns.

Scoring

Methodology

This section describes the approach for understanding climate-related risks to the transportation network in the Fresno COG region and prioritizing the most vulnerable and critical assets for future action. Specifically, the prioritization approach is intended to identify the relative vulnerability of different transportation assets to climate-related hazards using available information. Higher priority assets can be assessed in further detail to determine how they can be adapted to climate change. The approach incorporates information on hazard likelihood, as well as the asset's criticality and condition. The approach addresses the most important climate-related hazards in the region but could not address the full range of all potential hazards. This does not mean that the risks associated with hazards excluded from the analysis are negligible. This approach is similar to the ones being used for the systemwide climate change vulnerability assessments for the Caltrans Climate Action Report project and for the Sacramento Area Council of Governments (SACOG) Vulnerability and Criticality Assessment project.

Agencies can use a few different methods to prioritize projects. There are at least three different prioritization techniques currently in use. These techniques, ordered from lower to higher level of effort, are the (1) risk matrix/heat map approach, (2) the indicators approach, and (3) the cost-based approach.

1. The risk matrix/heat map approach involves creating a matrix with one axis qualitatively representing the likelihood of an event (low to high probability categories) and the other representing the consequences (low to high consequence categories). Each asset type-hazard combination is assigned to a cell within the matrix by using professional judgment. High risk asset type-hazard combinations are identified for immediate action.
2. The indicators approach involves collecting data on a variety of variables that are deemed relevant to affecting the prioritization. These are then put on a common scale, weighted (if necessary), and used to create a score for each asset. The scores collectively account for all the variables of interest and can be ranked to determine priorities.
3. The most sophisticated approach, the cost-based approach, involves an effort to determine the "do-nothing" cost of climate change if no adaptation is undertaken. This is a very data intensive approach as it requires (1) knowledge of the probability of the event happening, (2) an engineering assessment of what damage/disruptions occur when the asset is exposed to a hazard, and (3) economic analysis to determine the costs to repair damage to the asset along with the socioeconomic costs associated with loss of the asset. Because of its data

intensiveness, the cost-based approach is rarely used for initial assessments. However, an agency can begin with one of the simpler techniques and lay the groundwork for conversion to a cost-based approach later.

Given the resources and timeframe for this project, an indicators approach (the option entailing an intermediate level of effort) was chosen. With the proposed indicators approach, various metrics are used to capture (1) the nature of the asset's exposure to each relevant hazard (timing, severity, and/or extensiveness), (2) the consequences of that exposure (in terms of the sensitivity of the asset to damage and/or impacts to the traveling public, such as through the assessment of traffic volumes on the affected roadway) and (3) programming considerations that affect how rapidly adaptations can be implemented, if necessary. Ultimately, these metrics were compiled mathematically into a score for each individual asset, that can be ranked to show the assets that should be prioritized for detailed study under each hazard. For example, this scoring identifies which bridges are the most vulnerable to riverine flooding hazards out of all the bridges in the region, according to the criteria used in the analysis.

Different metrics were applied to each combination of asset type and hazard. Table 2. Asset Type and Hazards lists the hazards and denotes with an "X" the types of assets that are sensitive to each. Each cell marked with an "X" has its own set of metrics. The metrics used were based on what is relevant to prioritizing amongst assets exposed to the indicated hazard. For example, culvert condition rating is a very relevant metric for prioritizing culverts exposed to riverine flooding, but it is not relevant to prioritizing bridges exposed to the same hazard.

Table 2. Asset Type and Hazards

	Flooding	Wildfire	Extreme Heat
Roadways	X	X	x
Culverts (state-owned)	X	X	x
Bridges	X		x
Airports	X		X
Transit Stops	X	X	X

Indicators

The number of possible metrics for any given asset type-hazard combination is extensive and can be overwhelming. With any prioritization scheme, a limiting factor is data availability, and the effort is restricted to the best available information. Table 3. Asset Type Hazard Combinations lists all the metrics used in the prioritization approach. Also included is a description of each metric, a rationale for inclusion, the data source, other relevant metadata, and the asset type and hazard combinations it is used to assess.

After the metrics were compiled for each asset, each metric was placed on a 0 to 100-point scale where 100 represents that the asset is a priority. With the traffic volume metric, for example, a 0 might be assigned to a minor residential street with extremely low volumes, while a value of 100 would be assigned to the busiest highway in the region. Putting the metrics on a common scale helps reconcile the different units of measurement between metrics.

Table 3. Asset Type Hazard Combinations

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Recurring damage classification	A classification of if the asset has experienced damage and/or been closed or operated at reduced capacity due to extreme weather events in the past couple decades. Values are provided as 1 or 0 for each asset. A 1 represents that the asset has been damaged by extreme weather events in the past and 0 represents no known asset damages from extreme weather.	Assets that have experienced more issues in the past are likely to experience more issues in the future as climate changes and should be prioritized.	Analysis of information from VAWG, stakeholders, public outreach, and news article review	scale_dmg_fld or scale_dmg_fire (field names, depending on hazard type) categorical (field type) scaling: {1(raw value):100 (scaled valued),nan:0} (note: nan indicates null values) unscaled units: binary flag	Flood, Wildfire	Flood, Wildfire	Flood	Flood	Flood, Wildfire
Initial timeframe for elevated level of concern for wildfire	The first timeframe (2010-2039, 2040-2069, 2070-2099, or never), under either representative concentration pathway (RCP) 4.5 or 8.5, during which the asset is exposed to a moderate or higher level of concern for wildfire.	Assets that are more likely to be impacted by wildfire sooner should be prioritized.	Wildfire Model Composite[24]	scale_time_elev_burn categorical scaling: {3:100,2:75,1:50} unscaled units: timeframe priority sequence {2010:3,2040:2,2070:1}	Wildfire	Wildfire			Wildfire

[23] For items marked with "*" in this column: the full citation is included in the Task 1 geodatabase.

[24] The fire model composite summaries shown are based on wildfire projections from three models: 1) MC2 – EPA Climate Impacts Risk Assessment, developed by John Kim, USFS; 2) MC2 – Applied Climate Science Lab at the University of Idaho, developed by Dominique Bachelet, University of Idaho; and 3) University of California Merced model, developed by Leroy Westerling, UC Merced. For each of these wildfire models, climate inputs were used from three Global Climate Models: 1) CAN ESM2, 2) Had_GEM2-ES, and 3) MIROC5. Data shows the multi-model maxima for each grid cell across the nine combinations of the three fire models and three GCMs. As a means of establishing a level of concern for wildfire impacts, a classification was developed based on the expected percentage of cell burned. The classification is as follows: 1) Very Low 0-5%, 2) Low 5-15%, 3) Moderate 15-

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Highest projected wildfire level of concern	The highest level of concern for wildfire (low, moderate, high, or very high) that an asset is exposed to through 2100 under either RCP 4.5 or 8.5.	Assets that have a greater likelihood of experiencing wildfire should be prioritized.	Wildfire Model Composite[25]	scale_cat_burn categorical scaling: {4:100,3:75,2:50,1:25} unscaled units: level of concern (ranging from "very high":4 to "low":1)	Wildfire	Wildfire			Wildfire
Maximum change in 100-year peak flow for the 2010-2039 timeframes	The highest change in 24-hour duration, 100-year peak flow in the 2010-2039 timeframe across Global Climate Models (GCMs) and RCPs.	Assets that have relatively higher peak flow increases in the near-term should be prioritized.	Scaling of past peak flows (USGS StreamStats) using relationship between watershed historical extreme precip. (NOAA Atlas 14) and future extreme precip. (processed from Scripps LOCA downscaled daily GCM outputs).	scale_flow_t1mx continuous scaling: log min-max normalization (natural log of max value: 100,…,natural log of min value: 0) unscaled units: cubic feet per second			Flood		

50%, 4) High 50-100%, 5) Very High 100%+. A classification of greater than 100% means fires are burning portions of each cell more than once in each time period. Time periods are averages of 30-year periods, where 2010 to 2039 is represented by the median year 2025, 2040 to 2069 is represented by the median year 2055, and 2070 to 2099 is represented by the median year 2085. Projected increases in wildfire are compared to a historical backcasted period from 1975 to 2004. Emissions scenarios used are RCP 4.5 or RCP 8.5, representing low and high emissions, respectively.

[25] Ibid.

					Asset Type-Hazard Combinations Applied To				
Metric	**Description**	**Rationale for Inclusion**	**Input Data Source**[23]	**Other Metadata: Field Name, Type, Scaling**	**Roadways**	**Culverts (state-owned)**	**Bridges**	**Airports**	**Transit Stops**
Maximum change in 100-year peak flow across all timeframes	The highest change in 24-hour duration, 100-year peak flow asset across timeframes, GCMs and RCPs.	Assets that have relatively higher peak flow increases over their lifetimes should be prioritized.	Scaling of past peak flows (USGS StreamStats) using relationship between watershed historical extreme precip. (NOAA Atlas 14) and future extreme precip. (processed from Scripps LOCA downscaled daily GCM outputs).	scale_flow_mx continuous scaling: log min-max normalization (natural log of max value: 100,…,natural log of min value: 0) unscaled units: cubic feet per second			Flood		
Maximum Caltrans future riverine flooding exposure score for the 2010-2039 timeframe[26]	The highest Caltrans riverine flooding exposure score for the asset in the 2010-2039 timeframe across all GCMs and RCPs. This score incorporates information on projected future peak flows, projected future wildfire, and capacity.	Assets that have relatively higher riverine flooding exposure in the near-term should be prioritized.	Caltrans Climate Change Action Report project (original data sources include USGS StreamStats, NOAA Atlas 14, Scripps, and Wildfire Model Composite (see above for sources))	scale_ riv_t1mx continuous scaling: not needed unscaled units: 0-100 scale		Flood			

[26] This data source is currently on hold, so results are not included for culverts.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Maximum Caltrans future riverine flooding exposure score across all timeframes[27]	The highest Caltrans riverine flooding exposure score for the asset across all timeframes, GCMs and RCPs. This score incorporates information on projected future peak flows, projected future wildfire, and capacity.	Assets that have relatively higher riverine flooding exposure over their lifetimes should be prioritized.	Caltrans Climate Change Action Report project (original data sources include USGS StreamStats, NOAA Atlas 14, Scripps, and Wildfire Model Composite (see above for sources))	scale_riv_mx continuous scaling: not needed unscaled units: 0-100 scale		Flood			
Maximum change in 100-year precipitation for the 2010-2039 timeframes	The highest change in 24-hour duration, 100-year precipitation in the 2010-2039 timeframe across Global Climate Models (GCMs) and RCPs.	Assets that have relatively higher precipitation increases in the near-term should be prioritized.	Scripps LOCA downscaled daily GCM outputs	scale_pre_t1mx continuous scaling: log min-max normalization (natural log of max value: 100,…,natural log of min value: 0) unscaled units: inches per day	Flood			Flood	Flood
Maximum change in 100-year precipitation across all timeframes	The highest change in 24-hour duration, 100-year precipitation asset across timeframes, GCMs and RCPs.	Assets that have relatively higher precipitation increases over their lifetimes should be prioritized.	Scripps LOCA downscaled daily GCM outputs	scale_pre_mx continuous scaling: log min-max normalization (natural log of max value: 100,…,natural log of min value: 0) unscaled units: inches per day	Flood			Flood	Flood

[27] This data source is currently on hold, so results are not included for culverts.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To: Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Maximum change in 7-day maximum temperature	The highest change for extreme temperature across timeframes, GCMs, and RCPs.	Assets that have relatively higher extreme temperature increases over their lifetimes should be prioritized.	Comb. of Scripps LOCA downscaled daily projections and Caltrans Climate Change Vulnerability Assessment	scale_temp7_mx continuous scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: °F	Extreme Temp.				
Average annual maximum of daily maximum temperature across timeframes	The highest average annual maximum of the daily maximum temperature across timeframes, GCMs, and RCPs.	Extreme high heat can create issues for aircraft and airport operations.	Scripps LOCA downscaled daily projections	scale_temp1_mx continuous scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: °F				Extreme Temp.	
Maximum change in average annual maximum of daily maximum temperature across timeframes	The highest change in the average annual maximum of the daily maximum temperature across timeframes, GCMs, and RCPs.	Changes in extreme high temperature could cause bridges to expand beyond design threshold	Scripps LOCA downscaled daily projections	scale_tdelt_mx continuous scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: °F			Extreme Temp.		
Highest Annual Number of Heat Health Events	The projected number of Heat Health Events (heat events that generate public health impacts) across timeframes and GCMs and emissions scenarios.	Assets where users are exposed to heat health events in the asset lifetime should be prioritized.	California Heat Assmt. Tool	scale_max_hh continuous scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: # events					Extreme Temp.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Lowest floodplain increment that facility lies within or crosses	The lowest floodplain increment that the facility is within or intersects of the following: 100-year floodplain, 500-year floodplain, or none	In general, assets within existing 100-year floodplains should be prioritized most; and assets within existing 500-year floodplain should also be prioritized	FEMA Flood Maps	scale_flood_pln categorical {100:100,500:75,9999:0,nan:0} unscaled units: recategorized into simplified return intervals (100, 500, or none) from FEMA designations[28]	Flood			Flood	Flood
Bridge substructure condition rating	The National Bridge Inventory (NBI) substructure condition rating assigned to the bridge. Possible values range from 9 to 2 with lower values indicating poorer condition. Culverts (code value N, not applicable) are not included nor are bridges closed to traffic (code values 0 and 1).	Poor bridge substructure condition can contribute to failure during extreme weather events. Thus, bridges with poor substructure condition should be prioritized.	National Bridge Inventory (NBI) (Item 60)	scale_Bsubstruct_cond categorical scaling: {'9':0,'8':10,'7':30,'6':50,'5':60,'4':70,'3':80,'2':90,'1':100,'0':100,'N':0,nan:50} unscaled units: see NBI coding guide[29]			Flood		

[28] https://www.arcgis.com/home/item.html?id=e96f674e765b4327bbde92d41a12b087
[29] See NBI coding guide for more information: https://www.fhwa.dot.gov/bridge/mtguide.pdf

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Channel and channel protection condition rating	The NBI channel and channel protection condition rating assigned to the asset. Possible values range from 9 to 2 with lower values indicating poorer condition. Assets with code values N (not applicable because not over water) are not included nor are assets closed to traffic (code values 0 and 1).	Poor channel or channel protection conditions can contribute to failure during extreme weather events. Thus, assets with poor channel or channel protection conditions should be prioritized.	NBI (Item 61)	scale_Bchannel_cond categorical scaling: {'9':0,'8':15,'7':30,'6':45,'5':60,'4':75,'3':90,'2':100,'1':100,'0':100,'N':0,nan:50} unscaled units: see NBI coding guide			Flood		
Culvert condition rating[30]	The Caltrans culvert condition rating (for small culverts) assigned to the culvert. Possible values include Good, Fair, or Critical. Culverts with N/A, NA, or no data coding will be assigned a Fair rating.	Poor culvert condition can contribute to failure during extreme weather events. Thus, culverts in poor condition should be prioritized.	Caltrans conveyances shapefile (Condition field)	scale_Bchannel_cond categorical scaling: {'9':0,'8':15,'7':30,'6':45,'5':60,'4':75,'3':90,'2':100,'1':100,'0':100,'N':0, nan:50} unscaled units: see NBI coding guide		Flood			

[30] This data source is currently on hold, so results are not included for culverts.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Culvert material[31]	The material used to construct the culvert. Possible values include HDPE (high density polyethylene), PVC (polyvinyl chloride), CSP (corrugated steel pipe), Composite, Wood, Masonry, Concrete, -1, N/A, Other, and Unkn.	Culvert material plays a role in determining the sensitivity of assets to wildfire. HDPE, PVC, CSP, Composite, and Wood culvert types should be prioritized. Culverts with values of -1, N/A, Other, and Unkn will be assigned a moderate level of concern.	Caltrans conveyances shapefile (CMaterial field)	scale_CMaterial_fire categorical scaling: {'Concrete':0, 'CSP':0, '-1':50, 'PVC':100, 'HDPE':100,'Composite':100 ,'Wood':100,'Other':50,'Masonry':0} unscaled units: materials categories (see scaling)		Flood			

[31] This data source is currently on hold, so results are not included for culverts.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To: Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Scour rating	The NBI scour critical bridge rating assigned to the bridge. Possible values range from 8 to 2 with lower values indicating greater scour concern. Bridges coded N (not over waterway), U (unknown foundation), T (over tidal waters with minimal concern), or 9 (bridge foundations on dry land) will be assigned a value of 6, a moderate value assigned to bridges where no scour analysis has been performed. This reflects the possibility that higher flood levels could cause scour at these facilities which heretofore had not been studied for scour because of a belief that flooding wouldn't affect them.	Excessive scour of bridge foundations makes bridges more prone to failure during extreme weather events. Thus, bridges with a high amount of scour should be prioritized.	NBI (Item 113)	scale_Bscour_crit categorical scaling: {'N':0,'U':50,'T':40,nan:50,'9':0,'8':15,'7':30,'6':50,'5':60,'4':75,'3':90,'2':100,'1':100,'0':100} unscaled units: see NBI coding guide			Flood		
Bridge capacity	NBI Item 71 on Waterway Adequacy to approximate capacity. Values range from 9 to 2 with lower values indicating smaller capacity.	Bridges with lower capacities should be prioritized.	NBI (Item 71)	scale_Bwaterway_adequ categorical scaling: {'N':0,nan:50,'9':0,'8':15,'7':30,'6':45,'5':60,'4':75,'3':90,'2':100,'0':100} unscaled units: see NBI coding guide			Flood		

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Culvert capacity[32]	CDiameter or combination of CWidth and CHeight fields are used to calculate area. Smaller areas are associated with smaller capacities.	Culverts with lower capacities should be prioritized.	Caltrans Conveyances shapefile	scale_Cwaterway_adequ categorical scaling: {'Fair':50, 'Good':0, 'Poor':75, 'Critical':100, '-1':0} unscaled units: Caltrans' categories (see scaling)		Flood			
Facility Level of Service (LOS)	The forecasted LOS from the Fresno COG VMIP 2 travel demand model for 2042. For roadway segments that contain two overlapping model links, the maximum LOS was taken.	Roadways with high congestion and capacity constraints should be prioritized.	Fresno COG VMIP 2, 2042 forecast, LOS_DAILY field	scale_los categorical scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: numerical scores 1-6 corresponding to AASHTO LOS ratings A-F[33]	Flood, Wildfire, Extreme Temp.				

[32] This data source is currently on hold, so results are not included for culverts.
[33] https://en.wikipedia.org/wiki/Level_of_service

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Average Annual Daily Traffic Volume	For roadways, this is the average daily volume from Fresno COG VMIP 2 travel demand model for 2042. For roadway segments that contain two overlapping model links, the sum of the two volumes was used. For bridges, this is the NBI future ADT and future ADT years used to adjust the future volumes to a common year of 2036 across the assets. For culverts, this is the AADT developed through the Caltrans Climate Action Report project.	The consequences of weather-related failures/disruptions (from either extreme events or more frequent maintenance needs) are greater for assets that convey a higher volume of traffic. Thus, assets associated with higher volumes should be prioritized.	Fresno COG VMIP 2 travel demand model, 2042 forecast, D24_VOL field for roadways. NBI (Items 114 and 115) for bridges. Caltrans Climate Action Report project for culverts.[34]	scale_fac_vol continuous scaling: min-max normalization (max value: 100,…,min value: 0} unscaled units: volume (differs by mode; see Description column for details)	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		

[34] This data source is currently on hold, so results are not included for culverts.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Average Annual Daily Traffic Volume for Trucks	For roadways, this is the average daily truck volume from Fresno COG VMIP 2 travel demand model for 2042. For roadway segments that contain two overlapping model links, the sum of the two volumes was used.	The consequences of weather-related failures/disruptions (from either extreme events or more frequent maintenance needs) are greater for assets that convey a higher volume of freight traffic. Thus, assets associated with higher freight volumes should be prioritized.	Fresno COG VMIP 2 travel demand model, 2042 forecast, D24_TRK_VO field	scale_trk_vol continuous scaling: min-max normalization (max value: 100,…,min value: 0} unscaled units: daily truck volume	Flood, Wildfire, Extreme Temp.				
Airport Type	The airport type associated with the asset. Values include Primary, General, Other, and Reliever.	Airports with more intensive uses (e.g., primary hubs) should be prioritized.	Fresno COG airports layer	scale_aport_class categorical scaling: {'Primary':100,'General':50,'Other':50,'Reliever':0} unscaled units: Airport Type (see above)				Flood, Extreme Temp.	

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To: Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
NBI Bypass, Detour Length	The NBI Bypass, Detour Length (XXX kilometers) assigned to the bridge. It represents the total additional travel for a vehicle which would result from a closing of the bridge. Values range from 000 up to a maximum of 199 kilometers.	The greater the detour length around the asset (should it need to be closed due to an extreme weather event) the lower the network redundancy. Assets with low network redundancy should be prioritized.	NBI (Item 19)	scale_Bdetour continuous scaling: min-max normalization (max value: 100,…,min value: 0} unscaled units: kilometers			Flood, Wildfire		
Nodal density (density of network nodes within 0.5 miles)	The density of roadway network intersections (i.e., nodes) within a 0.5-mile buffer of the asset. Units are nodes per square mile. Buffers are clipped to the Fresno COG region.	Nodal density is a proxy for network redundancy. Assets with low network redundancy should be prioritized.	Fresno COG VMIP 2, 2042 forecast network	scale_node_dens continuous scaling: percentile ranking (min value: 100,…,max value: 0} unscaled units: # nodes within .5 miles	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.			Flood, Wildfire, Extreme Temp.
Employment density	Fresno COG employment density within a quarter mile buffer of the asset, aggregated by area weighted mean (AWM).	Assets in areas of higher employment density should be prioritized.	Fresno COG TAZ feature class, EMP field	scale_emp_dens continuous scaling: min-max normalization (max value: 100,…,min value: 0} unscaled units: employment density AWM within 0.25 mile	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		Flood, Wildfire, Extreme Temp.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Household density	Fresno COG household density within a quarter mile buffer of the asset, aggregated by area weighted mean (AWM).	Assets in areas of higher household density should be prioritized.	Fresno COG TAZ feature class, HH field	scale_pop_dens continuous scaling: min-max normalization (max value: 100,…,min value: 0) unscaled units: household density AWM within 0.25 mile	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		Flood, Wildfire, Extreme Temp.
Asset within Fresno COG Environmental Justice (EJ) community	Whether an asset at least partially overlaps a Fresno COG Environmental Justice community.	Disadvantaged communities tend to be more vulnerable to weather-related events, and assets serving these communities should be prioritized.	Fresno COG MIP1_EJ_TAZ feature class, MIP1_EJ_1 field	scale_in_ej categorical scaling: {-1:100,0:0} unscaled units: binary flag	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		Flood, Wildfire, Extreme Temp.
CalEnviroScreen Percentile Score	The percentile CalEnviroScreen score density within a quarter mile buffer of the asset, aggregated by area weighted mean. Values range from 0 to 100, with the most disadvantaged communities receiving larger scores.	Disadvantaged communities tend to be more vulnerable to weather-related events, and assets serving these communities should be prioritized. This is a State indicator of disadvantaged communities.	California OEHHA	scale_ces_den continuous no scaling unscaled units: % AWM within 0.25 miles	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		Flood, Wildfire, Extreme Temp.

Metric	Description	Rationale for Inclusion	Input Data Source[23]	Other Metadata: Field Name, Type, Scaling	Asset Type-Hazard Combinations Applied To				
					Roadways	Culverts (state-owned)	Bridges	Airports	Transit Stops
Percent of Households with No Vehicle	The percent of households with no vehicle within a quarter mile buffer of the asset, aggregated by area weighted mean.	Assets serving communities with high proportion of individuals without vehicle access should be prioritized.	American Community Survey	scale_noveh_den continuous no scaling unscaled units: % AWM within 0.25 miles	Flood, Wildfire, Extreme Temp.	Flood, Wildfire, Extreme Temp.	Flood, Extreme Temp.		Flood, Wildfire, Extreme Temp.

Asset Prioritization Scoring

Once the metrics were placed on a common scale, weights were assigned based on the relative importance of each metric to the overall risk. Table 4. Metric Weights by Asset-Hazard Combination shows the weights for each metric.

After the weights were assigned, they were multiplied by the scaled scores. These products were then summed for each asset type-hazard combination (i.e. each column in the table). Then, a final re-scaling of the results was done to ensure that the final scores were all on a 0-to-100 scale for each asset. Larger numbers on the scale (i.e., closer to 100) represent higher priority (more vulnerable) assets.

After these scaled scores were developed, they were categorized into ten equal intervals, so that categories with scores 90-100 were assigned a 10, scores 80-90 were assigned a 9, and so on. This classification of results helped remove some of the potentially confusing and misleading precision of the numeric scores.

The final product of this approach is a prioritized listing of assets with a separate ranking for each asset type-hazard combination. For example, all culverts are prioritized based on their vulnerability to riverine flooding. Likewise, there are separate prioritized lists for culverts vulnerable to sea level rise and to storm surge.

As described in other portions of this section, the indicator-based prioritization is a helpful tool given the number of different assets, hazard types, and information sources needed to assess relative vulnerability. But it should not be mistaken as a complete understanding of risks facing those assets. It's a tool for system-level analysis that needs to be accompanied with professional judgement and on-the-ground context. It is useful in that it can help identify at-risk assets that should be examined individually at a facility-level.

Table 4. Metric Weights by Asset-Hazard Combination

Metric	Flooding					Wildfire			Extreme Temperature			
	Roads	Bridges	Culverts	Transit Stops	Airports	Roads	Culverts	Transit Stops	Roads	Bridges	Transit Stops	Airports
Initial timeframe for elevated level of concern for wildfire						25%	25%	25%				
Highest projected wildfire level of concern						25%	25%	25%				
Maximum change in 100-year flow for the 2010-2039 timeframe		15%										
Maximum change in 100-year flow across timeframes		15%										
Maximum Caltrans future riverine flooding exposure score for the 2010-2039 timeframe			16%									
Maximum Caltrans future riverine flooding exposure score			16%									
Maximum change in 100-year precipitation for the 2010-2039 timeframe	10%			10%	10%							
Maximum change in 100-year precipitation	10%			10%	10%							
Max change in max 7-day temperature across timeframes									60%			
Avg annual max daily max temperature across timeframes												60%
Max change in avg annual max daily max temperature across all timeframes										55%		
Highest Annual Number of Heat Health Events across timeframes											50%	
Lowest floodplain increment that facility lies within or crosses	30%			30%	30%							
Recurring Damage Classification (flooding)	15%	15%	15%	15%	15%							

Metric	Flooding					Wildfire			Extreme Temperature			
	Roads	Bridges	Culverts	Transit Stops	Airports	Roads	Culverts	Transit Stops	Roads	Bridges	Transit Stops	Airports
Recurring Damage Classification (fire)						10%	10%	10%				
Bridge substructure condition rating		2%										
Channel and channel protection condition rating		2%										
Scour rating		5%										
Bridge capacity		28%										
Culvert condition rating			5%									
Culvert material							4%					
Culvert capacity			30%				4%					
Facility Level of Service (LOS)	5%					5%			5%			
Facility Volume	12.5%	10%	10%			15%	15%		20%	20%		
Facility Truck Volume	2.5%					3%			5%			
Airport class					35%							40%
Detour length		5%								15%		
Density of roadway network nodes within 0.5 miles of facility	10%		4%	5%		10%	10%	10%	5%		5%	
TAZ employment density: AWM within 0.25 miles of facility	1%	0.5%	0.5%	5%		1%	1%	5%	1%	2%	5%	
TAZ household density: AWM within 0.25 miles of facility	1%	0.5%	0.5%	5%		1%	1%	5%	1%	2%	5%	

Metric	Flooding					Wildfire			Extreme Temperature			
	Roads	Bridges	Culverts	Transit Stops	Airports	Roads	Culverts	Transit Stops	Roads	Bridges	Transit Stops	Airports
Facility within or overlaps Fresno COG EJ TAZ	1%	0.5%	1%	5%		2%	2%	5%	1%	2%	15%	
CalEnviroScreen Score: AWM within 0.25 miles of facility	1%	0.5%	1%	5%		1%	1%	5%	1%	2%	5%	
% Households with No Vehicle: AWM within 0.25 miles of facility	1%	1%	1%	10%		2%	2%	10%	1%	2%	15%	
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Analysis Documentation

The scoring approach described in the previous subsections involves many different datasets and analysis processes. This subsection helps document that process and serves as a reference for replicating the analysis.

There are several portions of the analysis. The first is the input data development, which includes the gathering and cleaning of hazard and asset data. The second is the metric development, where this information is combined into the metrics described in the approach section. The final is the scoring, where the metrics are scaled and weighted together to produce scaled scores for each combination of hazard and asset type.

There are several files and folders that were used to conduct the analysis and contain the results:

- The previous subsections of this Methodology section document the raw datasets used and includes important metadata, such as original data sources, scaling methodology, and field names of scaled values.
- The results geodatabase (“fcog_tnva_20190918.gdb”) contains the asset feature classes with the results. The fields include:
    - The final tiered scores, which are provided in 10 equal interval tiers, with 10 corresponding with more vulnerable assets and 1 corresponding with less vulnerable assets. These fields are named “final_score_”, followed by a hazard type abbreviation, followed by an asset type abbreviation.[35] For example, “final_score_flood_brid” in the bridge feature class contains the final scores for flooding threats to bridges.
    - The scaled overall scores for each asset type-hazard combination, which range from 0 to 100, with 100 corresponding with more vulnerable assets and 0 corresponding with less vulnerable assets. These fields are named “scalescore_”, followed by a hazard type abbreviation, followed by an asset type abbreviation.
    - The scaled metrics scores that are weighted together into the scaled overall scores. The Indicators subsection of this memorandum documents all of these field names and definitions.
    - Unscaled metrics values. The Metric Weights Template file (see below) contains a list of all the unscaled metric field names and their corresponding scaled metric field names. The Asset Prioritization Scoring subsection in this memorandum also documents these weights.
    - Other fields that were included in the original asset files, such as asset name, location, and description. There are also a few other intermediary fields created during the metric development.
- Summary sheets and scores spreadsheets: “fcog_scores_tables_20190918” folder. This includes

[35] In these fields and others in this geodatabase, hazard abbreviations are {Wildfire: “fire”, Extreme Temperature: “temp”, Flooding: “flood”}. The asset abbreviations are {Roadways: “road”, Transit stops: “trans”, Culverts: “culv”, Bridges: “brid”, Airports: “air}.

.csv versions of the results by asset type in the results geodatabase. It also includes summary .csv files with results broken out by asset type-hazard combination.

- Metric Development Python script for ArcGIS: “fresno_arcpy_processing_v02.py”. Most of the metric development occurred with this Python script, which relies heavily on ArcPy, the Python package for running ArcGIS geoprocesses. The script can be viewed in Notepad++ or other source code editor. It is commented with instructions on how to rerun the metric development geoprocesses.
- Scoring Development Jupyter Notebook for Python: “fresnocog_asset_scaling_weighting_scoring.ipynb”. This Jupyter Notebook runs blocks of Python code.[36] This notebook was used for the metric scaling, weighting, and final scoring and classification. While ArcGIS is offers rich geoprocessing functionality, traditional Python packages such as pandas and numpy are better suited for systematic tabular data manipulation. This notebook is commented and can be rerun in the future. It reads .xls (or other tabular) files exported from ArcGIS. It also reads the Metric Weights Template (see below) for the weighting process.
- Metric Weights Template: “Fresno_COG_TNVA_weights_20190918.csv”. This is an input file into the Scoring development Jupyter Notebook. It is a table with rows corresponding to metric names, columns corresponding to asset type-hazard combinations, and values corresponding to the weights used to combine the scaled metrics together for each asset type-hazard score. The weights in that table are the same as those that appear in the Asset Prioritization Scoring subsection of this document. The weights in the Metric Weights Template can be modified if the user wants to rerun the scoring with a different weighting. However, the formatting of the Template should not be modified, as the Notebook may not be able to process the weights properly.
- The supplemental geodatabase (“fcog_tnva_20190918_supplemental.gdb”) contains additional feature classes used in this memorandum, including those used for the climate projection maps in the Future Projections subsection and for the landslide maps used in the Future Deep-Seated Landslides subsection.

Note regarding bridge analysis: We analyzed bridges from two data sources: the Fresno County Department of Public Works and Planning’s bridge inventory and the National Bridge Inventory (NBI). We combined the two datasets into one feature class of 1,336 bridge features. Of these, 761 appeared in the NBI alone, 136 appeared in both the NBI and the Fresno County inventory, and 439 appeared in the Fresno County inventory alone. We wanted to include in the scoring the rich information on conditions and consequences in the NBI. But we also did not want to ‘penalize’ bridges for not being in the NBI. For bridges not appearing in the NBI, we composed their scores from using all of the non-NBI variables and scaled them accordingly. While we show results for all bridges on the same map, the scores for the non-NBI bridges were compiled with fewer inputs. The NBI scores are therefore somewhat more robust than the non-NBI scores.

[36] Jupyter Notebook is free and open source and can be downloaded here: https://jupyter.org/.

Note regarding roadway analysis: We analyzed roadways using the Fresno COG VMIP 2 travel demand mode network for 2042. This network contains forecasts of numerous metrics related to travel volumes and congestion. The network is more spatially accurate in the heavily trafficked urban areas and less spatially accurate in the sparser mountainous regions of the County. We pre-processed the network by combining directly overlapping links (those that shared endpoints A and B) into single links. For each combined link, we added volume across its two composite links and took the maximum of the LOS ratings between the two composite links. Many links in the network did not span all the way from intersection to intersection but rather started or ended between intersections. For the vulnerability assessment, we sought units of analysis that were true intersection-to-intersection segments. But we also wanted to preserve the volume information in the segments. Therefore, we slightly rounded volume and then dissolved by volume to combine segments with very similar volumes. We then used the network nodes (which represented the true intersections) to split the dissolved network into intersection-to-intersection segments with volume information.

Results

This section covers the full results of the vulnerability scoring exercise. It is organized by hazard-asset combinations. Each combination includes a map of results, table of top scoring assets, and brief narrative of the results. The accompanying files contain the results in geodatabase feature class (GIS) and comma-separated value (CSV) format. The Summary section synthesizes the results from the scoring and from other Vulnerability Assessment analyses.

Bridges and Future Flooding

Riverine peak flows are expected to increase under at least some of the future climate scenarios. Many bridges were identified as vulnerable to future riverine flooding. Most of these are lightly traveled roads in low-density areas, though network redundancy is limited in many of these areas, so detour routes are often long.

Several of the most vulnerable bridges span the Kings River South Fork on the SR-180 or nearby roads in far eastern Fresno County. These roads are characterized by low travel volumes but significant detour lengths. Some of these bridges already experience flooding issues and have below average conditions ratings. A couple other bridges along SR-180 were flagged as highly vulnerable; one across Mill Creek farther west in the Sierras, and one across Fresno Slough near Mendota.

There were three bridges with vulnerability scores over 80 along the I-5 over the Panoche Creek and Little Panoche Creek. These have higher travel volumes than the other highly vulnerable bridges and each received at least one weak condition score (substructure condition rating, channel condition rating, scour critical rating, or waterway adequacy rating).

One of the most vulnerable bridges to future flooding was the North Fork Road bridge over the San Joaquin River in Friant. It has experienced flooding in the past, rates poorly for scour, and will likely experience high increases in flows under many of the climate scenarios.

There were a few other highly vulnerable bridges north of Reedley across Cameron Slough and Wahtoke Creek, one farther west over the Cole Slough on SR-43, and one in the county's southwestern corner on SR-198 over Warthan Creek. There are also a couple in the county's northwestern corner on N Russell Ave over Outside Canal and Delta-Mendota Canal.

Non-NBI bridges (i.e. those in the Fresno County bridge inventory that are not in the NBI) were also scored, though there is less confidence in these results given the lack of condition and consequence information that is available for the NBI bridges. Of the non-NBI bridges, many of the most vulnerable are several bridges in the Kings River watershed that have high expected increases in flows. Some of these assets are on the Murphy Slough, a side channel of the Kings River. It appears that USGS Streamstats, the data source for the watershed geometries, assigns Murphy Slough a large portion of the overall Kings River watershed area, which could overstate the flow in Murphy Slough and understate the flow in the parallel portion of the Kings River. Therefore, these flows should be assessed in more detail as part of facility-level assessments.

Figure 20. Vulnerability Scoring: Bridges & Future Flooding

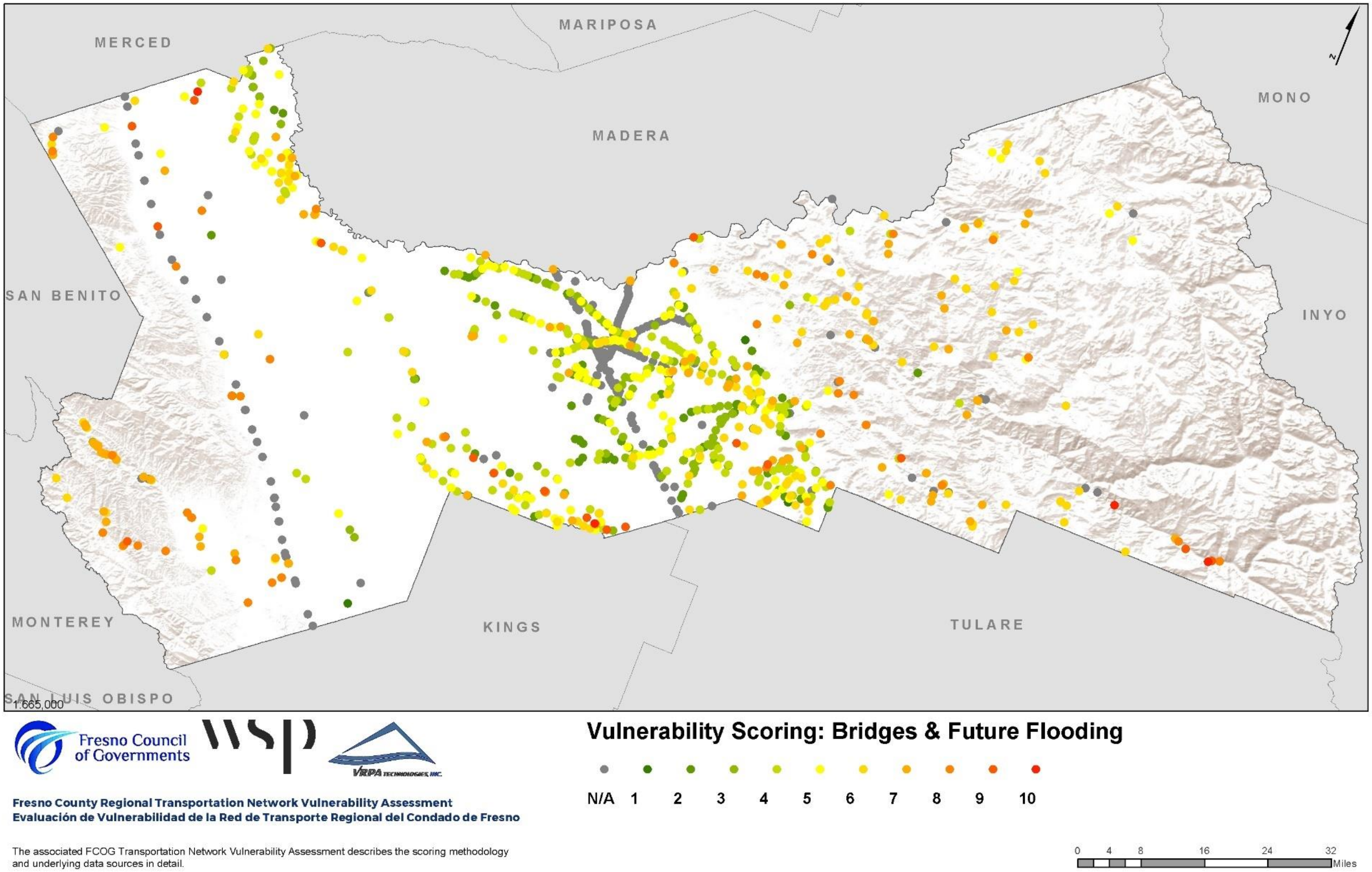


Table 5. Highest Flooding Vulnerability Scores for Bridges

OID_num	FCBN	NBI_STRUCTURE_NUMBER_008_trim	ROUTE_NUMBER_005D	FEATURES_DESC_006A	FACILITY_CARRIED_007	LOCATION_009	final_score_flood_brid	scalescore_flood_brid	scale_flow_t1mx	scale_flow_mx	scale_dmg_fld	scale_Bsubstruct_cond	scale_Bchannel_cond	scale_Bscour_crit	scale_Bwaterway_adequ	scale_fac_vol	scale_Bdetour	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
34	05-064						10	90	95	94	0					0		4	15	100	14	2
154	01-017	42C0047	0	OUTSIDE CANAL '	'N RUSSELL AVE '	'3.9 MI NORTH OF NEES AVE '	10	95	65	62	0	60	60	60	100	1	19	3	3	0	15	6
578		8580003P0000000	11	ROARING RIVER'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY. MP 31.9'	10	92	81	76	0	30	45	15	75	0	100	0	0	0	6	2
583		42 0024	180	'SOUTH FORK KINGS RIVER '	'STATE ROUTE 180 '	06-FRE-180-130.13'	10	100	87	83	0	30	60	60	75	0	100	1	2	0	6	2
33	05-058						9	87	95	94	0					0		7	17	0	14	2
110	05-039						9	87	95	94	0					0		6	10	0	15	3
118	05-049						9	88	95	94	0					0		3	7	0	31	5
157	01-021	42C0142	0	'DELTA-MENDOTA CANAL '	'N RUSSELL AVE '	AT ALTHEA AVE '	9	85	59	53	0	60	15	15	100	1	10	3	3	0	15	6
221	07-001	42C0001	0	'SAN JOAQUIN RIVER '	'NORTH FORK ROAD '	'0.1 MI W/O FRIANT RD '	9	83	36	37	100	60	30	90	45	2	26	0	11	0	58	6
372	05-069						9	87	95	94	0					0		3	14	0	14	2
406	10-040						9	87	95	94	0					0		2	4	0	15	0
420	10-053	42C0237	0	WAHTOKE CREEK '	'E JEFFERSON AVE '	'0.31 MI W BUTTONWILLOW AV'	9	83	77	71	0	30	30	50	75	0	1	4	7	0	15	0
504	05-054						9	87	95	94	0					0		3	4	0	15	3
577		8580005P0000000	11	' SOUTH FORK KINGS RIVER'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY. MP 32.3'	9	86	85	82	0	50	30	90	45	0	100	0	0	0	6	2
579		8580006P0000000	205	' SOUTH FORK KINGS RIVER'	' WEST SIDE ROAD'	'KINGS CANYON HWY. MP 28.8'	9	81	85	82	0	30	15	50	60	0	5	0	0	0	6	2
622		42 0080	180	MILL CREEK '	'STATE ROUTE 180 '	06-FRE-180-92.18 '	9	86	84	80	0	30	30	60	60	3	45	6	33	0	6	2
711		42C0007	0	CAMERON SLOUGH '	'E GOODFELLOW AVE '	'0.14 MI E/O RIVERBEND AVE'	9	81	95	94	0	30	30	60	45	2	7	2	4	0	15	0
789		42 0081	43	COLE SLOUGH '	'STATE ROUTE 43 '	06-FRE-043-0.78 '	9	83	95	94	0	30	45	60	45	7	9	3	3	0	14	2
1243		42 0041	180	KINGS SLOUGH '	'STATE ROUTE 180 '	06-FRE-180-26.95 '	9	86	95	94	0	30	60	60	45	4	19	5	2	100	74	26
1278		42 0012	198	WARTHAN CREEK '	'STATE ROUTE 198 '	06-FRE-198-13.60 '	9	80	82	82	0	60	45	15	45	2	100	2	3	0	11	3
1322		42 0249R	5	PANOCHE CREEK '	'INTERSTATE 5 NB '	06-FRE-005-49.99 '	9	80	79	87	0	30	60	60	45	8	20	7	1	100	18	13
1323		42 0249L	5	PANOCHE CREEK '	'INTERSTATE 5 SB '	06-FRE-005-49.99 '	9	81	79	87	0	60	60	60	45	8	17	7	1	100	18	13
1331		42 0374	5	'LITTLE PANOCHE CREEK '	'INTERSTATE 5 '	06-FRE-005-62.21 '	9	88	81	80	0	0	90	15	75	16	1	1	1	0	15	6

Bridges and Future Temperature Change

Bridges expected to experience large increases in temperature could be at risk of thermal expansion that exceeds design thresholds. Generally, the highest absolute daily maximum temperature *increases* (not to be confused with temperatures themselves) are expected in the eastern regions of Fresno County, with lower increases toward the western and southwestern regions. Therefore, bridges farther east and north tend to receive higher temperature vulnerability scores. For NBI bridges, the travel volume and detour length of the bridges also contributes considerably to their vulnerability scores.

Given their low redundancy and high exposure, several bridges on the SR-168 and SR-180 in the Sierras receive most of the highest vulnerability scores. The highest volume bridge in the dataset which is on the short stretch of SR-180 between SR-168 and SR-41 near downtown Fresno, also receives a very high vulnerability score.

Figure 21. Fresno County Bridges & Future Temperature

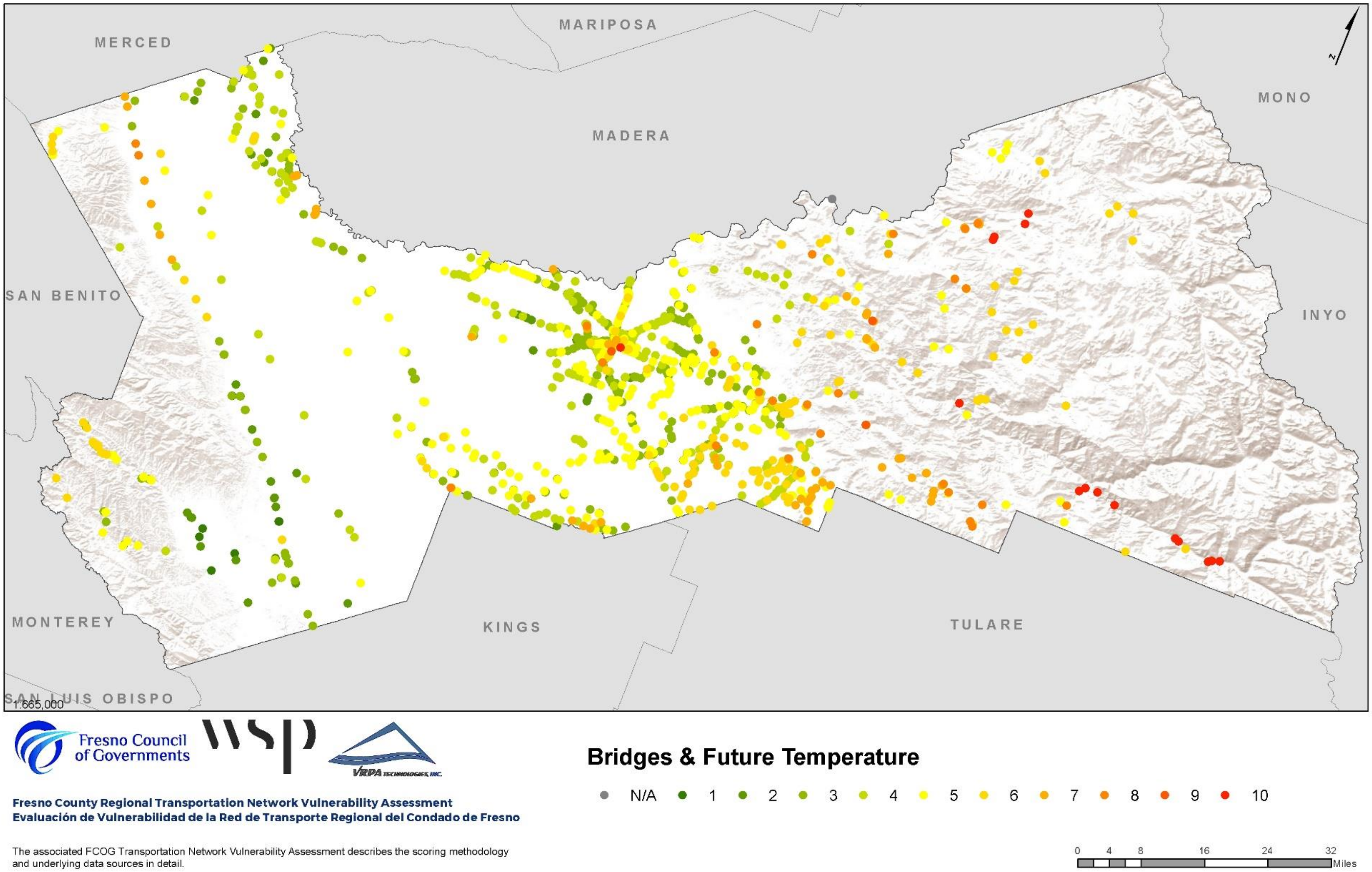


Table 6. Highest Temperature Vulnerability Scores for Bridges

OID_num	FCBN	STRUCTURE_NUMBER_008_trim	ROUTE_NUMBER_005D	FEATURES_DESC_006A	FACILITY_CARRIED_007	LOCATION_009	final_score_temp_brid	scalescore_temp_brid	scale_tdelt_mx	scale_fac_vol	scale_Bdetour	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
249	09-006	42C0591	0	'KINGS RIVER '	'TRIMMERS SPRING RD'	'14 MI E OF MAXSON RD '	10	93	95	0	100	3	16	0	9	4
576		8580002P0000000	11	' GRANITE CREEK'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY MP 33.1 '	10	96	97	0	100	0	0	0	6	2
577		8580005P0000000	11	' SOUTH FORK KINGS RIVER'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY. MP 32.3'	10	96	97	0	100	0	0	0	6	2
578		8580003P0000000	11	' ROARING RIVER'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY. MP 31.9'	10	96	97	0	100	0	0	0	6	2
580		8580004P0000000	11	' SOUTH FORK KINGS RIVER'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY MP 32.1 '	10	97	98	0	100	0	0	0	6	2
581		8580001P0000000	11	' LEWIS CREEK'	'CEDAR GROVE ROAD ('	'KINGS CANYON HWY. MP 27.2'	10	99	99	0	100	1	2	0	6	2
583		42 0024	180	'SOUTH FORK KINGS RIVER '	'STATE ROUTE 180 '	'06-FRE-180-130.13 '	10	100	100	0	100	1	2	0	6	2
584		42 0411	180	'HILLSIDE '	'SR 180 '	'06-FRE-180-126.14 '	10	100	100	0	100	1	2	0	6	2
585		42 0432	180	'SIDEHILL VIADUCT '	'ROUTE 180 '	'06-FRE-180-124.40 '	10	98	99	0	100	1	2	0	6	2
586		42 0020	180	'TEN MILE CREEK '	'STATE ROUTE 180 '	'06-FRE-180-123.56 '	10	98	99	0	100	1	2	0	6	2
615		42 0121	168	'BIG CREEK '	'STATE ROUTE 168 '	'06-FRE-168-64.12 '	10	97	98	1	100	2	1	0	3	5
616		42 0122	168	'RANCHERIA CREEK '	'STATE ROUTE 168 '	'06-FRE-168-65.74 '	10	99	99	1	100	2	1	0	3	5
619		42 0111	168	'TAMARACK CREEK '	'STATE ROUTE 168 '	'06-FRE-168-58.67 '	10	96	97	1	100	3	11	0	3	5
620		42 0057	168	'S FK TAMARACK CREEK '	'SR 168 '	'06-FRE-168-58.23 '	10	95	96	1	100	3	11	0	3	5
946		42 0443G	180	'SR 41-E180 CONNECT '	'E180-E168 CONNECT '	'06-FRE-180-R58.60 '	10	92	77	100	2	5	65	100	38	36
636		42C0573	0	'MILL CREEK '	'LUPINE DRIVE '	'0.2 MI NORTH OF ELWOOD RD'	9	81	87	0	100	3	16	0	6	2
648		42C0624	0	'LITTLE DRY CREEK '	'SYCAMORE ROAD '	'0.17 MI E OF WATTS VALLEY'	9	85	89	0	100	4	24	0	6	6
976		42 0283	0F347	'STATE ROUTE 41 '	'TULARE ST '	'06-FRE-041-R23.74-FRE '	9	85	75	24	100	50	53	0	39	42

Roadways and Future Flooding

According to the scoring, many of the roads vulnerable to flooding occur in the western portion of the county in the rural portions of the San Joaquin Valley. There are several vulnerable mountain roads in the foothills of both the Diablo Range and the Sierra Nevada. There are also some pockets of vulnerable roads in the Fresno metropolitan area where the street network overlaps riverine floodplains.

The roadway segment with the highest vulnerability scores was the SR-180 over the Fresno Slough near Mendota. This stretch was identified as a location experiencing recurring issues. It lies within the 100-year floodplain and is projected to experience relatively high increases in precipitation. It is also relatively high volume and low redundancy and is in a Fresno COG designated EJ community. Belmont Avenue in Mendota near its intersection with SR-180 was also highlighted by the scoring.

The SR-269 north of Huron was another high vulnerability stretch of roadway, identified because of its past issues, exposure, low redundancy, and being located within an EJ community.

A few short stretches of SR-99 were also rated highly vulnerable. These include a portion just south of the interchange with SR-41 and a portion just south of the S Cedar Avenue overpass in Fresno.

Other segments identified as highly vulnerable include Manning Avenue over Kings River in Reedley and North Fork Road over the San Joaquin River in Friant.

Portions of SR-41 just north of downtown Fresno were flagged for vulnerability, though this may have been in part due the resolution and accuracy of the floodplain and or the roadway data; it appears to be elevated above the surface in some places where it intersects the 100-year floodplain.

Figure 22. Vulnerability Scoring: Roadways & Future Flooding

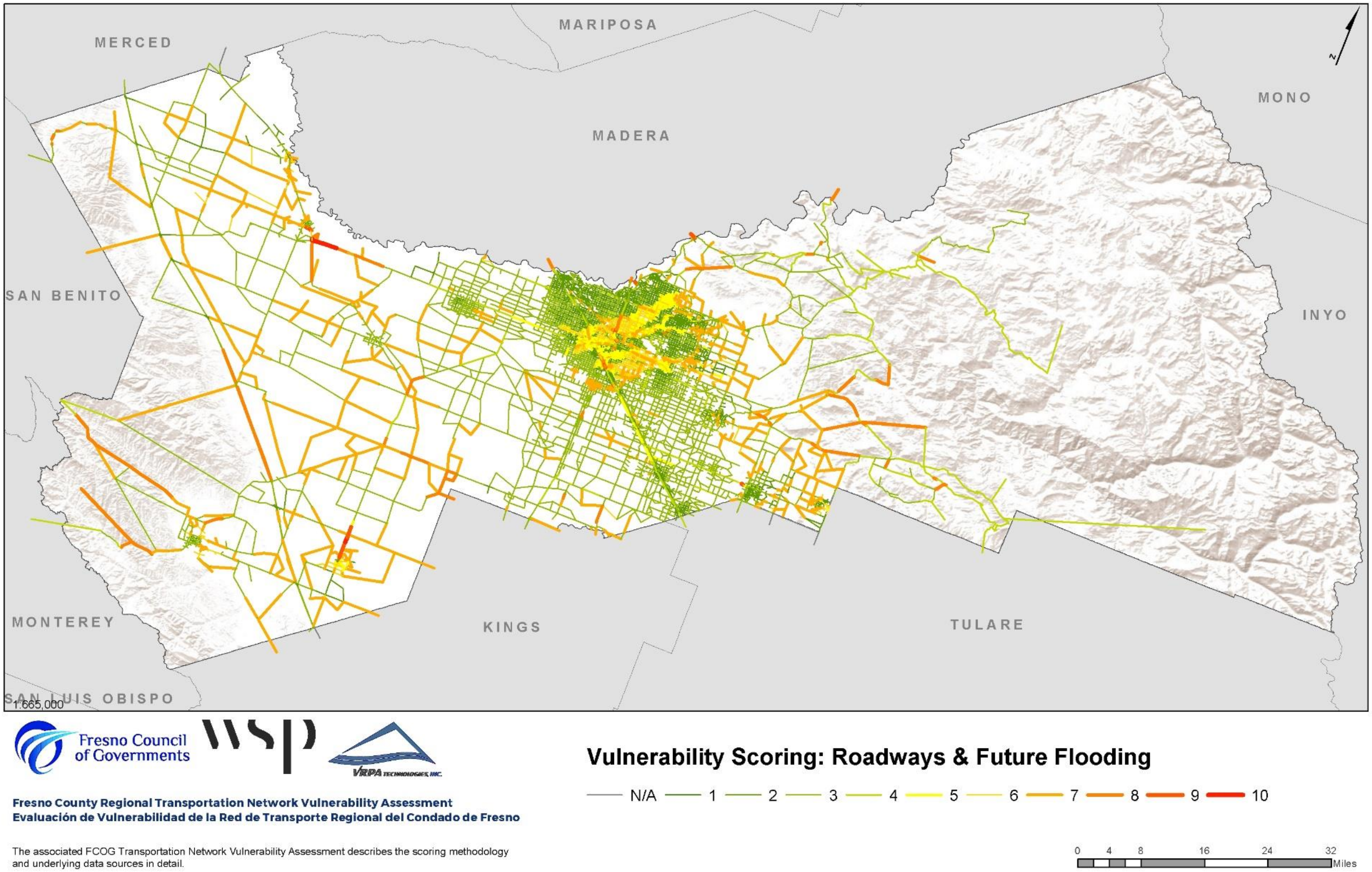


Table 7. Highest Flooding Vulnerability Scores for Roadways

OID_num	NAME	ROUTE	JURISDICTI	AB_code	FACTYP	final_score_flood_road	scalescore_flood_road	scale_pre_t1mx	scale_pre_mx	scale_flood_pln	scale_dmg_fld	scale_los	scale_fac_vol	scale_trk_vol	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
20273	SR 180	0	CALTRANS	28445_28446	2	10	100	55	79	100	100	33	19	6	98	3	1	100	30	16
20277	SR 180	0	CALTRANS	28448_43135	2	10	99	55	79	100	100	33	19	6	98	1	0	100	4	2
20274	SR 180	0	CALTRANS	28446_28447	2	10	99	55	79	100	100	33	19	6	98	3	1	0	32	17
20275	SR 180	0	CALTRANS	28447_43135	2	10	99	55	79	100	100	33	19	6	98	3	1	0	31	16
20271	SR 180	0	CALTRANS	28444_28445	2	10	99	55	79	100	100	33	19	6	90	2	1	100	19	10
20691	SR 180	0	Fresno County	6767_30994	2	10	98	55	79	100	100	50	20	6	79	0	0	100	17	13
20272	SR 180	0	CALTRANS	28444_53875	2	10	97	55	79	100	100	33	19	6	82	0	0	100	14	11
20309	SR 180	0	CALTRANS	30995_53875	2	10	97	55	79	100	100	33	19	6	81	0	0	100	11	9
20666	SR 180	0	Fresno County	30994_30995	2	10	97	55	79	100	100	33	18	5	80	0	0	100	14	11
20665	SR 180	0	Fresno County	30993_30994	2	10	93	55	79	100	100	17	1	1	79	0	0	100	19	15
20351	SR 180	0	CALTRANS	6768_30995	2	10	93	55	79	100	100	17	1	0	80	0	0	100	15	12
7187	Belmont	0	Mendota	28349_30173	4	10	91	56	63	100	100	17	7	2	76	1	8	100	16	11
7188	Belmont	0	Mendota	28349_42639	4	10	91	56	63	100	100	17	7	2	76	1	8	100	16	11
20990	SR 269	0	Fresno County	6621_28224	2	10	91		30	100	100	17	9	2	94	2	0	100	3	8
20965	SR 269	0	Fresno County	28224_39466	2	9	90		24	100	100	17	9	2	95	1	0	100	2	6
22823	Upper Brdg	0	Reedley	6961_28994	2	9	90	53	34	100	100	17	23	5	76	4	7	100	20	12
22821	Upper Brdg	0	Reedley	6960_28993	2	9	90	53	34	100	100	17	22	5	76	4	7	100	20	12
20964	SR 269	0	Fresno County	28223_39466	2	9	88		24	100	100	17	9	2	85	2	3	100	3	6
20968	SR 269	0	Fresno County	28404_52033	2	9	88	41	40	100	100	17	9	2	95	2	0	100	3	6
21005	SR 269	0	Huron	28223_42222	2	9	88		24	100	100	17	9	2	82	3	7	100	8	17
20991	SR 269	0	Fresno County	6621_6622	2	9	88	41	40	100	100	17	9	2	92	3	0	100	4	10
21004	SR 269	0	Huron	28222_42223	2	9	88		24	100	100	17	9	2	81	2	7	100	7	16
21007	SR 269	0	Huron	42222_42223	2	9	88		24	100	100	17	9	2	81	3	7	100	8	17
20966	SR 269	0	Fresno County	28225_52033	2	9	88	41	40	100	100	17	9	2	90	6	1	100	9	20
20992	SR 269	0	Fresno County	6622_28225	2	9	88	41	40	100	100	17	9	2	90	6	1	100	8	18
20709	SR 180	0	Mendota	30175_38552	2	9	86	56	63	75	100	50	21	7	79	1	8	100	16	11
20708	SR 180	0	Mendota	28350_30175	2	9	86	56	63	75	100	50	21	7	78	2	9	100	19	13
21389	SR 41	0	CALTRANS	18572_51555	1	9	85	76	47	100	0	100	96	9	10	7	55	100	32	36

Roadways and Future Wildfire

The Central Valley is home to most of Fresno County's population, where wildfire risk is lower. But the rural roadway networks in of both the Sierra Nevada and Diablo Range are highly exposed to wildfire.

The longest stretches of highly vulnerable roadway are the SR-180, Auberry Road, and the SR-168 in the Sierras. These have very low redundancy and relatively high volume (especially portions of Auberry Road and SR-168 lower in the mountains) compared to other rural roads in the county's exposed areas. Other highly vulnerable Sierra roadways include Lodge, Powerhouse, SR-63, Trimmer Springs, and Watts Valley.

On the Diablo Range side, the most vulnerable roadways were the SR-198 west of Coalinga and Los Gatos Creek Road. Little Panoche Road was also flagged as highly vulnerable, though the portion of the roadway in Fresno County appears to be mostly in grassland (rather than woodland or scrub) and therefore likely poses less of a threat to the transportation network.

Figure 23. Vulnerability Scoring: Roadways and Future Wildfire

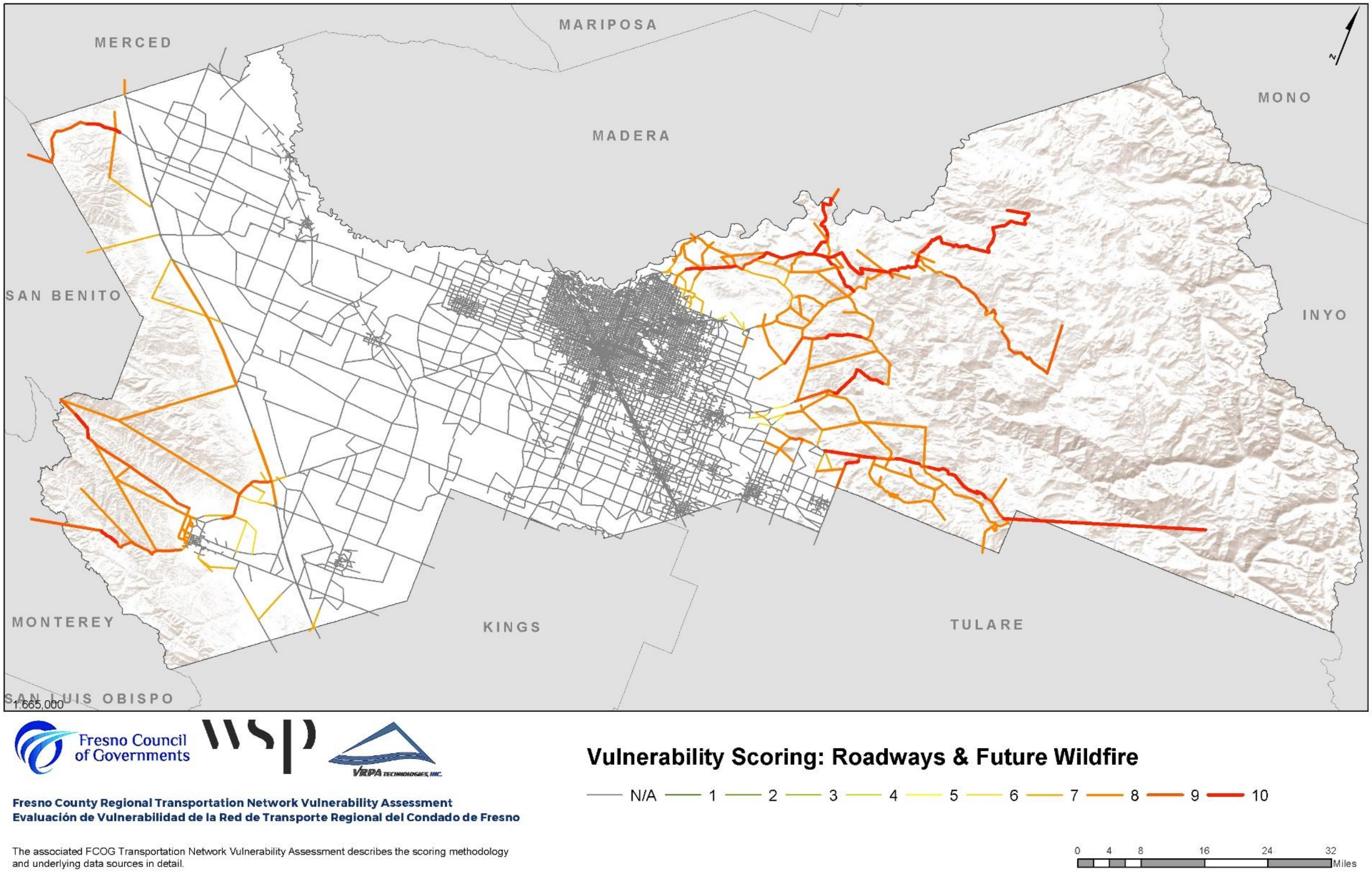


Table 8. Highest Wildfire Vulnerability Scores for Roadways

OID_num	NAME	JURISDICTI	AB_code	FACTYP	final_score_fire_road	scalescore_fire_road	scale_time_elev_burn	scale_cat_burn	scale_dmg_fire	scale_los	scale_fac_vol	scale_trk_vol	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
6505	Auberry	Fresno County	7620_45095	4	10	100	100	75	100	100	18	3	98	0	1	0	1	1
20175	SR 168	Fresno County	41850_47404	2	10	100	100	100	100	17	2	0	98	2	8	0	2	4
20224	SR 168	Fresno County	7134_7135	2	10	100	100	100	100	17	2	0	98	2	7	0	2	4
20156	SR 168	Fresno County	36658_47353	2	10	100	100	100	100	17	2	0	98	2	6	0	2	3
20155	SR 168	Fresno County	36623_53909	2	10	100	100	100	100	17	2	0	98	2	6	0	2	3
20154	SR 168	Fresno County	36622_36623	2	10	100	100	100	100	17	2	0	98	2	6	0	2	3
20157	SR 168	Fresno County	36658_47404	2	10	100	100	100	100	17	2	0	98	1	5	0	1	2
20169	SR 168	Fresno County	38917_47984	2	10	100	100	100	100	17	2	0	98	1	1	0	2	4
20221	SR 168	Fresno County	7105_36622	2	10	100	100	100	100	17	2	0	98	1	1	0	2	4
20159	SR 168	Fresno County	36663_36664	2	10	100	100	100	100	17	2	0	98	1	1	0	2	4
20173	SR 168	Fresno County	41849_41850	2	10	100	100	100	100	17	2	0	98	1	4	0	1	2
20164	SR 168	Fresno County	36667_53903	2	10	100	100	100	100	17	2	0	98	1	0	0	2	3
20163	SR 168	Fresno County	36667_47984	2	10	100	100	100	100	17	2	0	98	1	0	0	2	3
20166	SR 168	Fresno County	36668_47991	2	10	100	100	100	100	17	2	0	98	1	0	0	2	3
20168	SR 168	Fresno County	36686_38845	2	10	100	100	100	100	17	2	0	98	1	0	0	2	3
20174	SR 168	Fresno County	41849_47351	2	10	100	100	100	100	17	2	0	98	1	3	0	1	2
20167	SR 168	Fresno County	36686_38844	2	10	100	100	100	100	17	2	0	98	1	0	0	1	2
20165	SR 168	Fresno County	36668_38844	2	10	100	100	100	100	17	2	0	98	1	0	0	1	2
20223	SR 168	Fresno County	7134_47351	2	10	100	100	100	100	17	2	0	98	1	3	0	1	1
20160	SR 168	Fresno County	36664_47971	2	10	100	100	100	100	17	2	0	98	1	0	0	1	2
20225	SR 168	Fresno County	7135_36659	2	10	99	100	100	100	17	2	0	98	1	3	0	1	1
20161	SR 168	Fresno County	36665_47572	2	10	99	100	100	100	17	2	0	98	1	0	0	1	2
20170	SR 168	Fresno County	38917_47991	2	10	99	100	100	100	17	2	0	98	1	0	0	1	2
20162	SR 168	Fresno County	36665_47971	2	10	99	100	100	100	17	2	0	98	1	0	0	1	1
20177	SR 168	Fresno County	47572_53903	2	10	99	100	100	100	17	2	0	98	1	0	0	1	1
20176	SR 168	Fresno County	47353_53909	2	10	99	100	100	100	17	2	0	98	0	2	0	0	1
20222	SR 168	Fresno County	7105_50049	2	10	99	100	100	100	17	2	0	98	0	0	0	1	1
20158	SR 168	Fresno County	36659_36663	2	10	99	100	100	100	17	2	0	98	0	0	0	1	1
6506	Auberry	Fresno County	7620_7621	4	10	99	100	75	100	100	18	3	91	0	2	0	2	1
6507	Auberry	Fresno County	7621_51354	4	10	99	100	75	100	100	18	2	88	0	3	0	3	2
4561		Fresno County	2852_38845	10	10	98	100	100	100	0	2	0	98	0	0	0	0	1
4564		Fresno County	2855_7166	10	10	98	100	100	100	0	0	0	97	0	0	0	0	0
14635	Ll Panoche	Fresno County	28249_38449	4	10	95	100	75	100	17	9	0	98	3	1	100	17	13
14636	Ll Panoche	Fresno County	28250_38448	4	10	95	100	75	100	17	9	0	98	3	0	100	15	11
6480	Auberry	Fresno County	43652_51354	4	10	95	100	75	100	50	18	2	90	0	1	0	1	0
14639	Ll Panoche	Fresno County	28251_38448	4	10	95	100	75	100	17	9	0	98	3	0	100	13	10
14633	Ll Panoche	Fresno County	28248_28249	4	10	95	100	75	100	17	9	0	98	2	0	100	10	8
14637	Ll Panoche	Fresno County	28250_38449	4	10	95	100	75	100	17	9	0	98	1	0	100	8	6
14634	Ll Panoche	Fresno County	28248_39548	4	10	95	100	75	100	17	9	0	98	1	0	100	5	4
6452	Auberry	Fresno County	27829_43652	4	10	95	100	75	100	50	17	2	86	3	7	0	1	0

Roadways and Future Temperature Change

Changes in prolonged periods of high temperatures can exceed the design thresholds of the pavement binder grades used on the roadways. To measure exposure, we analyzed the maximum change in 7-day moving average maximum temperature across different climate scenarios and timeframes. Generally, the eastern and northern portions of Fresno County are projected larger increases in this metric compared to portions of the County farther to the west and south. Because exposure was combined with consequence information and travel volumes were weighted highly in the scoring, most of the high-volume roadways in Fresno County were flagged as most vulnerable to future temperature increases. This includes most of SR-99 within Fresno County, the SR-41 north of its interchange with SR-99, and a small portion of SR-180 between its interchanges with SR-41 and SR-168 near downtown Fresno.

Figure 24 Vulnerability Scoring: Roadways & Future Temperature

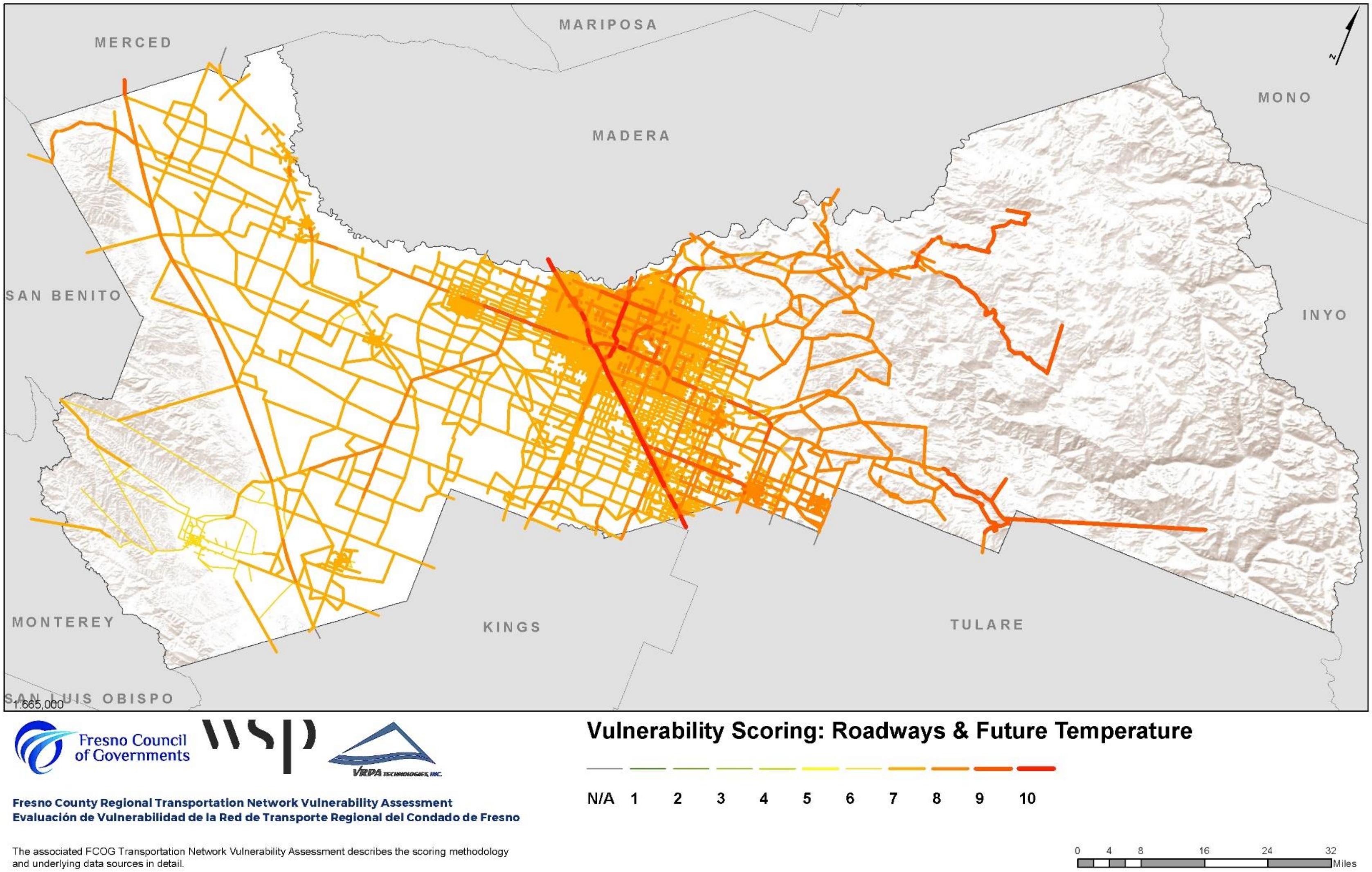


Table 9. Highest Temperature Vulnerability Scores for Roadways

OID_num	NAME	JURISDICTI	AB_code	FACTYP	final_score_temp_road	scalescore_temp_road	scale_temp7_mx	scale_los	scale_fac_vol	scale_trk_vol	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
21408	SR 41	CALTRANS	19677_19680	1	10	100	78	100	99	8	14	27	30	100	21	21
21400	SR 41	CALTRANS	18825_40109	1	10	100	78	100	99	8	19	6	31	100	17	19
21409	SR 41	CALTRANS	19677_55277	1	10	100	78	100	99	8	16	21	24	100	17	10
21396	SR 41	CALTRANS	18746_18747	1	10	100	78	100	98	7	11	9	41	100	27	29
21952	SR 99	Fresno County	24202_52216	1	10	100	78	100	91	37	47	1	8	0	9	2
21404	SR 41	CALTRANS	18841_18843	1	10	100	78	100	98	7	19	6	33	100	25	20
21484	SR 41	CALTRANS	18585_50368	1	10	100	76	100	100	9	9	5	59	100	37	41
21406	SR 41	CALTRANS	18842_55277	1	10	100	78	100	99	8	14	8	28	100	19	16
21483	SR 41	CALTRANS	18583_50368	1	10	100	76	100	100	9	8	5	59	100	37	41
21937	SR 99	Fresno County	10959_10961	1	10	99	77	100	88	35	63	6	1	0	16	7
21913	SR 99	Fowler	24271_24522	1	10	99	78	100	88	37	59	1	2	0	5	2
21951	SR 99	Fresno County	24200_52217	1	10	99	78	100	91	37	43	1	6	0	11	2
21973	SR 99	Fresno County	52216_52217	1	10	99	78	100	91	37	43	1	6	0	11	2
21243	SR 41	CALTRANS	19678_55258	1	10	99	78	100	98	7	16	21	24	100	18	10
21912	SR 99	Fowler	24271_24275	1	10	99	78	100	88	37	54	2	12	0	7	2
21979	SR 99	Fresno County	7445_24202	1	10	99	78	100	91	37	40	2	9	0	8	2
21395	SR 41	CALTRANS	18745_55281	1	10	99	78	100	99	8	13	6	27	100	6	9
21922	SR 99	Fowler	24522_24531	1	10	99	78	100	88	37	51	1	1	0	18	5
21407	SR 41	CALTRANS	18843_55258	1	10	99	78	100	98	7	13	8	28	100	19	16
21481	SR 41	CALTRANS	18577_18583	1	10	99	76	100	100	9	4	4	52	100	36	43
21915	SR 99	Fowler	24274_24275	1	10	99	78	100	88	37	50	2	15	0	9	2
21881	SR 99	CALTRANS	11133_50221	1	10	99	76	100	97	38	12	6	14	100	10	8
21889	SR 99	CALTRANS	50221_50356	1	10	99	76	100	97	38	11	6	15	100	10	9
21908	SR 99	Fowler	24209_24210	1	10	99	78	100	91	37	35	1	13	0	10	2
21397	SR 41	CALTRANS	18747_55254	1	10	99	78	100	98	7	12	6	27	100	6	9
21926	SR 99	Fowler	7445_24209	1	10	99	78	100	91	37	35	1	13	0	8	2
21947	SR 99	Fresno County	11011_52360	1	10	99	77	100	85	34	66	5	1	0	21	9
21975	SR 99	Fresno County	52224_52360	1	10	99	77	100	85	34	66	5	1	0	21	9
21883	SR 99	CALTRANS	11191_11193	1	10	99	76	100	97	38	8	9	2	100	16	12
21888	SR 99	CALTRANS	50220_50356	1	10	99	76	100	97	38	9	6	11	100	8	7
21938	SR 99	Fresno County	10959_11011	1	10	99	77	100	85	34	66	4	1	0	16	7
21884	SR 99	CALTRANS	11191_50220	1	10	99	76	100	97	38	8	5	2	100	8	7

Transit Stops and Future Flooding

In Fresno County, the most vulnerable transit stops to future flooding lie in the Fresno metro area, though there are a few pockets elsewhere. Large swaths of the metro area are located within the current 500-year floodplain, rendering many of the transit stops in the area vulnerable.

The largest concentrations of highly vulnerable stops are in the portions of the Roosevelt neighborhood of Fresno and downtown Fresno that overlap the 500-year floodplain. The cluster of Roosevelt stops is in an EJ community with a high population density and high 'no vehicle access' rates. The downtown stops are in an EJ community with a high employment density, high 'no vehicle access' rates, and high CalEnviroScreen scores. Several transit stops along Dry Creek to the North of downtown Fresno are within the 100-year floodplain and thus are considered high vulnerable. Closer to downtown, there are several stops in the 100-year floodplain near the channel that runs on north of and parallel to SR-180 as well as along the SR-99.

Outside of the Fresno metro area, several stops along the SR-180 across the Fresno Slough floodplain near Mendota are highly vulnerable due to their high exposure, sparsity of the roadway network, and location within a designated EJ community. There are a few highly vulnerable stops in the 100-year floodplain between Five Points and Lanare on W Mount Whitney Avenue. These are also in an EJ community on roadways with low redundancy.

Figure 25 Fresno County Vulnerability Scoring: Transit Stops & Future Flooding

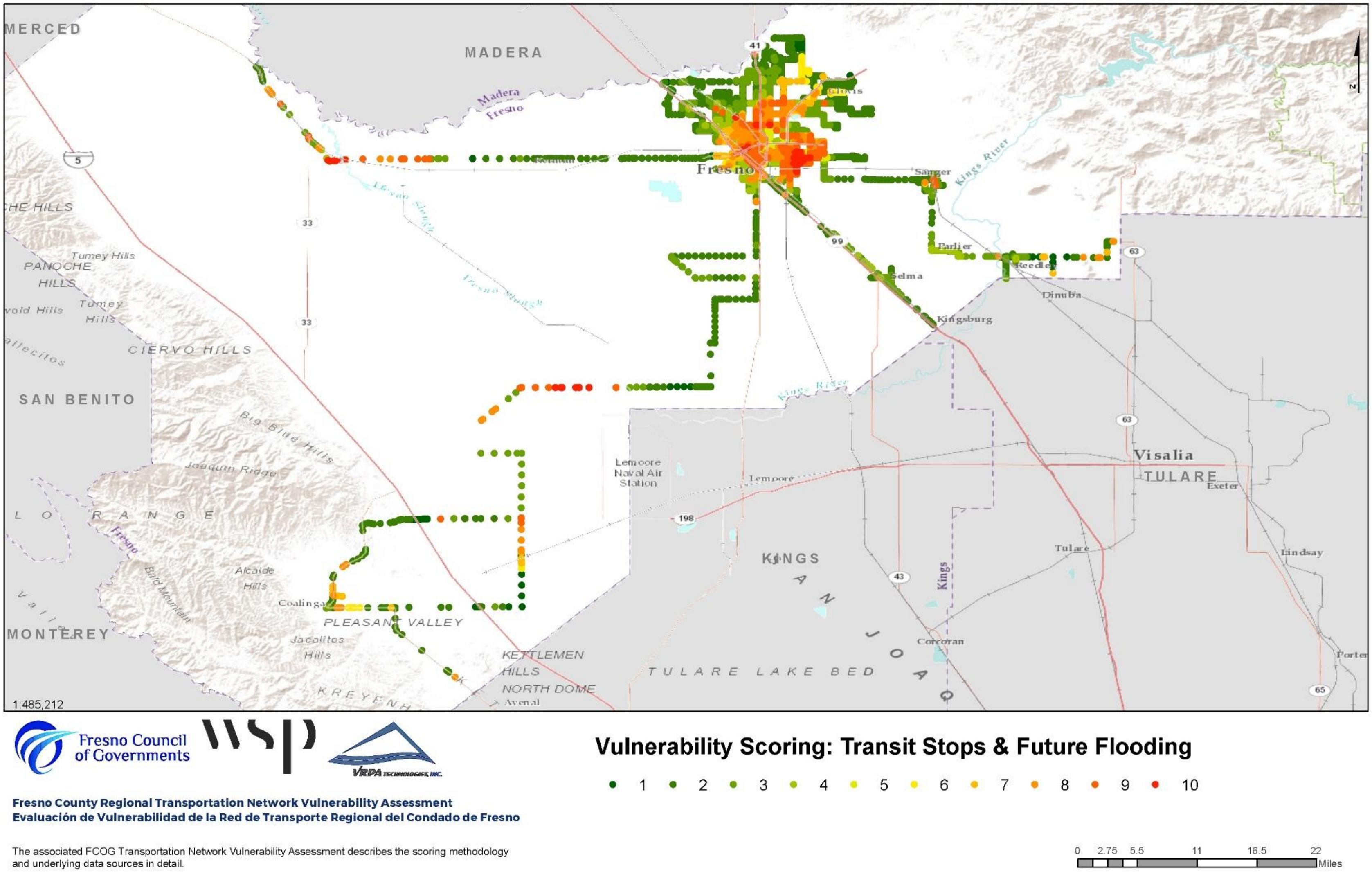


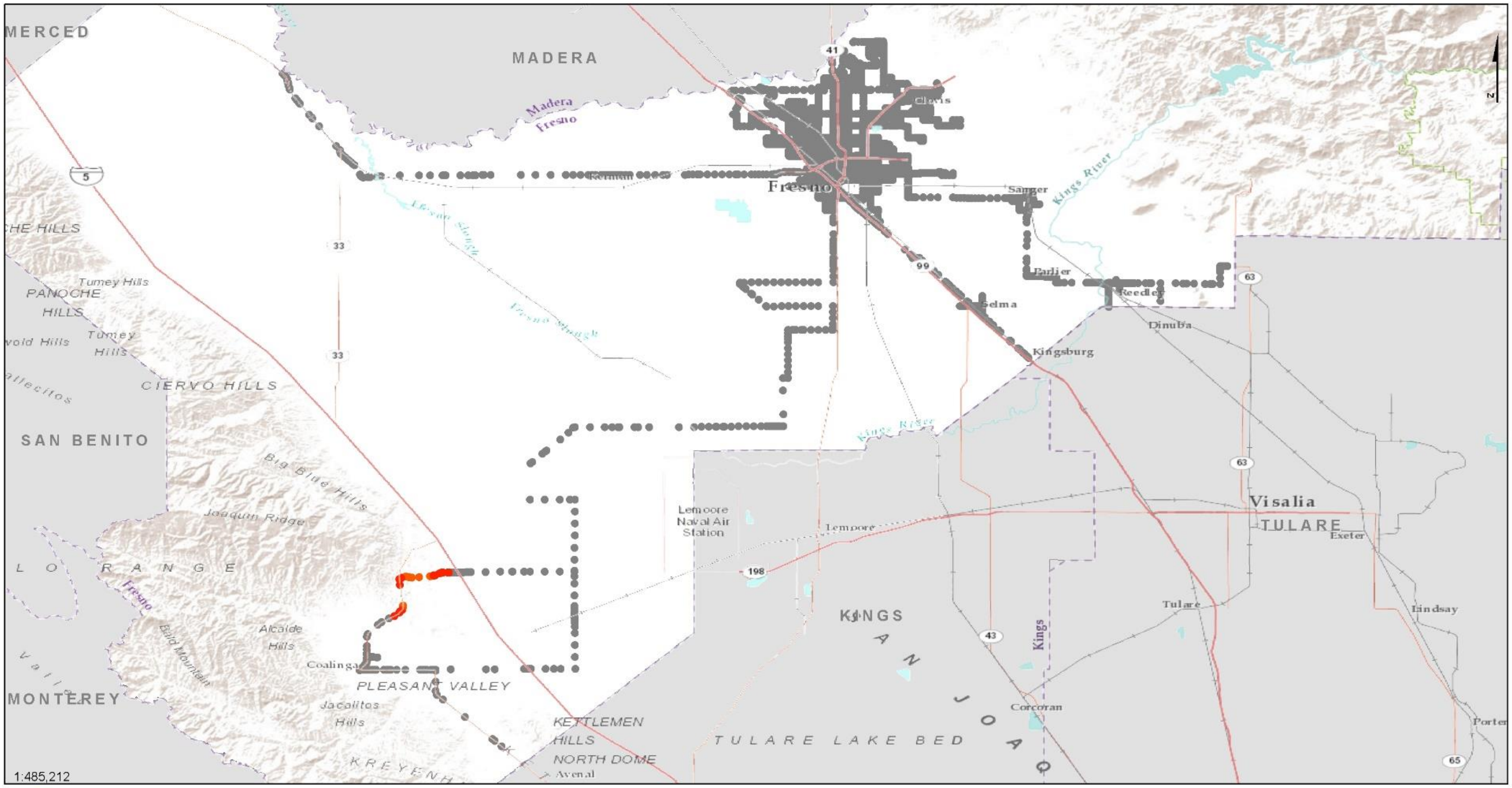
Table 10. Highest Flooding Vulnerability Scores for Transit Stops

OID_num	OBJECTID	LINEID	SEQNO	NODES	final_score_flood_trans	scalescore_flood_trans	scale_pre_t1mx	scale_pre_mx	scale_flood_pln	scale_dmg_fld	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
7172	7172	37	61	28445	10	100	66	100	100	0	99	4	2	100	71	19
7491	7491	38	163	28445	10	100	66	100	100	0	99	4	2	100	71	19
2589	2589	13	73	27907	10	99	96	59	100	0	24	9	45	100	67	37
8114	8114	42	95	27907	10	99	96	59	100	0	24	9	45	100	67	37
4629	4629	22	164	16535	10	98	96	59	100	0	28	9	37	100	67	37
2587	2587	13	71	16535	10	98	96	59	100	0	28	9	37	100	67	37
3984	3984	19	73	16535	10	98	96	59	100	0	27	9	37	100	67	37
8112	8112	42	93	16535	10	98	96	59	100	0	27	9	37	100	67	37
2434	2434	12	97	16535	10	98	96	59	100	0	27	9	37	100	67	37
2061	2061	10	110	16535	10	98	96	59	100	0	27	9	37	100	67	37
8089	8089	42	70	16535	10	98	96	59	100	0	27	9	37	100	67	37
9826	9826	55	165	16535	10	98	96	59	100	0	27	9	37	100	67	37
4115	4115	20	55	16535	10	98	96	59	100	0	27	9	37	100	67	37
6409	6409	32	61	13132	10	98	100	66	75	0	57	15	100	100	75	48
9614	9614	54	210	13132	10	98	100	66	75	0	56	15	100	100	75	48
10734	10734	66	27	13130	10	98	100	66	75	0	68	41	67	100	53	55
1473	1473	8	49	13130	10	98	100	66	75	0	68	41	67	100	53	55
10683	10683	65	12	13130	10	98	100	66	75	0	68	41	67	100	53	55
1373	1373	7	202	13130	10	98	100	66	75	0	67	41	67	100	53	55
10745	10745	66	38	13058	10	97	100	66	75	0	70	8	67	100	74	57
8213	8213	42	194	13058	10	97	100	66	75	0	70	8	67	100	74	57
10744	10744	66	37	13061	10	97	100	66	75	0	62	8	67	100	74	57
8212	8212	42	193	13061	10	97	100	66	75	0	62	8	67	100	74	57
8211	8211	42	192	13064	10	97	100	66	75	0	62	8	67	100	74	57
7580	7580	39	28	10591	10	97	96	59	100	0	12	8	44	100	55	39
7747	7747	40	83	10591	10	97	96	59	100	0	12	8	44	100	55	39
10743	10743	66	36	13064	10	97	100	66	75	0	61	8	67	100	74	57

Transit Stops and Future Wildfire

Very few transit stops in Fresno County are flagged as vulnerable to wildfire. The only exposed stops were a few north of Coalinga along the SR-198, which has limited redundancy. However, this area appears to be mostly grassland, which poses less of a threat to the transportation system than an exposed woodland or scrubland.

Figure 26. Fresno County Vulnerability Scoring: Transit Stops & Future Wildfire



Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

The associated FCOG Transportation Network Vulnerability Assessment describes the scoring methodology and underlying data sources in detail.

Vulnerability Scoring: Transit Stops & Future Wildfire

NA 1 2 3 4 5 6 7 8 9 10

0 2.75 5.5 11 16.5 22 Miles

Table 11. Highest Wildfire Vulnerability Scores for Transit Stops

OID_num	OBJECTID	LINEID	SEQNO	NODES	final_score_fire_trans	scalescore_fire_trans	scale_time_elev_burn	scale_cat_burn	scale_dmg_fire	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
8846	8846	49	159	42244	10	100	100	50	0	99	3	1	0	11	2
5854	5854	29	30	42244	10	100	100	50	0	99	3	1	0	11	2
6011	6011	30	79	42244	10	100	100	50	0	99	3	1	0	11	2
8925	8925	50	40	42244	10	100	100	50	0	99	3	1	0	11	2
5981	5981	30	49	38236	10	100	100	50	0	99	2	1	0	11	2
5885	5885	29	61	29660	10	100	100	50	0	99	2	1	0	11	2
8953	8953	50	68	38235	10	100	100	50	0	99	2	1	0	11	2
8954	8954	50	69	46461	10	100	100	50	0	99	2	1	0	11	2
5982	5982	30	50	46461	10	100	100	50	0	99	2	1	0	11	2
5983	5983	30	51	38235	10	100	100	50	0	99	2	1	0	11	2
8955	8955	50	70	38236	10	100	100	50	0	99	2	1	0	11	2
8951	8951	50	66	29659	10	100	100	50	0	99	2	1	0	11	2
8956	8956	50	71	29660	10	100	100	50	0	99	2	1	0	11	2
8819	8819	49	132	39397	10	100	100	50	0	99	2	1	0	11	2
5980	5980	30	48	29660	10	100	100	50	0	99	2	1	0	11	2
5984	5984	30	52	39397	10	100	100	50	0	99	2	1	0	11	2
5985	5985	30	53	29659	10	100	100	50	0	99	2	1	0	11	2
8816	8816	49	129	38236	10	100	100	50	0	99	2	1	0	11	2
8820	8820	49	133	29659	10	100	100	50	0	99	2	1	0	11	2
5882	5882	29	58	38235	10	100	100	50	0	99	2	1	0	11	2
5880	5880	29	56	29659	10	100	100	50	0	99	2	1	0	11	2
5881	5881	29	57	39397	10	100	100	50	0	99	2	1	0	11	2
5883	5883	29	59	46461	10	100	100	50	0	99	2	1	0	11	2
5884	5884	29	60	38236	10	100	100	50	0	99	2	1	0	11	2
8815	8815	49	128	29660	10	100	100	50	0	99	2	1	0	11	2
8817	8817	49	130	46461	10	100	100	50	0	99	2	1	0	11	2
8818	8818	49	131	38235	10	100	100	50	0	99	2	1	0	11	2
8952	8952	50	67	39397	10	100	100	50	0	99	2	1	0	11	2
5986	5986	30	54	28190	10	100	100	50	0	98	2	1	0	11	2
5987	5987	30	55	28189	10	100	100	50	0	98	2	1	0	11	2
5988	5988	30	56	29658	10	100	100	50	0	98	2	1	0	11	2
5989	5989	30	57	28188	10	100	100	50	0	98	2	1	0	11	2
8948	8948	50	63	29658	10	100	100	50	0	98	2	1	0	11	2
8934	8934	50	49	28180	10	100	100	50	0	97	3	1	0	11	2

Transit Stops and Future Extreme Heat

Extreme temperature and associated poor air quality pose threats to transit users. The projected future high temperatures are relatively uniform in the Central Valley portion of Fresno County, where virtually all the transit stops are located. The variation in high heat vulnerability scores are therefore driven primarily by social factors.

The most vulnerable stops are in the Fresno metro area. There are two major clusters of highest vulnerability stops. One is in downtown Fresno area, roughly bounded by E Divisadero Street, E Street, Ventura Avenue, and P Street. This area is a County-designated EJ community, has very high CalEnviroScreen scores, ‘no vehicle access’ rates, and density (particularly employment density). The other cluster is in the Roosevelt neighborhood, particularly on S Chestnut Avenue between E Huntington Avenue and E Florence Avenue, and on the blocks of E Kings Canyon Road and E Butler Avenue near there. Most of this area is an EJ community and characterized by high CalEnviroScreen scores, relatively high ‘no vehicle access’ rates, and high population density.

There are many other highly vulnerable transit stops surrounding both these clusters too. Most of central Fresno and the broader Roosevelt neighborhood are considered highly vulnerable. Other highly vulnerable clusters of transit stops outside of the Fresno metro area include several along SR-180 between Mendota and Kerman, and along and near S Golden State Boulevard in and just outside of Selma.

The scoring results are not meant to be interpreted in an overly precise or a binary manner. In general, extreme heat poses risks to transit users, particularly those in Fresno County’s disadvantaged communities and those with few transportation alternatives. Warming temperatures are expected to amplify this risk.

Figure 27 Vulnerability Scoring: Transit Stops & Future Temperature

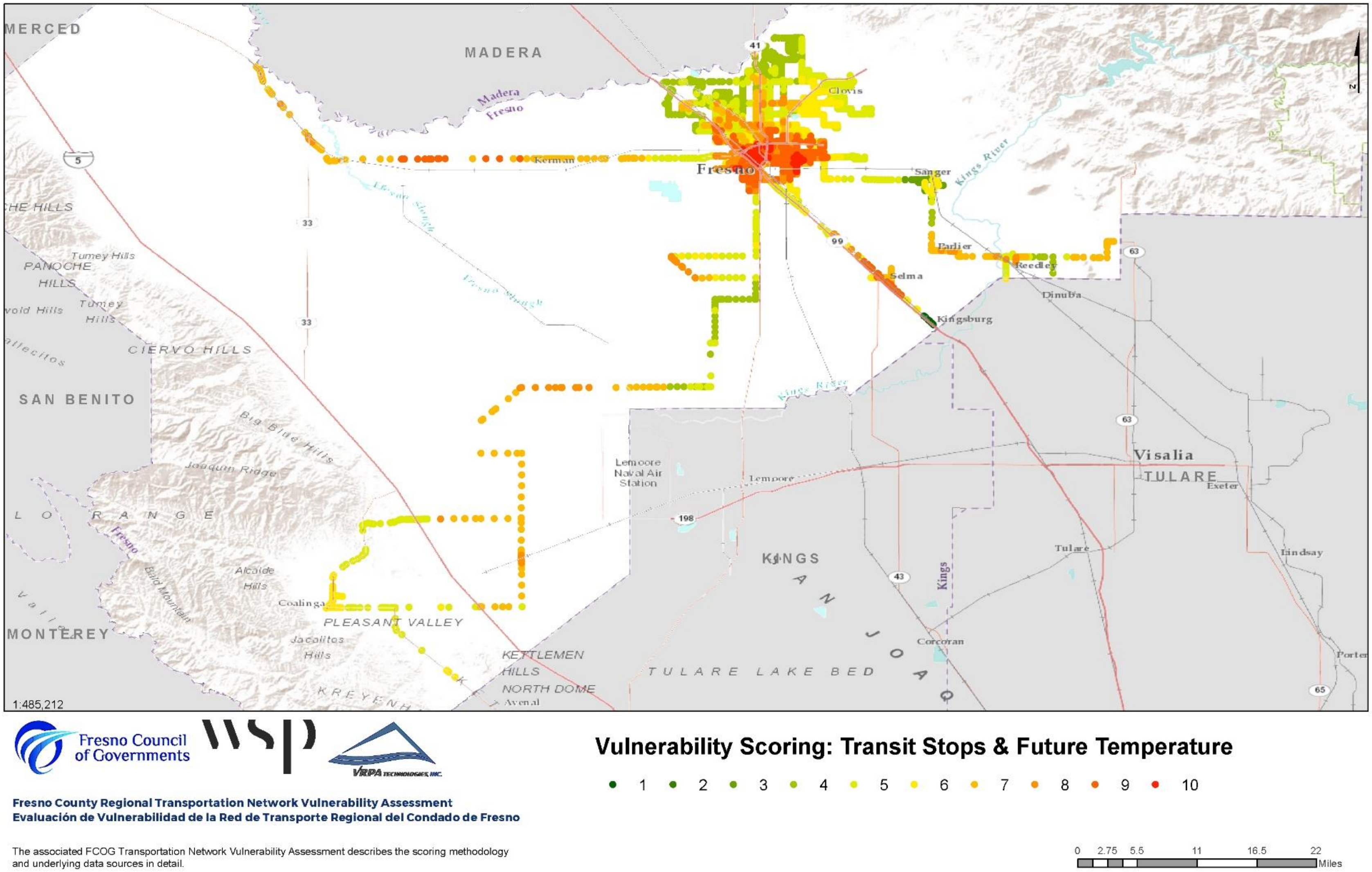


Table 12. Highest Temperature Vulnerability Scores for Transit Stops

OID_num	OBJECTID	LINEID	SEQNO	NODES	final_score_temp_trans	scalescore_temp_trans	scale_max_hh	scale_node_dens	scale_emp_dens	scale_pop_dens	scale_in_ej	scale_ces_den	scale_noveh_den
9783	9783	55	122	11734	10	100	86	8	89	41	100	58	78
5538	5538	28	95	11576	10	100	86	1	21	8	100	98	100
6337	6337	31	297	11576	10	100	86	1	21	8	100	98	100
6361	6361	32	13	11576	10	100	86	1	21	8	100	98	100
1999	1999	10	48	11576	10	100	86	1	21	8	100	98	100
3077	3077	15	138	11576	10	100	86	1	21	8	100	98	100
3199	3199	16	57	11576	10	100	86	1	21	8	100	98	100
9566	9566	54	162	11576	10	100	86	1	21	8	100	98	100
5350	5350	27	285	11576	10	100	86	1	21	8	100	98	100
9754	9754	55	93	11576	10	100	86	1	21	8	100	98	100
1863	1863	9	172	11576	10	100	86	1	21	8	100	98	100
10581	10581	62	21	11732	10	100	86	7	89	41	100	58	78
2390	2390	12	53	11732	10	100	86	7	89	41	100	58	78
560	560	4	7	11732	10	100	86	7	89	41	100	58	78
9538	9538	54	134	11732	10	100	86	7	89	41	100	58	78
10579	10579	62	19	11732	10	100	86	7	89	41	100	58	78
6972	6972	36	3	10467	10	100	86	4	79	11	100	79	84
7285	7285	37	174	10467	10	100	86	4	79	11	100	79	84
6346	6346	31	306	10467	10	100	86	4	79	11	100	79	84
6351	6351	32	3	10467	10	100	86	4	79	11	100	79	84
7375	7375	38	47	10467	10	100	86	4	79	11	100	79	84
6967	6967	35	135	10467	10	100	86	4	79	11	100	79	84
2010	2010	10	59	10483	10	100	86	2	80	12	100	79	84
3634	3634	18	3	10483	10	100	86	2	80	12	100	79	84
6976	6976	36	7	10483	10	100	86	2	80	12	100	79	84
3088	3088	15	149	10483	10	100	86	2	80	12	100	79	84
2663	2663	13	147	10483	10	100	86	2	80	12	100	79	84
1315	1315	7	144	10483	10	100	86	2	80	12	100	79	84
1530	1530	8	106	10483	10	100	86	2	80	12	100	79	84
10633	10633	64	11	10483	10	100	86	2	80	12	100	79	84
1850	1850	9	159	10483	10	100	86	2	80	12	100	79	84
811	811	5	133	10483	10	100	86	2	80	12	100	79	84
9543	9543	54	139	10483	10	100	86	2	80	12	100	79	84
2273	2273	11	138	10483	10	100	86	2	80	12	100	79	84
1002	1002	6	92	10483	10	100	86	2	80	12	100	79	84
1314	1314	7	143	10479	10	100	86	3	67	23	100	79	84
10634	10634	64	12	10479	10	100	86	3	67	23	100	79	84
1003	1003	6	93	10479	10	100	86	3	67	23	100	79	84
1849	1849	9	158	10479	10	100	86	3	67	23	100	79	84
810	810	5	132	10479	10	100	86	3	67	23	100	79	84

Airports and Future Extreme Heat

Extreme high temperatures can affect aircraft operations and assets. High temperature projections are relatively uniform across the Central Valley portion of Fresno County, where the region's airports are located. Thus, the scores are driven primarily by the airport type, which is an indicator of consequence in the event of disruption. Fresno Yosemite International Airport is the County's sole Primary airport, so it received the highest heat vulnerability score.

Figure 28. Fresno County Vulnerability Score: Airport and Future Temperature

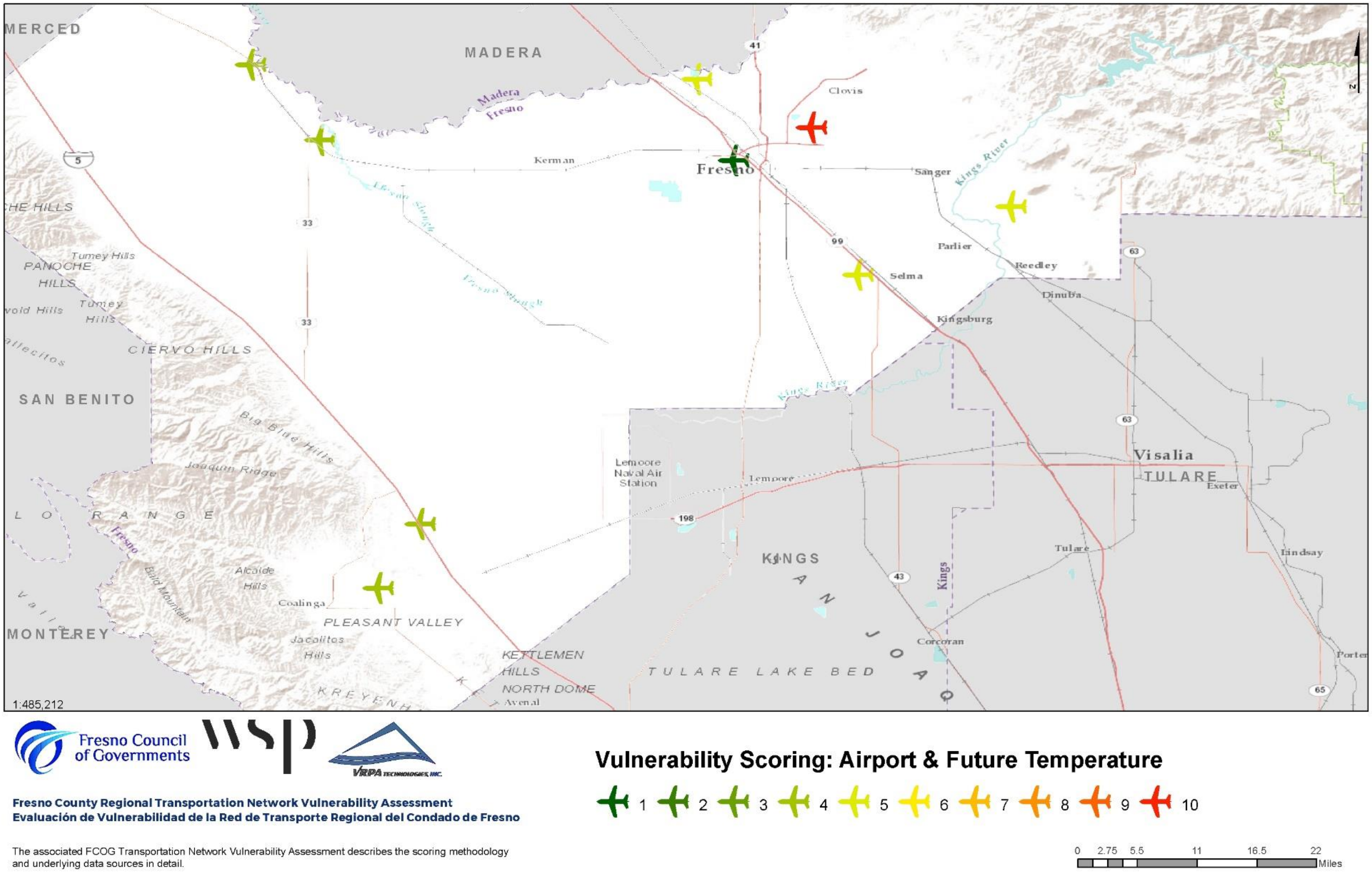


Table 13. Temperature Vulnerability Scores for Airport

OID_num	OBJECTID	AIRPORT_NAME	final_score_temp_air	scalescore_temp_air	scale_temp1_mx	scale_aport_class
9	9	Fresno Yosemite International	10	100	100	100
5	5	Selma Aerodome	5	42	94	50
6	6	Reedley Municipal Airport	5	47	97	50
8	8	Sierra Sky Park	5	48	98	50
1	1	Firebaugh Municipal Airport	4	32	87	50
2	2	Mendota Municipal Airport	4	32	87	50
3	3	Coalinga Municipal Airport	4	40	92	50
4	4	Harris Ranch Airport	4	36	90	50
7	7	Chandler Downtown Airport	1	0	99	0
10	10	Lemoore NAS			88	50

Airports and Future Flooding

Selma Airport is considered the most vulnerable to future flooding, as it overlaps the current 100-year floodplain and is projected to experience increases in heavy precipitation under some of the future climate scenarios. Fresno Yosemite International was also flagged as vulnerable given its designation as the county's sole Primary airport and high heavy precipitation projections under some of the climate scenarios. Chandler Downtown Airport is located in the current 500-year floodplain but did not receive a high vulnerability score since it is classified as a Reliever facility.

Figure 29. Fresno County Vulnerability Scoring: Airport & Future Flooding

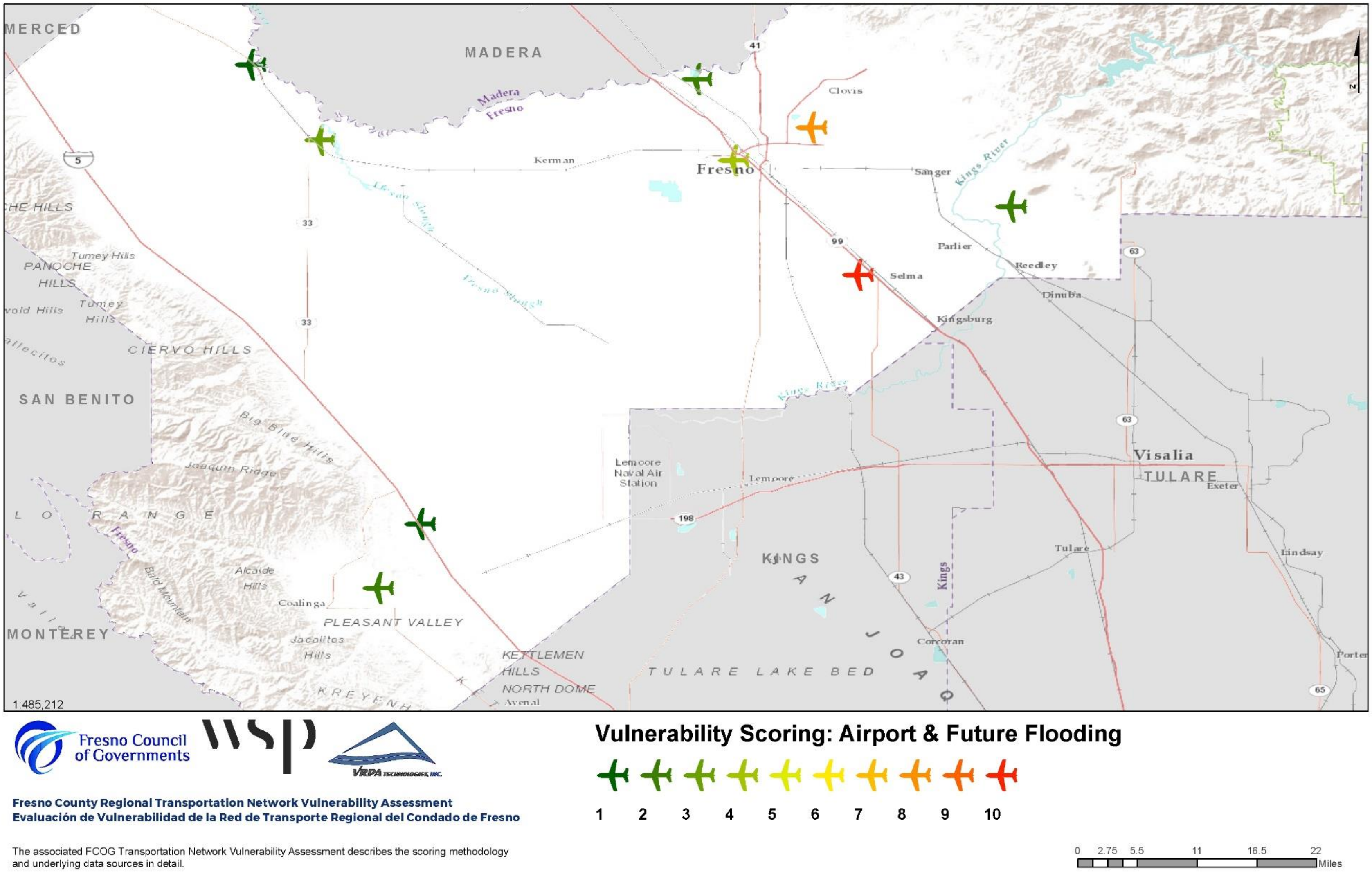


Table 14. Flooding Vulnerability Scores for Airport

OID_num	OBJECTID	AIRPORT_NAME	final_score_flood_air	scalescore_flood_air	scale_pre_t1mx	scale_pre_mx	scale_flood_pln	scale_dmg_fld	scale_aport_class
5	5	Selma Aerodome	10	100	79	100	100	0	50
9	9	Fresno Yosemite International	8	73	100	81	0	0	100
7	7	Chandler Downtown Airport	4	34	80	50	75	0	0
2	2	Mendota Municipal Airport	3	22	42	85	0	0	50
3	3	Coalinga Municipal Airport	2	15	54	42	0	0	50
6	6	Reedley Municipal Airport	2	10	42	31	0	0	50
8	8	Sierra Sky Park	2	14	76	16	0	0	50
1	1	Firebaugh Municipal Airport	1	0	27	0	0	0	50
4	4	Harris Ranch Airport	1	6	36	20	0	0	50
10	10	Lemoore NAS			0	34	0	0	50

Additional Analysis

Transit Ridership and High Heat

The project team analyzed transit ridership data from the Fresno Area Express (FAX) to explore the relationship between ridership and high heat events.[37] We paired systemwide daily ridership estimates with historical maximum temperature observations on the same days in the summers of 2017 and 2018. The ridership data were from Tuesdays, Wednesdays, and Thursdays during the summer break for school occurring in June, July, and August. Limiting the ridership to this window helped control for ridership variability due to school-related rides or day-of week-fluctuations.

Figure 30 FAX Summer Ridership and Maximum Temperature (2017, 2018) scatterplots show daily ridership on the vertical axes and degrees Fahrenheit daily maximum temperatures on the horizontal axes. The left scatterplot shows all of the data points included in the analysis. The right scatterplot shows the same data points minus the Fourth of July records. The right plot also includes a linear trendline, which indicates a negative correlation between daily maximum temperature and summer ridership.

We also conducted a brief regression analysis to evaluate the effect of daily maximum temperature (an explanatory variable) on ridership (the dependent variable). An Ordinary Least Squared (OLS) regression was used. The control variables were (1) a binary outlier flag indicating whether a day was the Fourth of July and (2) the date, which helped control for changes in service over time, particularly in between years.

According to the regression, daily maximum temperature is a significant predictor of daily ridership in the summer months. Controlling for the data and for holidays, higher maximum temperatures are associated with lower ridership. A 1°F increase in summer daily maximum temperature is associated with a roughly 130-person ridership decrease (90% confidence interval of 65-196 person decrease). Figure 31. FAX Summer Ridership and Maximum Temperature Regression Results shows the regression results and diagnostics.

The analysis implies that fewer people ride transit on very hot days in Fresno County. This could be for a variety of reasons, such as concerns about heat-related or poor air quality-related health issues for transit-dependent riders, discomfort, and the use of other modes, such as personal vehicles on these days.

[37] Ridership data were provided by the City of Fresno Department of Transportation.

Figure 30. FAX Summer Ridership and Maximum Temperature (2017, 2018)

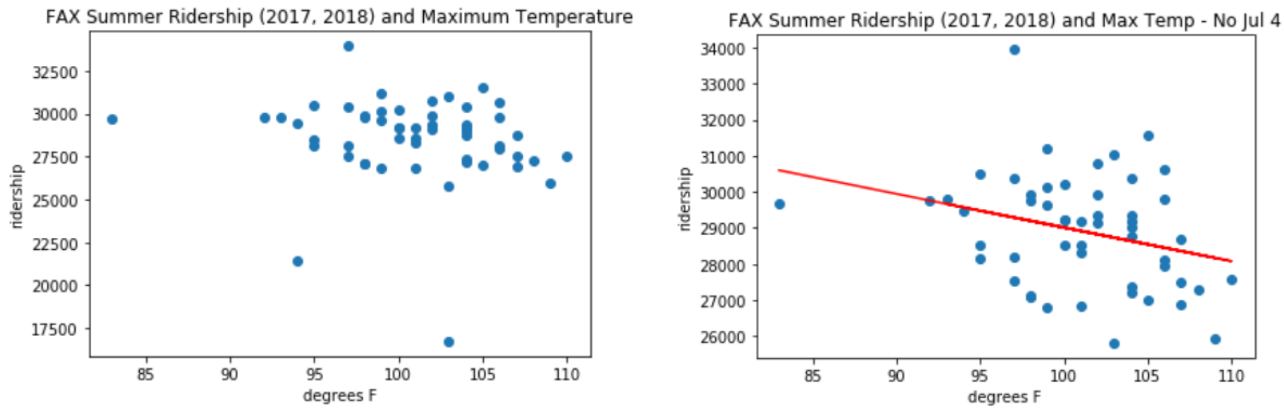


Figure 31. FAX Summer Ridership and Maximum Temperature Regression Results

Dep. Variable:	ridership	**R-squared:**	0.701
Model:	OLS	**Adj. R-squared:**	0.683
Method:	Least Squares	**F-statistic:**	39.13
Date:	Fri, 06 Sep 2019	**Prob (F-statistic):**	3.68e-13
Time:	16:40:53	**Log-Likelihood:**	-465.29
No. Observations:	54	**AIC:**	938.6
Df Residuals:	50	**BIC:**	946.5
Df Model:	3		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
const	-2.702e+06	7.72e+05	-3.500	0.001	-4.25e+06	-1.15e+06
tempmax	-130.7304	39.167	-3.338	0.002	-209.399	-52.062
holiday_outlier	-1.016e+04	1005.109	-10.104	0.000	-1.22e+04	-8137.058
date	3.7248	1.049	3.551	0.001	1.618	5.832

Omnibus:	3.194	**Durbin-Watson:**	1.202
Prob(Omnibus):	0.202	**Jarque-Bera (JB):**	2.496
Skew:	0.520	**Prob(JB):**	0.287
Kurtosis:	3.160	**Cond. No.**	3.01e+09

Battery Electric Buses and Heat-Related Operating Costs

Battery Electric Buses (BEBs) are being more readily deployed across California, due to the state's mandate to adopt such infrastructure to meet greenhouse gas reduction goals. In high-heat environments – such as Fresno County – and with the risk of increased high-heat days and heatwave events due to climate change, transit providers have a few key factors to consider when opting to procure BEB fleets. This subsection provides descriptions of potential risks of procuring BEBs in these geographies, including the risk of increased energy usage which underlie energy costs, risk of increased electricity costs during high-demand, and reliability concerns for batteries in these environments.

Risks of Increased Energy Usage & Risks of Increased Electricity Costs:

Material from Arcadia Power indicates that Los Angeles, CA residents saw a 42% increase in usage when comparing June 2016 average usage to June 2017 average usage—a result of above average temperatures.[38] Additionally, research conducted by the US Environmental Protection Agency (EPA) states that if the U.S.'s climate warms by 1.8 degrees Fahrenheit, the demand for energy used for air conditioning is expected to increase by 5% to 20%. These trends have implications for energy costs and for the sustainability of energy infrastructure, such as transmission lines and power stations, which may be pushed to capacity to meet energy demands.

Energy costs increase during high demand, which is exacerbated by increased temperatures and sustained increased temperatures when residents are relying heavily on air conditioning to keep cool. These are often referred to as "cooling degree days." Material from Arcadia Power indicates that Los Angeles, CA residents saw a 7% increase in the price per Kilowatt hour (kWh) when comparing June 2016 and June 2017 energy prices due to the heat waves in 2017.[39] The percent increase in price per kWh and average monthly usage for LA, Phoenix, Reno, and Tucson are listed in Table 15 below.

[38] Arcadia Power, 2018. <https://blog.arcadiapower.com/why-a-heatwave-costs-more-than-you-might-think/>

Table 15: Energy Usage and Costs for Cities in the Western US

City/State	Month/Year	Avg. Energy Usage/Month (kWh/month)	Avg. Rate ($/kWh)	Avg. Cost/Month ($/month)	% Increase in price per kWh	% Increase in Usage
Los Angeles, CA	June 2016	264 kWh/month	18.11 cents/kWh	$48/month		
	June 2017	374 kWh/month	19.39 cents/kWh	$73/month	7%	42%
Phoenix, AZ	June 2016	963 kWh/month	12.54 cents/kWh	$121/month		
	June 2017	1377 kWh/month	12.65 cents/kWh	$174/month	1%	43%
Reno, NV	June 2016	512 kWh/month	11.40 cents/kWh	$58/month		
	June 2017	643 kWh/month	11.64 cents/kWh	$75/month	2%	28%
Tucson, AZ	June 2016	932 kWh/month	12.54 cents/kWh	$117/month		
	June 2017	1078 kWh/month	12.65 cents/kWh	$136/month	1%	17%

While the 7% increase in cost per kWh cannot be used as a standard increase for all high-heat events, it provides a California-based example of the potential spike in energy costs, which will have implications for the operating costs of BEB infrastructure. The remaining examples help to bolster the argument that utility users should be cognizant of rate spikes and the strain of high demand on the system during high-heat events. Further, it is worth noting that these costs are indicative of residential power usage.

Reliability Concerns due to Increased Temperature & Increased Use of A/C:
External temperatures have implications on the performance of the battery. Research from the National Renewable Energy Laboratory indicates that the desired operating temperature to maximize efficiency for a BEB ranges between 15 degrees Celsius and 35 degrees Celsius.[40] The same research indicates that lithium ion batteries experience higher rates of power loss over a fifteen-year lifecycle of the asset in high temperature environments when compared to moderate and lower temperature environments. Operating at temperatures that exceed the desired range results in discharge degradation. The power loss through HVAC/air conditioning used to keep the bus operator and passengers cool influences the overall state of charge, resulting in a reduced range for the bus.[41] Further, high temperatures can also lead to non-uniform aging of batteries due to the experienced thermal gradients, which has implications for the full lifecycle cost of the asset or fleet. For example, battery electric bus pilot trials in Phoenix and Minnesota saw increased operating costs due to the demands for running cooling and heating systems.[42]

[40] National Renewable Energy Laboratory, 2011. <https://www.nrel.gov/docs/fy13osti/52818.pdf>
[41] Jewels Carter, WSP Bus/Public Works Facilities expert at WSP's Fleet & Facilities Division.
[42] Levy, Alon. 2019. <https://www.citylab.com/transportation/2019/01/electric-bus-battery-recharge-new-flyer-byd-proterra-beb/577954/>

Electric heat will be the primary factor to impact battery range impact, with electric cooling as the secondary factor and the individual driver performance (how the operator starts / stops / brakes) the tertiary factor. These three factors are not directly impacted by ambient air temperature but managing the heat and cool of the ambient air creates the decrease in battery range. Good operator training can potentially reduce the negative impact of efficiency and range.

It is worth noting, that when procuring buses, agencies can define the bus vehicle specifications to be suitable for the climate and elevation range of the geography. The current American Public Transit Association (APTA) bus procurement standard range before being confirmed tweaked by each agency is 10 degrees Fahrenheit to 115 degrees Fahrenheit at a relative humidity between 5% and 100% and at an altitude from 3000 ft. above sea level down to sea level.[43]

Future Deep-Seated Landslides

The project team also identified and assessed locations of deep-seated landslide risk around Fresno County.[44] This assessment did not fit into the indicator scoring approach explained in the earlier section and transportation network impacts were analyzed separately. The assessment paired existing, landslide susceptible locations with future precipitation projections to identify areas where there is an existing risk of landslides that may be exacerbated or triggered by heavier precipitation events in the future.

Deep-seated landslides are slow-moving slides where the majority of the moving earth is deep under the ground, by anywhere from ten to several hundred feet. Once moving, these slides can continue on for years.[45] While shallow landslides are much more sudden and intense, deep-seated landslides can cause dangerous slope failure and can even trigger additional shallow slides. The deadliest landslide in the US, the 2014 Oso slide, which killed 45 and led to over $50 million in damages, was caused by the reactivation of an ancient, deep-seated landslide.[46] These types of slides can be triggered by geological and hydrological changes such as earthquakes and soil saturation from precipitation, respectively.

For this assessment, existing deep-seated landslide risk was based upon the California Geological Survey's (CGS) deep-seated landslide susceptibility dataset.[47] Future precipitation projections were included by calculating the change in the 60-day duration, 100-year depth precipitation values between historical observations and future projections for 2085.[48] The 60-day precipitation totals were used as an indicator

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[43] Jewels Carter, WSP Bus/Public Works Facilities expert at WSP's Fleet & Facilities Division.

[44] Due to data availability, the assessment did not analyze shallow landslides like debris flows and rock falls.

[45] http://www.wfpa.org/news-resources/blog/deep-seated-landslides-shallow-landslides-washington/

[46] http://www.geerassociation.org/administrator/components/com_geer_reports/geerfiles/GEER_Oso_Landslide_Report_low-res.pdf

[47] See metadata for more information: https://atlas.resources.ca.gov/arcgis/rest/services/Ocean/CSMW_Landslide_Susceptibility_in_California/MapServer/0

[48] These projections were calculated by finding the percentage change between the 100-year, 60-day precipitation ensemble median, RCP 8.5 projections in 2085 (2070 to 2099) and the backcasted projections. This percentage

for heavy soil saturation conditions that can trigger deep-seated landslides.[49] These layers were overlaid with one another to identify locations with *both* high deep-seated landslide susceptibility and high percentage increase in 60-day precipitation totals.

A scale was created to distinguish between low and high concern areas based upon existing susceptibility combined with considerations of future precipitation. This scale is as follows:

- **Very low** = These areas *do not* show any existing deep-seated landslide susceptibility **and** show *low* changes in 60-day precipitation totals.
- **Low** = These areas show *low* existing susceptibility ratings **and/or** *low* changes in 60-day precipitation totals.
- **Medium** = These areas fall in-between low and high levels of concern.
- **High** = These areas show *high* existing deep-seated landslide susceptibility **and/or** *high* percentage changes in 60-day precipitation totals.
- **Very High** = These areas demonstrate a high landslide susceptibility rating **and** high percentage change in 60-day precipitation totals.

The figures on the following pages show a selection of the of the results of combining the two datasets.[50] The transportation assets intersecting the areas of high to very high concern areas are shown on the maps in red. However, assets directly above or below the areas of concern may also be exposed. Nearly all of the high/very high concern areas appear in the Sierra Nevada and Diablo Range. Note that in the mountain regions, the roadway GIS layer used in the analysis is fairly sparse and has some spatial inaccuracies. Thus, some roads may not be shown here or be shown in incorrect locations.

Figure 32 on the following page provides an overview of the landslide concern areas across Fresno County. This map does not highlight individual assets that are in high to very high concern areas, but instead shows the general geography of deep-seated landslide risk areas.

Figure 33 shows landslide concern areas near Piedra and North Pine Flat Lake. This map demonstrates how landslide concern is consistent across Wildcat, Red, and Hog mountains. Watts Valley Rd (to the north) and East Trimmer Springs (to the south, near Piedra) both cross this terrain. This map also provides an example of how the roadway GIS layer has spatial inaccuracies. The center road that crosses right across the range from Stony Point eastward represents a rural and winding road through the mountains, but it is represented as a straight line in the network file.

Figure 34 follows SR-180 east of Hume, which travels along the South Fork of the Kings River. SR-180 lies in high landslide concern areas until it approaches Stag Dome, where the concern increases to very high. This map was chosen to include here as it shows a very high concern area in the Sierra Nevada.

change was then applied to the NOAA Atlas 14 100-year, 60-day values, which are derived from historical observations.

[49] Kenneth Johnson, WSP Geotechnical Engineer.

[50] Nine zoomed-in maps were generated for high/very high concern areas around the county, four of which are shown in this memorandum.

Figure 35 follows SR-168 from Prather all the way northeast to Lake Shore, by Huntington Lake. The map shows how risk exists in select locations throughout the corridor. It also shows how some assets outside of the corridor are also exposed to landslide concern, but the roadway network is so sparse in this area that it does not full represent the network. For example, two bridges lie north of Sugarloaf Hill (one is labeled as exposed), but they do not lie on the roadway network file. This means that there could be many more exposed roadways in this area that are not represented on the map.

Finally, Figure 36 shows landslide exposure along I-5, Los Gatos Creek Road, and SR-198 near Coalinga. This map demonstrates that landslide concern exists close to the valley floor, and not just in the Sierra Nevada.

Figure 32: Future Landslide Concern across Fresno County

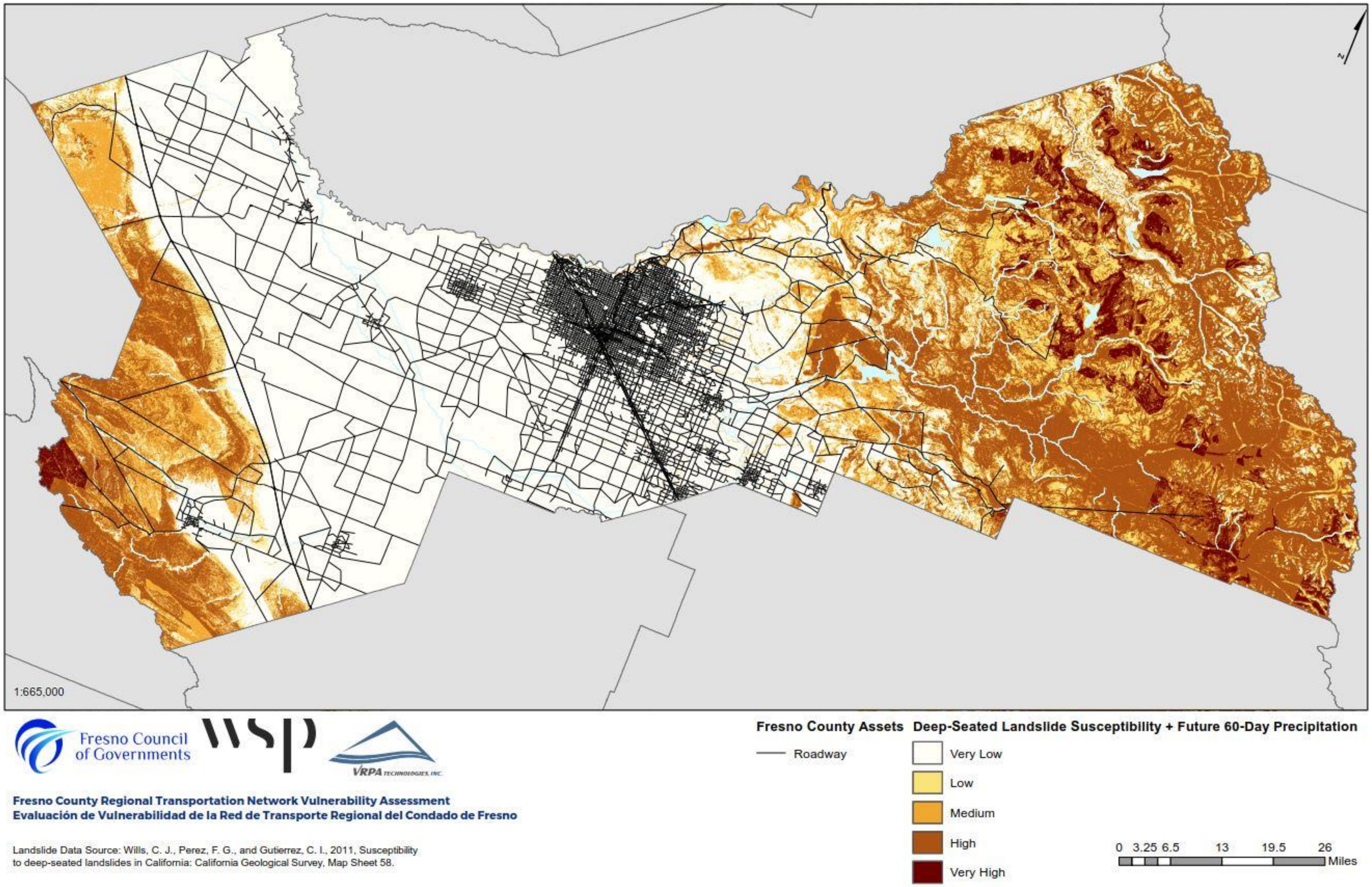


Figure 33: Future Landslide Concern North of Piedra and Pine Flat Lake (Map 1)

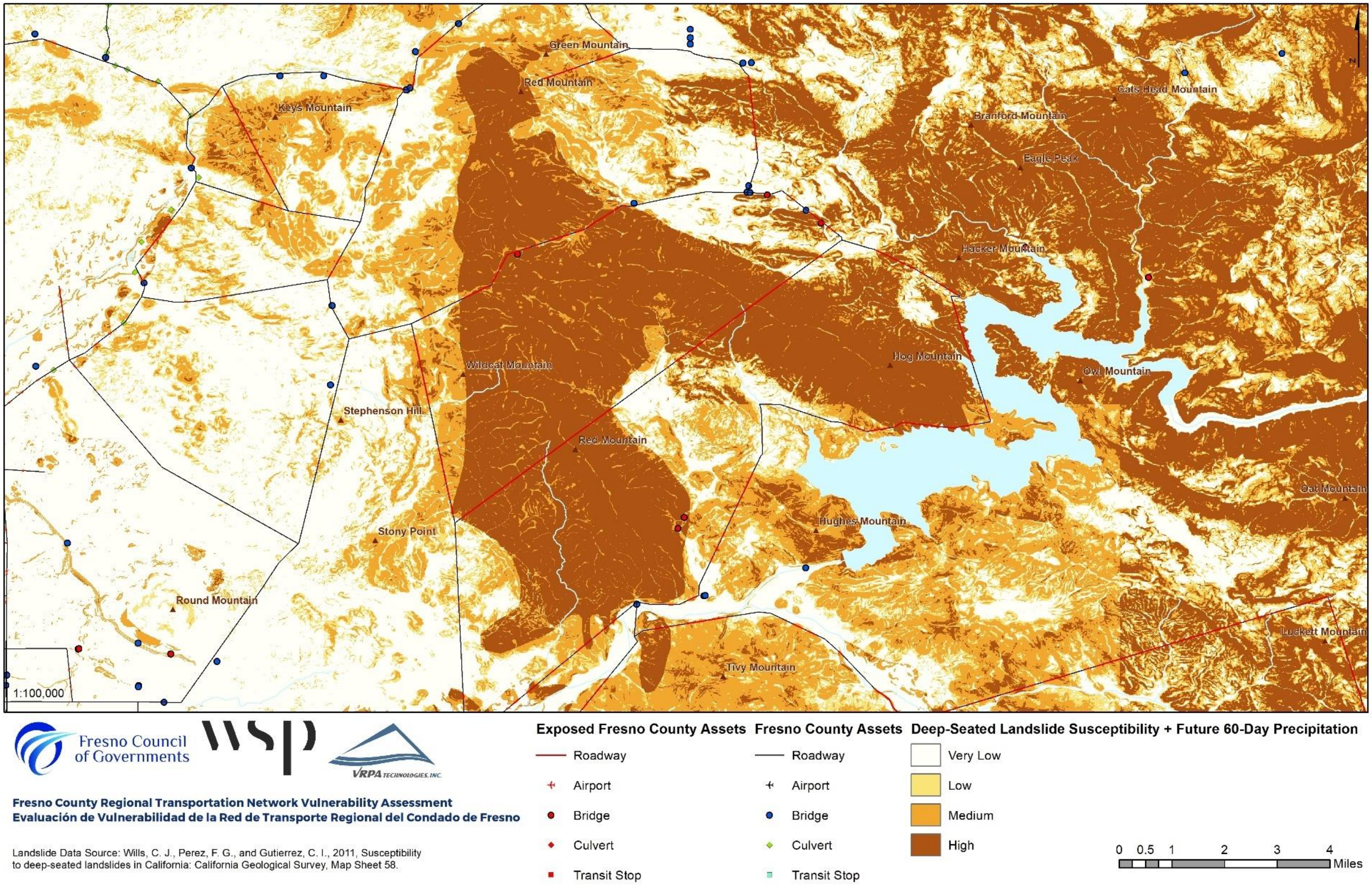
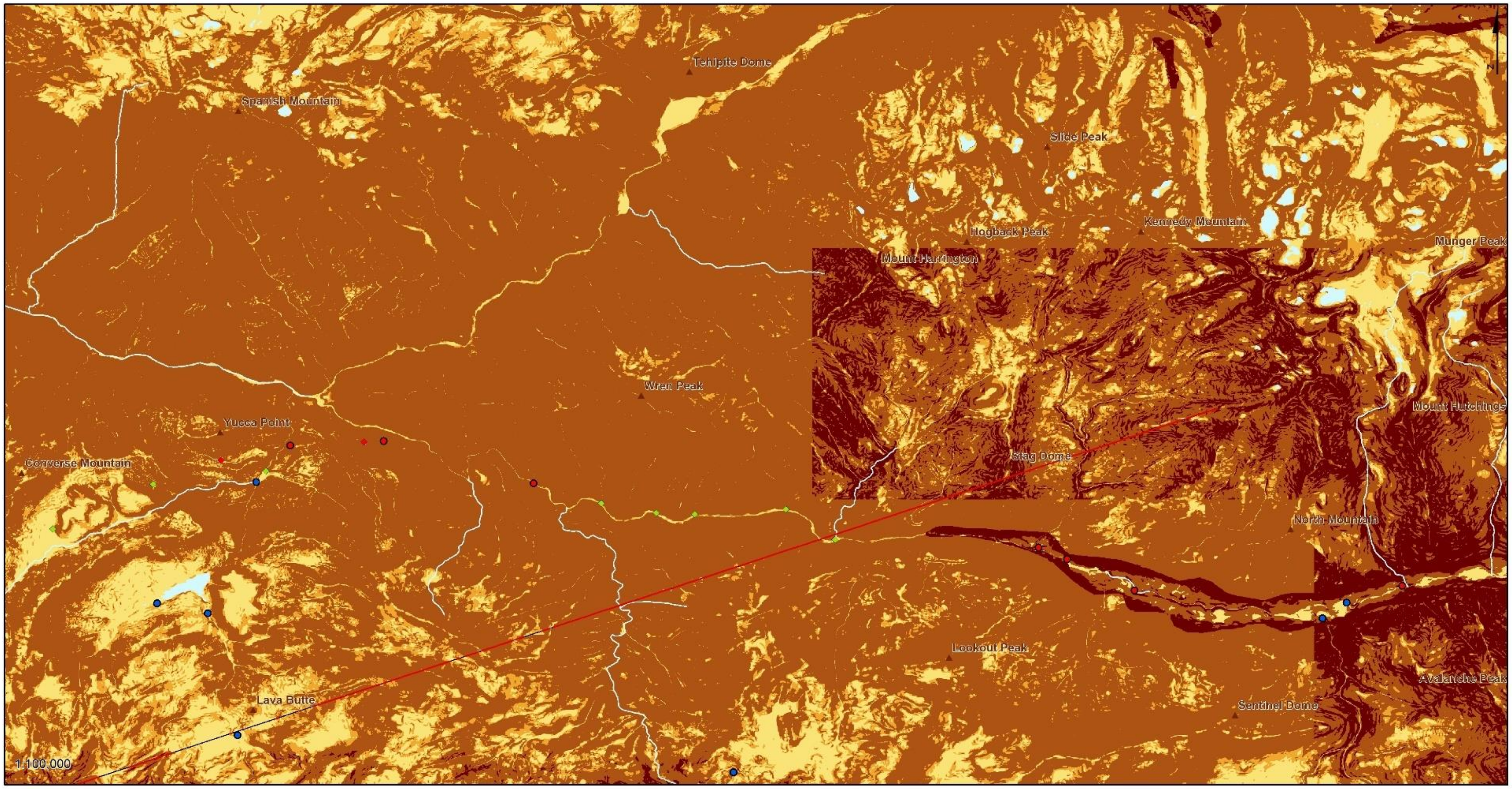


Figure 34: Future Landslide Concern along SR-180 East of Hume (Map 3)



Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Landslide Data Source: Wills, C. J., Perez, F. G., and Gutierrez, C. I., 2011, Susceptibility to deep-seated landslides in California: California Geological Survey, Map Sheet 58.

Exposed Fresno County Assets	Fresno County Assets	Deep-Seated Landslide Susceptibility + Future 60-Day Precipitation
Roadway	Roadway	Low
Airport	Airport	Medium
Bridge	Bridge	High
Culvert	Culvert	Very High
Transit Stop	Transit Stop	

0 0.5 1 2 3 4 Miles

Figure 35: Future Landslide Concern along SR-168 and Dinky Creek Rd (Map 4)

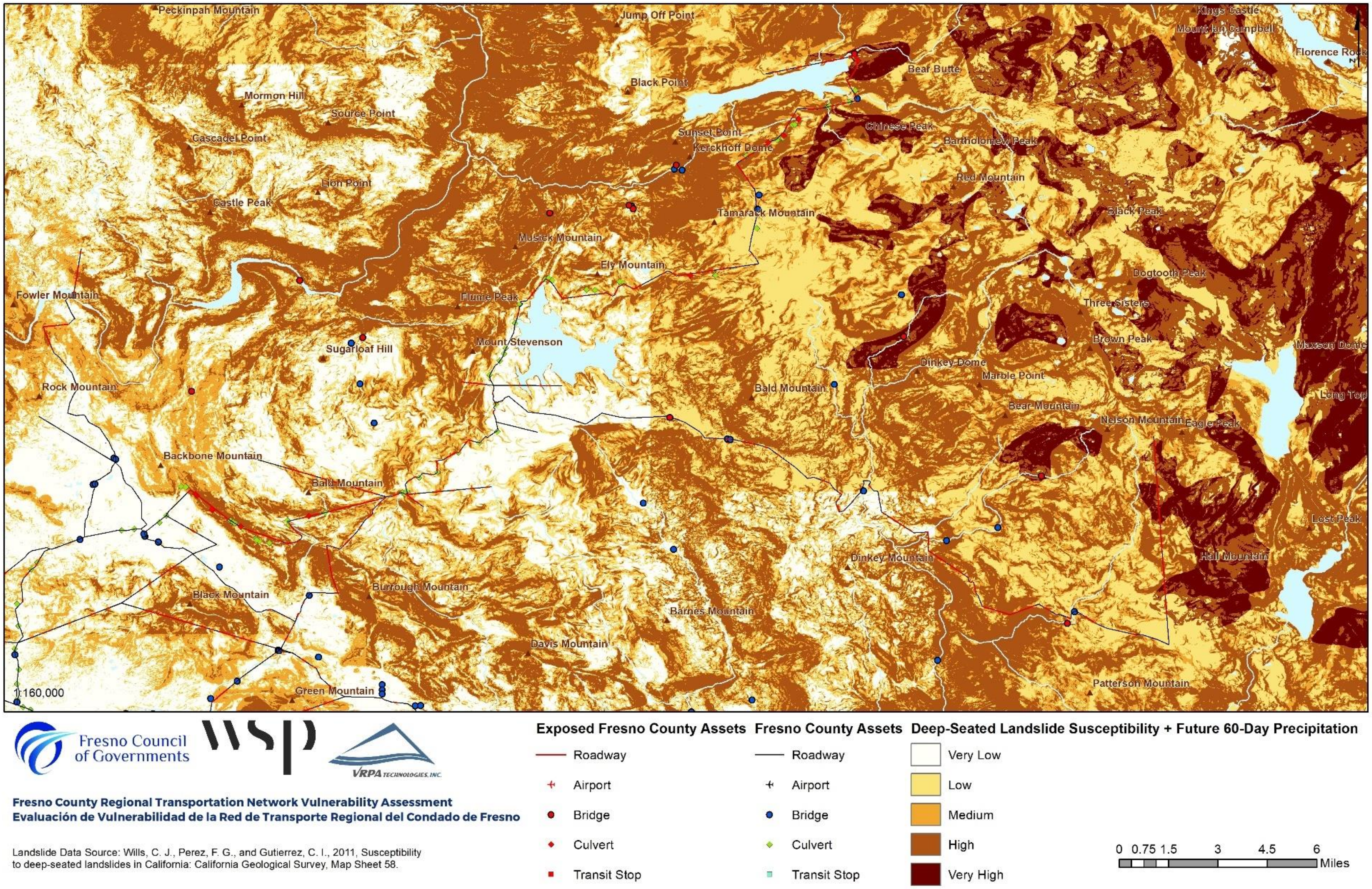
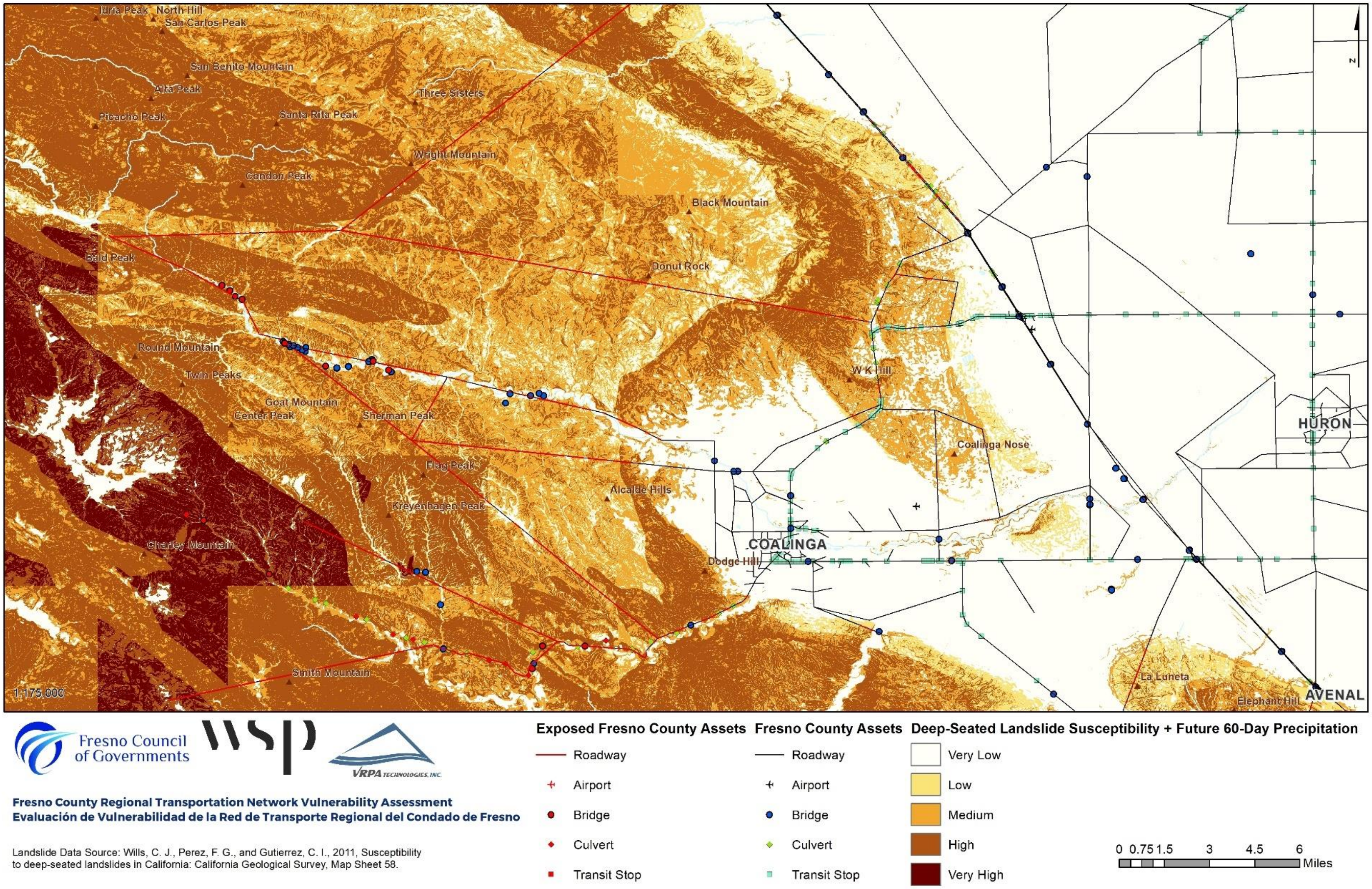


Figure 36: Landslide Concern along Los Gatos Creek Rd and SR-198 West of Coalinga (Map 5)



Summary

Results Synthesis

Extreme heat, riverine flooding, wildfire, and other weather-related conditions events have affected Fresno County's transportation system in the past. Going forward, the county is likely to experience a future that holds substantially more high heat events and associated air quality issues; more frequent wildfires; more uncertain precipitation patterns with the potential for heavier high precipitation events; and strains on water supply.

Roughly half of residents surveyed reported that weather events or conditions have affected their travel or required them to evacuate. Extreme heat and poor air quality were the most frequently cited reasons. With climate change, respondents are most concerned about extreme heat, drought, and air quality issues.

Socially vulnerable residents, such as those with low incomes, without English fluency, or with asthma or other respiratory issues, are disproportionately at risk. Many of these individuals are transit dependent and more exposed to high heat and poor air quality.

The projected future high temperatures are relatively uniform in the Central Valley portion of Fresno County, where virtually all the transit stops are located. In the FAX system, bus ridership tends to be lower on hotter summer days. Transit agencies also face operational challenges due to increased energy demand in higher temperatures.

While wildfire and riverine flooding affect a smaller portion of the population, they pose substantial risks, especially to rural parts of the County with limited redundancy in the transportation network.

Riverine peak flows are expected to increase under at least some of the future climate scenarios. The Kings River and San Joaquin River both pose threats to communities and associated transportation infrastructure. Failure of Friant Dam or Pine Flat Dam would be potentially catastrophic.

Many bridges and roadways were identified as vulnerable to future riverine flooding. Most of these are lightly traveled roads in low-density areas, though network redundancy is limited in many of these areas, so detour routes are often long. Specific areas of flood vulnerability include:

- Several of the most vulnerable bridges span the Kings River South Fork on the SR-180 or nearby roads in far eastern Fresno County. These roads are characterized by low travel volumes but significant detour lengths.
- There are a few vulnerable bridges the I-5 over the Panoche Creek and Little Panoche Creek.
- One of the most vulnerable bridges to future flooding was the North Fork Road bridge over the San Joaquin River in Friant. It has experienced flooding in the past, rates poorly for scour, and will likely experience high increases in flows many of the climate scenarios.
- The SR-180 over the Fresno Slough near Mendota.
- The SR-269 north of Huron.
- Selma Airport ranked as the most vulnerable airport to future flooding

- Some mobile home parks in river floodplains have experienced flooding in the past, including Wildwood Mobile Home Park and Woodward Bluffs Mobile Home Park in northern Fresno along the San Joaquin River and River Bend RV Park in Sanger.

For wildfire, there are many small communities in the Sierra Nevada and foothills with limited routes for access and egress. The longest stretches of highly vulnerable roadway are the SR-180, Auberry Road, and the SR-168 in the Sierras. These have very low redundancy and relatively high volume compared to other rural roads in the county's exposed areas. Other highly vulnerable Sierra roadways include Lodge, Powerhouse, SR-63, Trimmer Springs, and Watts Valley. On the Diablo Range side, the most vulnerable roadways were the SR-198 west of Coalinga and Los Gatos Creek Road.

Extreme heat and precipitation will have an impact the maintenance of roadways, causing potholes and other roadway degradations. This can ultimately lead to an increase in road maintenance costs.

Landslide susceptibility already exists around Fresno County and this susceptibility is expected to increase over time as more precipitation falls during heavy events. Some areas are higher concern than others, but this risk exists throughout the Diablo Range and Sierra Nevada.

From an organizational resiliency perspective, smaller cities often face the same hazards as larger cities but have less funding and fewer staff to address them. Funding constraints were mentioned repeatedly and make addressing vulnerabilities to climate change particularly challenging.

Application and Next Steps

Fresno COG's member agencies and other stakeholders can use this memorandum's findings in several ways. The memorandum material can be used to help members meet the California Senate Bill 379 requirements for accounting for climate change in local hazards mitigation plans and the safety elements of general plans.[51] Those requirements include conducting a vulnerability assessment. Members can draw on information in this document on Fresno County's projected future climate conditions and transportation network vulnerabilities for their vulnerability assessments. Members can also use the data and maps underlying this memorandum for their vulnerability assessments or other planning activities. Also, the indicator scoring approach is designed specifically to help agencies, such as Fresno COG and its members, prioritize which assets warrant more detailed facility-level assessments. These facility-level assessments help agencies select cost-effective, resilient courses of action for their assets and systems.

The next phase of the TNVA focuses on adaptation options. It will cover how agencies can conduct facility-level assessments, introduce transportation adaptation options for Fresno County, and provide further policy guidance to Fresno COG and its members.

[51] SB 379 will be discussed in greater detail in the next task of this study.
https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB379

Public Outreach Synopsis

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

Public Outreach Synopsis

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Introduction

The Fresno Council of Governments (Fresno COG) received grant funding from the California Department of Transportation (Caltrans) under the Senate Bill (SB) 1 Adaptation Planning Grants Program to conduct a Regional Transportation Network Vulnerability Assessment (TNVA) for Fresno County. The Vulnerability Assessment will assist Fresno COG and other local agencies in understanding the potential impacts of climate change on the region's transportation infrastructure, identify specific locations that may be affected, and identify strategies to ensure the stability and resiliency of the infrastructure moving into the future. Fresno COG wants to ensure that the region's multimodal transportation network continues to support the areas' communities and promote positive economic development. Information learned through the Vulnerability Assessment development process will inform the next Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) update, and provide data for local jurisdictions to integrate into their respective plans.

Objectives of the Fresno County Regional TNVA development process are to:

- ✓ Convene regional partners from multiple jurisdictions.
- ✓ Identify climate change impact risks to multi-modal transportation infrastructure in the project area.
- ✓ Identify specific transportation infrastructure vulnerable to climate change impacts.
- ✓ Develop adaptation strategies and specific actions to remedy identified climate-related vulnerabilities.

The development process for the TNVA is guided by a diverse Vulnerability Assessment Working Group (VAWG), which is made up of representatives from local jurisdictions, transit agencies, flood control, CalFire, and public health and environmental justice representatives. The VAWG is responsible for providing both policy and technical guidance and shaping how the TNVA can serve the different communities of Fresno County and adapt to the potential impacts of climate change.

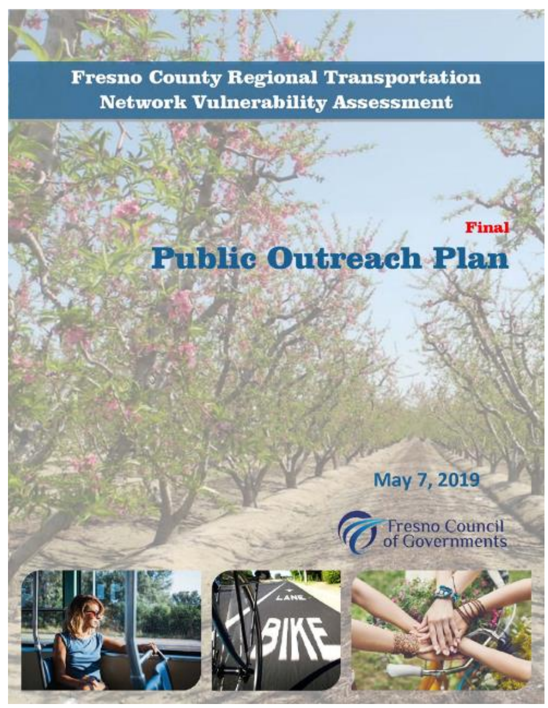
Public Participation Objectives

For the public and stakeholder agencies to effectively evaluate and comment on the TNVA, they should be adequately informed about the planning process and understand the details associated with the analysis. Input from the public and affected agencies lends credibility to key decisions made during the TNVA development process. Making timely, accurate and useful information available to the general public and other community members helped to achieve the following objectives of the outreach process:

- ✓ Conduct an open and transparent public outreach process that:

  - Provides up-to-date, easily accessible information on the TNVA process.
  - Provides a wide variety of opportunities for participation and comment.
  - Identifies critical issues and problems in need of resolution.
  - Incorporates feedback received and identifies potential resolutions.
- ✓ Create and implement a meaningful public outreach and involvement process, and evaluate the process on a regular basis.
- ✓ Provide accurate, timely, and comprehensive documentation of the outreach process.
- ✓ Keep elected officials and local city and county staff informed of the TNVA development process via email notices of upcoming meetings, public workshops, and outreach events.
- ✓ Create public forums and collateral materials that provide clear, concise, and easy-to-understand information to enable the public to make informed decisions.
- ✓ Seek opportunities to involve a broad range of community members, including non-traditional groups, to ensure that the TNVA Team understands the issues from all those who may be impacted.
- ✓ Address social equity and environmental justice issues, to provide information to comply with relevant regulations, Title VI, Executive Order 12898 on Environmental Justice, and Executive Order 13166 on Limited English Proficiency and the Americans with Disabilities Act (ADA).
- ✓ Educate the public by using language that is non-technical and easily understood.
- ✓ Engage the large number of disadvantaged communities found in the region.
- ✓ Provide outreach materials in multiple languages.

Public Outreach Plan



Community engagement is essential to bring together the public and interested parties along with planners to discuss complex issues facing the communities and their residents. Working together to achieve a common goal, this partnership encourages affected parties to bring forward unique ideas and solutions to potential issues. As each interested party is different, so too are their hopes and aspirations and the ways to implement them. By listening to each other, the decisions generated will reflect the greater community at large.

Community engagement is most successful when the process is transparent with access to decisions, services, and information for all interested stakeholders and community members. Active participation of the community ensures that the outcomes are better tuned to meeting the community's needs today and into the future. State and federal transportation laws, regulations, policies and guidance require and encourage public involvement throughout the planning process, particularly regarding environmental justice populations and underserved communities, including low-income and minority populations.

The TNVA Public Outreach Plan (POP) clarifies the outreach program to ensure that interested parties understood how they could become involved and provide input during the TNVA development process. The POP simplified the outreach process by providing a systematic approach, maximizing the use of available resources, and minimizing delays by ensuring that public outreach activities were coordinated with other TNVA tasks and milestones. The POP also identified the specific tasks for the TNVA outreach effort, which included:

- ✓ Providing the public multiple opportunities to learn about the TNVA, while also allowing them to provide feedback on how the transportation network and their transportation related needs are affected by climate change.
- ✓ Creating and distributing public information that is user-friendly and culturally sensitive to communities that may be potentially affected by changes to the region's transportation infrastructure due to climate change.
- ✓ Providing policy makers with information about the public's opinion and values regarding the TNVA, and how to respond to future climate change.

Multiple strategies were used to generate interest and participation from the community. Key among these strategies were pop-up events, community surveys (both online and in person), stakeholder interviews and a public workshop.

Public Outreach Activities

One of the major components of the planning process used to help inform development of the TNVA included receiving comments and input from the public. To collect input, the TNVA Team participated in multiple outreach events throughout Fresno County from May through July 2019. These outreach events included pop-up events, an online community survey, stakeholder interviews and a public workshop. Location and general activities for each event are noted below in Table 1. Summaries of each effort can be found on the following pages.

Public outreach activities were discussed at the initial VAWG meeting. During the discussion, it was noted that residents of rural communities, which are often those identified as disadvantaged communities, are transportation limited and have difficulty attending outreach events outside of their immediate area. This can be especially true if events occur in the evening when fixed-route services are limited or unavailable. With pop-up events, the TNVA Team was aiming to reach members of disadvantaged communities by going to them. For the public workshop the TNVA Team reached out to residents, businesses and local agency partners and staff of the Fresno-Clovis Metropolitan Area. The workshop was held at a venue

accessible to transit users, allowing those with transportation limitations to participate. The online survey was aimed at those stakeholders more comfortable with today's electronic forums, and who may have been unable to participate at the workshop or pop-up events due to time or location restraints. Ultimately, the TNVA Team felt that there would be the greatest participation and diversity in the combination of activities completed.

Surveys collected from pop-up event attendees and online survey participants revealed the following participant demographics:

- ✓ 73% of pop-up event respondents were from a Fresno County city/unincorporated community outside of the Fresno-Clovis Metropolitan Area.
- ✓ 63% of pop-up event respondents had a household income of less than $36,000 in the year 2018.
- ✓ While race/ethnicity questions were not asked of pop-up event attendees, 28% of pop-up event surveys were completed in Spanish.
- ✓ 82% of online surveys were completed by respondents who live in the Fresno-Clovis Metropolitan Area.
- ✓ 54% of online survey respondents were between the ages of 45 to 64. 36% were between the ages of 24 to 44.
- ✓ 54% of online surveys were completed by respondents who are White/Caucasian. 26% were completed by those who are Hispanic/Latino.
- ✓ 71% of online survey respondents had a household income of $50,000 or more in the year 2018.

With limited workshop attendance, polling/surveys were not administered and demographic data was not collected.

Table 1 – Completed TNVA Public Outreach Activities

Type of Outreach Event	Name	Dates	Location	Activities
Pop-up Event	Kerman Almond Festival	Saturday, May 4, 2019	Kerckhoff Park 15061 West G Street Kerman, CA 93630 11:00 AM to 3:00 PM	• Bilingual Plan flyers • Surveys • Comment cards • Interactive mapping
Pop-up Event	Reedley Street Faire	Saturday, May 5, 2019	G Street between 11th Street and 12th Street Reedley, CA 93654 10:00 AM to 4:00 PM	• Bilingual Plan flyers • Surveys • Comment cards • Interactive mapping
Stakeholder Interviews	TNVA Stakeholder Interviews	Wednesday, May 15th, 2019 to Friday, May 24, 2019	Conference call line	• Question and answer stakeholder interviews

Type of Outreach Event	Name	Dates	Location	Activities
Survey	Online Surveys	May to July 2019	SB1 Planning Studies webpage on Fresno COG website	• Bilingual transportation network vulnerability issues opinions survey
Pop-up Event	San Joaquin Carnival	Friday, June 7, 2019	City of San Joaquin Sports Park 8599 6th Street San Joaquin, CA 93660 6:00 PM to 9:00 PM	• Bilingual Plan flyers • Surveys • Comment cards • Interactive mapping
Workshop	Public and Stakeholder Workshop	Wednesday, June 19, 2019	Fresno City College, Staff Dining Room 1101 E. University Avenue Fresno, CA 93741 5:30 PM to 7:30 PM	• Open house format workshop with interactive activities
Pop-up Event	Fresno Grizzlies July 4th baseball game	Thursday, July 4, 2019	Chukchansi Park 1800 Tulare Street Fresno, CA 93721 5:45 PM to 8:15 PM	• Bilingual surveys

Pop-up Events

Pop-up events allowed the TNVA Team to engage with the public at events of interest to them, while ultimately reaching a significantly higher number of residents than traditional public workshops. The TNVA Team worked with Fresno COG staff and the VAWG to identify high-volume community events throughout Fresno County. Such events included the Kerman Almond Festival, Reedley Street Faire, San Joaquin Carnival and the Fresno Grizzlies July 4th baseball game.

Conducting Each Pop-up Event

At the first three pop-up events, the TNVA Team set-up an informational area, which included the use of study informational boards and study area mapping, informational flyers, comments cards and a short survey consisting of seven questions. All pop-up events were staffed with at least one bilingual TNVA Team member. At each pop-up event, at least one TNVA Team member remained at the informational booth to solicit survey and mapping exercise participation, while another TNVA Team member engaged with event goers who were further away from the informational booth. At the final pop-up event, the TNVA Team partnered with the Fresno County Transportation Authority (FCTA) Measure C Roadshow booth and distributed surveys to game day attendees. The TNVA Team also solicited survey responses from attendees who were already seated inside the stadium. A total of 178 surveys were completed by all pop-up event attendees over the course of the four pop-up events.

Comment cards were available for visitors to provide additional thoughts, suggestions, or concerns. Each visitor received a two-sided bilingual informational flyer and were encouraged to visit the Assessment webpage for updates on the TNVA. Additionally, as an incentive for survey participation, respondent's names were entered into a raffle drawing for a gift card.

Materials used for pop-up events, including study information boards, study area mapping, informational flyers, surveys and comment cards, can be found in Appendix A.

Summary of Individual Pop-up Events

Kerman Almond Festival

The first pop-up event was held at the Kerman Almond Festival on Saturday, May 4th, 2019, from 11:00 AM to 3:00 PM at Kerckhoff Park. Three members of the TNVA Team, including the Fresno COG Project Manager and one bilingual outreach specialist, were present at the TNVA informational booth. In addition, four bilingual college students from Reedley College assisted the TNVA Team's bilingual outreach specialist in soliciting survey responses from the public.

Pop-up Event Findings

Significant findings from Kerman Almond Festival pop-up event attendees included the following:

- ✓ 35% of survey respondents said that weather events or conditions have affected their travel or required them to evacuate. Of these respondents:
  - 27% listed heat wave or extreme heat days as the event or condition that they had experienced.
  - 24% said that poor air quality was the event or condition that they had experienced.
- ✓ When asked what impacts from climate change are most concerning to them, respondents provided the following answers:
  - Heat waves and higher temperatures (19%).
  - Longer and more severe droughts (18%).
  - Lower air quality (18%).
- ✓ When asked to identify which transportation improvements are most important for addressing extreme weather and climate change, respondents answered as follows:
  - Tree planting along roadways and sidewalks (21%) ranked highest of all choices.
  - The creation of more comfortable and shaded transit stops (17%) ranked second highest of all choices.

Reedley Street Faire

The second pop-up event was held at the Reedley Street Faire on Sunday, May 5th, 2019, from 10:00 AM to 4:00 PM in downtown Reedley. Three members of the TNVA Team, including the Fresno COG Project Manager and one bilingual outreach specialist, were present at the TNVA informational booth. In addition, four bilingual college students from Reedley College assisted the TNVA Team's bilingual specialist in soliciting survey responses from the public.

Pop-up Event Findings

Significant findings from the Reedley Street Faire pop-up event attendees included the following:

- ✓ 39% of survey respondents said that weather events or conditions have affected their travel or required them to evacuate. Of these respondents:

- 38% listed heat wave or extreme heat days as the event or condition that they had experienced.
- 36% said that poor air quality was the event or condition that they had experienced.

✓ When asked what impacts from climate change are most concerning to them, respondents provided the following answers:

- Heat waves and higher temperatures (18%).
- Longer and more severe droughts (17%).
- Lower air quality (17%).

✓ When asked to identify which transportation improvements are most important for addressing extreme weather and climate change, respondents answered as follows:

- Tree planting along roadways and sidewalks (22%) ranked highest of all choices.
- The creation of more comfortable and shaded transit stops (18%) was ranked second highest of all choices.

San Joaquin Carnival

The third pop-up event was held at the San Joaquin Carnival on Friday, June 7th, 2019, from 6:00 PM to 9:00 PM at the City of San Joaquin Sports Park. Two members of the TNVA Team, including one bilingual specialist, were present at the TNVA informational booth.

Pop-up Event Findings

Significant findings from the San Joaquin Carnival pop-up event attendees included the following:

✓ 55% of survey respondents said that weather events or conditions have affected their travel or required them to evacuate. Of these respondents:

- 50% listed heat wave or extreme heat days as the event or condition that they had experienced.
- 30% said that poor air quality was the event of condition that they had experienced.

✓ When asked what impacts from climate change are most concerning to them, respondents provided the following answers:

- Longer and more severe droughts (18%).
- Heat waves and higher temperatures (15%).
- Heavy rains and flooding (15%).

✓ When asked to identify which transportation improvements are most important for addressing extreme weather and climate change, respondents answered as follows:

- Tree planting along roadways and sidewalks (22%) ranked highest of all choices.
- The creation of more comfortable and shaded transit stops, expanded service of availability of on-demanded transportation, and better management of flammable vegetation near roadways and structures were tied for second highest of all choices with 16%.

Fresno Grizzlies July 4th Baseball Game

The last pop-up event was held at the Fresno Grizzlies July 4th baseball game on Thursday, July 4th, 2019, from 5:45 PM to 8:15 PM at Chukchansi Park. As mentioned previously, the TNVA Team partnered with the FCTA Measure C Roadshow booth during this pop-up event. One bilingual specialist from the TNVA Team was present at the event.

Pop-up Event Findings

Significant findings from the Fresno Grizzlies July 4th baseball game included the following:

- 83% of survey respondents said that weather events or conditions have affected their travel or required them to evacuate. Of these respondents:
  - 33% listed heat wave or extreme heat days as the event of condition that they had experienced.
  - 33% also said that poor air quality was the event of condition that they had experienced.
- When asked what impacts from climate change are most concerning to them, respondents provided the following answers:
  - Heat waves and higher temperatures (19%).
  - Lower air quality (19%).
  - Longer and more severe droughts (18%).
- When asked to identify which transportation improvements are most important for addressing extreme weather and climate change, respondents answered as follows:
  - The creation of more comfortable and shaded transit stops (27%) ranked highest of all choices.
  - Tree planting along roadways and sidewalks (21%) ranked second highest of all choices.

Stakeholder Interviews

The TNVA Team participated in stakeholder interviews to gather project-relevant information and stakeholder suggestions and concerns. Four interviews were conducted by telephone with key stakeholders who provided their knowledge, wisdom and insight to better assist with the TNVA development process. The stakeholder interview questionnaire can be found in Appendix B. Interviewees included representatives from the following agencies or organizations:

- California Rural Legal Assistance
- Central California Environmental Justice Network
- Central Valley Air Quality Coalition
- City of Fresno Engineering Department
- City of Reedley Community Development Department
- Fresno Area Express (FAX)
- Fresno County Department of Public Works and Planning
- Fresno County Office of Emergency Services
- Leadership Counsel for Justice and Accountability

Interviewees provided a wide range of feedback including:

- Concerns regarding extreme heat and poor air quality, especially for outdoor workers.
- Difficulty navigating flooding in rural areas that don't have sufficient drainage.
- The need for shaded areas for active transportation and transit users.
- Concerns regarding increases in operations and maintenance costs from heavy rain events.
- The TNVA should identify the highest priority threats that the region can respond to.

Online Survey

The TNVA Team augmented the previously mentioned pop-up event surveys with an online community survey. The Team prepared the surveys to reflect the questions desired for the development of the TNVA, while ensuring that the surveys were in a format and language easily understood by the general public. The survey consisted of a series of sixteen multiple choice, priority ranking and open ended questions, and was available in both English and Spanish. The survey was accessible through the Fresno COG webpage and was available from May through July 2019. A notification concerning the online survey's availability to the public was distributed as follows:

- By email to the TNVA Stakeholder Database.
- By email to an expanded Fresno County database.
- To the Fresno COG newsletter database.
- Postings to Fresno COG's Facebook and Twitter accounts.
- Via the California Safe Routes Partnership E-Newsletter.

Online Survey Findings

The online survey form and results from the online survey can be found in Appendix C. Sixty-three completed surveys were submitted by participants. Major survey findings included:

- 35% of online survey respondents stated that weather events or conditions have affected their travel or required them to evacuate. Of these respondents:
  - 44% listed heat wave or extreme heat day as the event or condition that they experienced.
  - 28% said that poor air quality was the event of condition that they had experienced.
- 60% of respondents believed that climate change will impact their lives directly. Key impacts listed from survey participants included the following:
  - Increased urban flooding.
  - Less water availability.
  - Limited travel options due to extreme heat or rain.
  - Health issues and poorer air quality.
  - Higher energy costs.
  - Impacts to agriculture.

- When asked what impacts from climate change are most concerning to them, respondents provided the following answers:
  - Longer and more severe droughts (20%).
  - Heat waves and higher temperatures (19%).
  - Lower air quality (19%).
- When asked to identify which transportation improvements are most importation for addressing extreme weather and climate change, respondents answered as follows:
  - Tree plantings along roads and sidewalks (19%) ranked highest of all choices.
  - The creation of more comfortable and shaded transit stops, and expanded service and availability of on-demand transportation during high heat or other extreme weather events were tied for second highest of all choices with 17%.

Public Workshop

The TNVA workshop was held on Wednesday, July 19th, from 5:30 PM to 7:00 PM at Fresno City College. The workshop was noticed in both English and Spanish and was posted online on the Assessment webpage, distributed via flyer at the first three pop-up events and was emailed out to a Fresno County database, which included well over 400 contacts including stakeholders, elected officials, the general public, and other local government agencies.

The TNVA Team was present at the workshop and available to respond to any questions or comments that attendees had. A Spanish translator was also available to ensure all attendees could comfortably participate in discussions and provide feedback. The workshop followed an open house format and included the following elements:

- Study area mapping displays.
- An introductory PowerPoint presentation that provided an overview of the TNVA planning process.
- An interactive mapping exercise so that attendees could identify areas of the region where the transportation network is vulnerable to climate and weather-related hazards.
- The use of Turning Point polling software, a tool that allows the TNVA Team to not only educate, but to gather ideas and input simultaneously from everyone attending a workshop through the use of a real-time response keypad.
- Comment cards for comments and feedback.
- Translation, which was provided using available translation equipment.
- Workshop stations for registration, comments, and refreshments.

The introductory PowerPoint, polling question PowerPoint and study area mapping can be found in Appendix D.

Key comments/recommendations from workshop attendees included the following:

- ✓ The need for better storm drainage and road improvements in proximity to disadvantaged and low-income communities.
- ✓ People are less likely to ride their bicycle due to heat, roadways degradation, poor air quality and flooding.
- ✓ Transit users are walking/biking to stations and waiting for buses to arrive, during which they are subject to heat extremes and precipitation events. Adaptation strategies could include improvements to bus shelters, such as benches, walls, shelters, lights and other safety components.
- ✓ Vanpool service that takes residents to cooling centers during heat waves.
- ✓ Plant additional trees to cool down sidewalks.
- ✓ Build more bicycle/pedestrian paths that will encourage active transportation and assist in reducing greenhouse gas (GHG) emissions.

The TNVA workshop was lightly attended, which may be partially attributed to the newness of the subject matter. Therefore, the TNVA Team decided to participate in an additional pop-up event following the workshop, which included the Fresno Grizzlies July 4th baseball game, referenced in the Pop-up Events section above.

Appendices

**Pop-up Event Materials, Online Survey Materials,
Stakeholder Interview Questionnaire, and Public Workshop Materials**

APPENDIX A

Pop-up Event Materials

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

Plan Overview

The Fresno Council of Governments has begun preparation of the ***Fresno County Regional Transportation Network Vulnerability Assessment (TNVA)***. The TNVA will identify areas of the region where the transportation network is vulnerable to climate and weather-related hazards, such as extreme heat, flooding, and wildfire, and identify strategies to remedy those impacts that will positively benefit local communities.

Objectives

Objectives of the Fresno County Regional TNVA development process include:

- Convene regional partners from multiple jurisdictions
- Identify climate and weather-related risks to multi-modal transportation infrastructure in Fresno County
- Identify specific transportation infrastructure vulnerabilities to weather and climate-related impacts
- Develop adaptation strategies and specific actions to remedy identified vulnerabilities

Learn More

Visit our webpage where you can stay up-to-date on the development of the vulnerability assessment and provide your input by completing the TNVA Stakeholder Survey.

www.fresnocog.org/project/sb1-planning-studies/

Plan Development Timeline	
Community Engagement • Stakeholder Survey • Workshops and Pop-up Events	**May 2019 – September 2019**
Plan Development • Vulnerability Assessment • Adaptation Strategies • Prepare Final Report	**March 2019 – February 2020**

Questions: Contact Meg Prince at (559) 233-4148 or mprince@fresnocog.org if you have any questions or would like additional information.

YOUR INPUT COUNTS!

We want to HEAR from YOU!

Please attend the upcoming Community Outreach Workshop to learn more about the vulnerability assessment. We are looking for your input and feedback to shape how the assessment can serve the community and keep Fresno County residents safe from climate and weather related impacts.

Wednesday, June 19, 2019

5:30pm – 7:30pm

Fresno City College, Staff Dining Room
1101 E. University Ave
Fresno, CA 93741

Spanish translation services will be available. Drop in at any time to learn more!

Consejo de Gobiernos de Fresno

Condado Regional de Fresno

Evaluación de la Vulnerabilidad del Transporte

Resumen del Plan

El Consejo de Gobiernos de Fresno ha comenzado preparativos de la ***Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno (TNVA).*** La TNVA identificará las áreas de la región en donde la red de transporte es vulnerable al clima y a los peligros asociados con el clima, tal como el calor extremo, inundaciones, incendios forestales, e identificar estrategias para remediar esos impactos que beneficien a las comunidades positivamente.

Objetivos

Los objetivos en el proceso del desarrollo TNVA Regional del Condado de Fresno incluyen:

- Convocar a partidos interesados regionales de múltiples jurisdicciones
- Identificar riesgos asociados con el clima e climáticos a la infraestructura de transportación multimodal en el Condado de Fresno
- Identificar las vulnerabilidades específicas de la infraestructura del transporte a impactos climáticos y relacionados con el clima
- Desarrollar estrategias de adaptación y acciones específicas para remediar las vulnerabilidades identificadas

Aprenda más

Visite nuestra página de internet donde usted puede estar al día con el desarrollo de la evaluación de vulnerabilidad y puede contribuir al completar La Encuesta de los Partidos Interesados TNVA.

www.fresnocog.org/project/sb1-planning-studies/

Cronograma para el Desarrollo del Plan

Participación de la Comunidad • Encuesta de los Partidos Interesados • Talleres y Eventos de Carpa	**May 2019 – September 2019**
Desarrollo del Plan • Evaluación de la Vulnerabilidad • Estrategias de adaptación • Preparación del Reporte Final	**March 2019 – February 2020**

Preguntas: Contactar a Meg Prince al (559) 233-4148 o mprince@fresnocog.org si tiene cualquier pregunta o necesita más información.

SU PARTICIPACIÓN CUENTA!

¡Queremos ESCUCHARLE a USTED!

Por favor asista al próximo Taller de Alcance Comunitario para aprender más sobre la evaluación de vulnerabilidad. Queremos su participación y comentarios para diseñar como la evaluación puede servir a la comunidad y mantener protegidos a los residentes del Condado de Fresno del clima y los impactos climáticos.

Miercoles, 19 de Junio del 2019

5:30pm – 7:30pm

Fresno City College,

Comedor del Personal
1101 E. University Ave
Fresno, CA 93741

Servicios de traducción al Español Estarán disponibles. ¡Llegue a cualquier horario del taller para aprender más!

Fresno County Regional Transportation Network Vulnerability Assessment

Fresno COG is preparing a Fresno County Regional Transportation Network Vulnerability Assessment that will identify where the region's **transportation network** is vulnerable to potential impacts of climate change, such as **increased temperature**, more **extreme heat days**, **flooding**, **drought**, and **wildfires**. The goal of this assessment is to find solutions that will benefit the entire Fresno County community and improve transportation in the region.

Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, what transportation improvements you would like to see locally in relation to climate change, and the solutions you think should be implemented to address these hazards to create a resilient regional transportation network.

1) What zip code do you live in? _______________

2) Have weather events or conditions ever affected your travel or required you to evacuate?
___Yes ____ No

If yes to the above, "What type of event or condition?" ___Heat wave or extreme heat day
___Flooding ____Wildfire ____Poor air quality day _____Other (Please describe below)

Place a pin on the map indicating where you dealt with the event or condition. Map pin number: ☐

If yes to the above, "Tell us about the event(s). How did it affect your travel?" (Please describe)

3) What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least the concerning)

_____Longer and more severe droughts _____ Heat waves and higher temperatures _____ Heavy rains and flooding ____Landslides and erosion ____Subsidence (land sinking from groundwater use) _____Wildfires _____ Lower air quality

Over →

Fresno County Regional Transportation Network Vulnerability Assessment

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Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, what transportation improvements you would like to see locally in relation to climate change, and the solutions you think should be implemented to address these hazards to create a resilient regional transportation network.

1) What zip code do you live in? _______________

2) Have weather events or conditions ever affected your travel or required you to evacuate?
___Yes ____ No

If yes to the above, "What type of event or condition?" ___Heat wave or extreme heat day
___Flooding ____Wildfire ____Poor air quality day _____Other (Please describe below)

Place a pin on the map indicating where you dealt with the event or condition. Map pin number: ☐

If yes to the above, "Tell us about the event(s). How did it affect your travel?" (Please describe)

3) What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least the concerning)

_____Longer and more severe droughts _____ Heat waves and higher temperatures _____ Heavy rains and flooding ____Landslides and erosion ____Subsidence (land sinking from groundwater use) _____Wildfires _____ Lower air quality

Over →

Fresno County Regional Transportation Network Vulnerability Assessment

4) Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)

_____Create more comfortable and shaded transit stops _____ Tree plantings along roadways and sidewalks _____ Improved flood control ____ Better evacuation planning and communications

____ Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) particularly for elderly or disabled people _____ Public transit service to cooling centers on high heat days _____ Better management of flammable vegetation near roadways and structures

____Other (Please describe)

5) What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation ? (Please describe)

6) What are your primary modes of transportation? (Check all that apply if you use multiple modes to reach your destination) ___Driving alone or with family ____Carpooling ___ Taking a Taxi or rideshare (Uber/Lyft) ____Public transit (bus, train) ____Biking ____ Walking

If biking, "How long do you bike to get to your destination or next mode of transportation (like a transit stop)?"

If walking "How long do you walk to get to your destination or next mode of transportation (like a transit stop)? "

7) What was your household income before taxes in 2018?

_____Less than $14,000 _____ $15,000 to $24,999 _____ $ 25,000 to $35,999

____$36,000 to $49,999 _____ $50,000 or more

Fresno County Regional Transportation Network Vulnerability Assessment

4) Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)

_____Create more comfortable and shaded transit stops _____ Tree plantings along roadways and sidewalks _____ Improved flood control ____ Better evacuation planning and communications

____ Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) particularly for elderly or disabled people _____ Public transit service to cooling centers on high heat days _____ Better management of flammable vegetation near roadways and structures

____Other (Please describe)

5) What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation ? (Please describe)

6) What are your primary modes of transportation? (Check all that apply if you use multiple modes to reach your destination) ___Driving alone or with family ____Carpooling ___ Taking a Taxi or rideshare (Uber/Lyft) ____Public transit (bus, train) ____Biking ____ Walking

If biking, "How long do you bike to get to your destination or next mode of transportation (like a transit stop)?"

If walking "How long do you walk to get to your destination or next mode of transportation (like a transit stop)? "

7) What was your household income before taxes in 2018?

_____Less than $14,000 _____ $15,000 to $24,999 _____ $ 25,000 to $35,999

____$36,000 to $49,999 _____ $50,000 or more

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

COG de Fresno está preparando una Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno la cual identificará el lugar donde la **Red de Transporte** es vulnerable a los posibles impactos de cambios climáticos, como el **aumento de temperatura**, más **días de calor extremoso, inundaciones, sequias, e incendios forestales**. La meta de esta evaluación es encontrar soluciones que beneficiarán a la comunidad entera del Condado de Fresno y mejorar el transporte en la región.

Por favor complete esta encuesta anónima para informarnos cuáles son los impactos del cambio climático que más le preocupan, qué mejoría en el transporte local le gustaría ver con relación al cambio climático, y las soluciones que usted piense que se deben implementar para afrontar estos riesgos y crear una red resistente de transporte regional.

1) ¿Cuál es el código postal donde vive usted?_______________

2) ¿Han afectado los eventos climáticos u otras condiciones su habilidad de viajar o que haya tenido que evacuar? ___Si ____ No

En caso de responder Si a lo de arriba, ¿Que tipo de evento o condición?"

___Ola de calor o día de calor extremo ___inundación ____incendio forestal ____día con mala calidad de aire_____ Otros (Por favor descríbalo abajo)

Ponga un indicador en el mapa señalando donde fue que confronto este evento o condición.

Numero de indicador en el mapa ☐

En caso de responder Si a lo de arriba, "Cuéntenos sobre el/los evento(s). ¿Cómo afectó su viaje?" (Favor de describir abajo)

3) ¿Cuales son los impactos por el cambio del clima que más le preocupan?(Favor de clasificar lo siguiente en orden de importancia, en donde el 1 es de más preocupación y el 7 es el que menos le preocupe)

_____Sequias más severas y alargadas_____ Olas de calos y temperaturas altas _____ Fuertes lluvias e inundaciones ____ Derrumbes y erosión ____ Subsidencia (hundimiento de las tierras debido al uso del agua subterránea) _____Incendios forestales _____ Mala calidad de aire

Dar vuelta →

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Dar vuelta →

4)) ¿ Cuál de las siguientes mejoras de transporte son de más importancia para combatir el clima extremo y los cambios climáticos? (Marca todas las opciones que aplican)

_____ Crear más paradas de transito cómodas y con sombra _____ Plantar árboles en el camino de las carreteras y las banquetas _____ Mejorar el control de inundaciones____ Mejores planes de planeación y evacuación ____ Expandir el servicio y la disponibilidad del transporte a pedido (como el viaje en grupo, paratránsito, etc.) particularmente para personas de edad avanzada y discapacitadas_____ Servicio de transporte público a centros de enfriamiento en días muy calurosos _____ Mejor manejo de la vegetación inflamables cerca de los carreteras y estructuras ___Otros (Favor de describir abajo)

5) ¿Que cree usted que la región de Fresno puede hacer para prepararse para los impactos del cambio climático referente al transporte? (Favor de describir abajo)

6) ¿Cuáles son sus medios de transporte primarios? (Marque todas las opciones que aplican si usted utiliza varios medios para llegar a su destino) ___ Manejando solo o con su familia ____ Viaje en grupo ___ Tomando un Taxi o un viajes compartidos (Uber/Lyft) ____ Transporte público (camión , tren) ____ Bicicleta ____ Caminando

Si usa bicicleta, “¿Cuánto le toma para llegar a su destino o a su siguiente forma de transporte (como una parada del autobús)?”

Si es caminando, “¿Cuánto camina para llegar a su destino o a su siguiente forma de transporte (como la parada del autobús)? “

7) ¿Cuál fue su ingreso familiar antes de impuestos en el 2018?

_____menos de $14,000 _____ $15,000 a $24,999 _____ $ 25,000 a $35,999

____$36,000 a $49,999 _____ $50,000 o más

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno.

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Fresno County Transportation Network Vulnerability Assessment
Pop-up Event - Kerman Almond Festival

Name:

Email:

Comments:

Visit www.fresnocog.org/project/sb1-planning-studies/ for additional information

Fresno Council of Governments

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Evaluación de Vulnerabilidad de la Red de Transporte del Condado de Fresno

Evento de Carpa - Kerman Almond Festival

Nombre:

Correo electrónico:

Comentarios:

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Para más información

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Fresno County Transportation Network Vulnerability Assessment

Pop-up Event - Reedley Street Faire

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Email:

Comments:

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Fresno Council of Governments

Fresno County Transportation Network Vulnerability Assessment

Pop-up Event – San Joaquin Carnival

Name: ____________________

Email: ____________________

Comments: ____________________

Visit www.fresnocog.org/project/sb1-planning-studies/ for additional information

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Pop-up Events – San Joaquin Carnival

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Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

The **Fresno Council of Governments** is preparing a **Fresno County Regional Transportation Network Vulnerability Assessment (TNVA),** funded through Senate Bill 1. The TNVA will identify areas of the region where the multi-modal transportation network is vulnerable to climate change hazards and identify strategies to remedy potential impacts. These responses will be designed to provide additional benefits to the broader community through public health, environmental, equitable, and economic improvements.

The main climate hazards that will be assessed as part of the TNVA are **temperature rise and extreme heat, flooding from extreme precipitation events, and wildfire risk.** In general, projected changes are:

- **High and low temperatures are expected to rise** across Fresno County, and there will be more heat waves and extreme heat days.
- Precipitation projections are uncertain and **precipitation will become even more volatile**, but in general it's expected that both droughts and storm events will become more frequent and severe.
- **Wildfire risk is increasing** as soils and vegetation dry out from temperature rise.

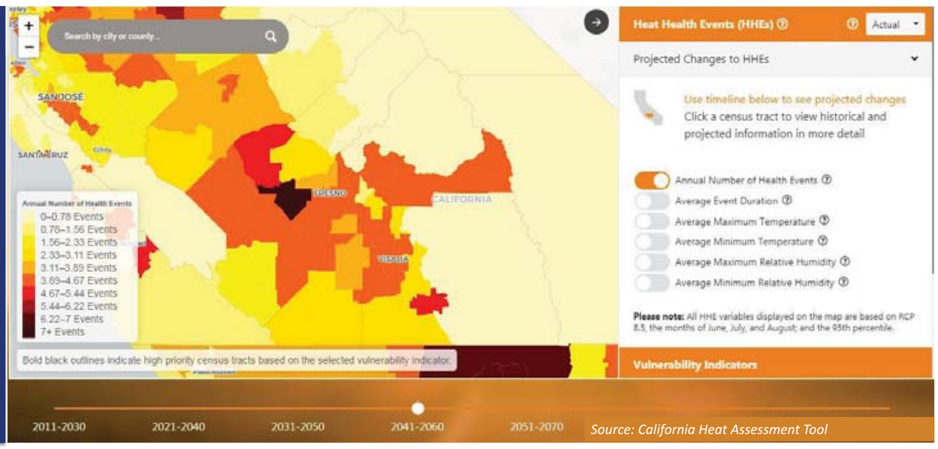
Clovis, CA, photo by David Prasad, Creative Commons License 2.0

Heat Health Events

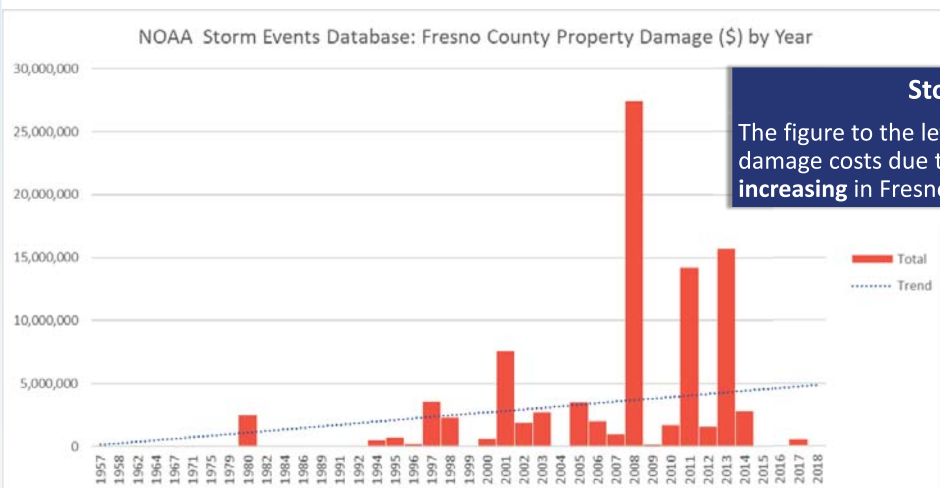
Heat health events are expected to increase over the coming century.

A heat health event is any event that results in a **negative public health impact**, such as an emergency room visit.

See the map to the right for the **projected increases in annual heat health events** by mid-century.



Source: California Heat Assessment Tool



Storm Events

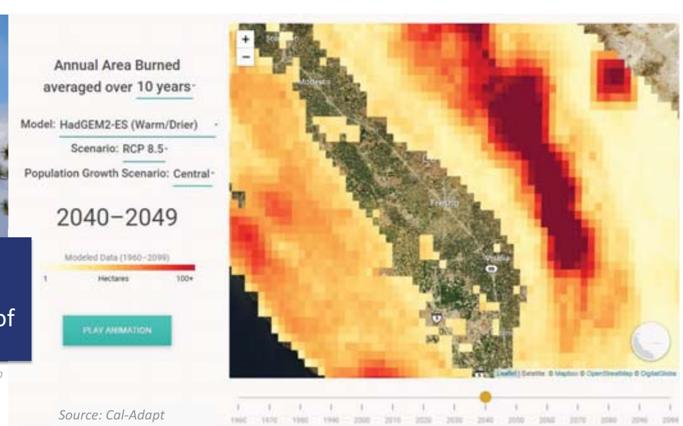
The figure to the left shows how property damage costs due to **storm events** are already **increasing** in Fresno County.

Washout on SR-41, photo courtesy of Caltrans

Area Burned

Average annual area burned is **expected to increase by 205%** in Fresno County by the end of the century.

Rim Fire as seen from SR-41, photo by Andrew Adams, Creative Commons License 2.0



Source: Cal-Adapt

Fresno Council of Governments

wsp

VRPA TECHNOLOGIES, INC.

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

El **Consejo de Gobiernos de Fresno** esta preparando una **Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno (TNVA),** financiada por la ley del Senado 1. La TNVA identificará las áreas de la región donde la red de transporte multimodal es vulnerable a los peligros por el cambio de clima e identificar estrategias para remediar los posibles impactos. Estas respuestas estarán diseñadas para proveer beneficios adicionales a la amplia comunidad por medio de mejoras a la salud pública, el medio ambiente, equitativas, y económicas.

Los principales peligros climáticos que serán evaluados como parte del TNVA son el **aumento de temperatura y calentamiento extremoso, inundaciones debido a eventos de precipitación extremosos, y riesgo de incendios forestales.** En general, los cambios que se proyectan son:

- **Las temperaturas altas y bajas se esperan que aumenten** por todo el Condado de Fresno, y habrá más olas de calor y días de calentamiento extremo.
- Las proyecciones de precipitación son inseguras y **la precipitación será aún más inestable**. Pero en general se espera que ambos eventos de sequias y tormentas sean más frecuentes y severos.
- **El incendio forestal esta incrementando** al secarse la tierra y la vegetación por el aumento de la temperatura.

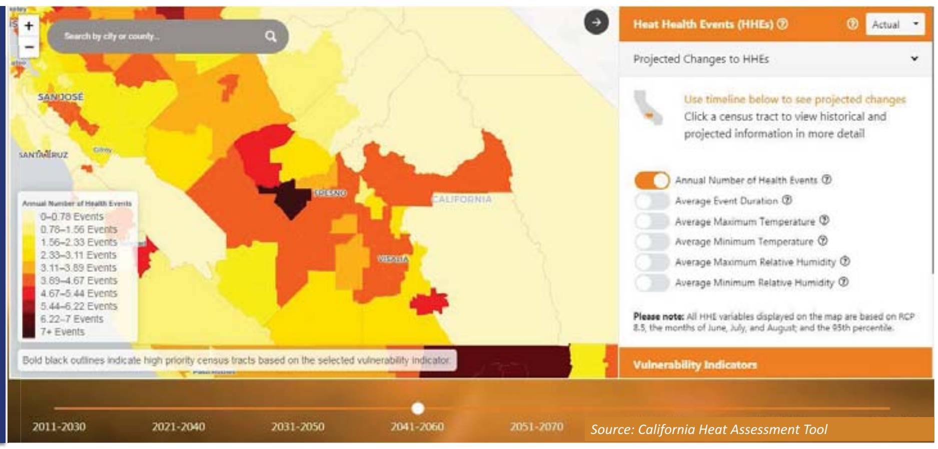
Clovis, CA, photo by David Prasad, Creative Commons License 2.0

Eventos de Salud por Calentamiento

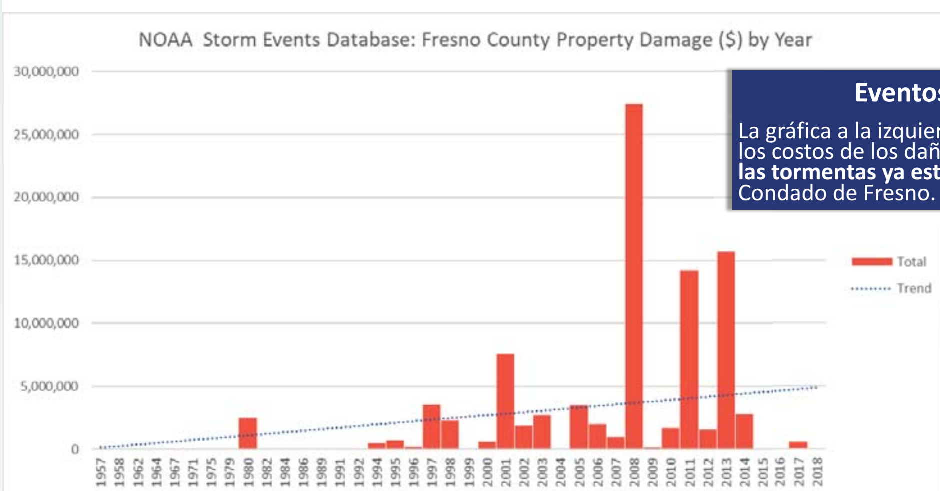
Los eventos de salud por calentamiento se espera que aumenten en el próximo siglo.

Un evento de salud por calentamiento es cualquier evento que resulta en un **impacto de salud pública negativa**, como la visita a la sala de emergencias.

Vea el mapa a la derecha para ver el **aumentos proyectados en los eventos de salud anuales a causa del calentamiento** de aquí a medio siglo.



Source: California Heat Assessment Tool



Eventos de Tormentas

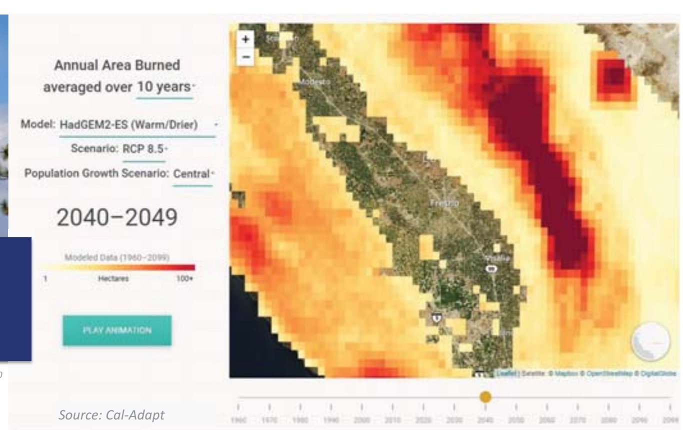
La gráfica a la izquierda nos enseña como es que los costos de los daños de propiedades debido a **las tormentas ya están aumentando en el** Condado de Fresno.

Washout on SR-41, photo courtesy of Caltrans

Área Quemada

El Promedio anual de área quemada se espera que **aumente por un 205 %** en el Condado de Fresno para fines del siglo.

Rim Fire as seen from SR-41, photo by Andrew Adams, Creative Commons License 2.0



Source: Cal-Adapt

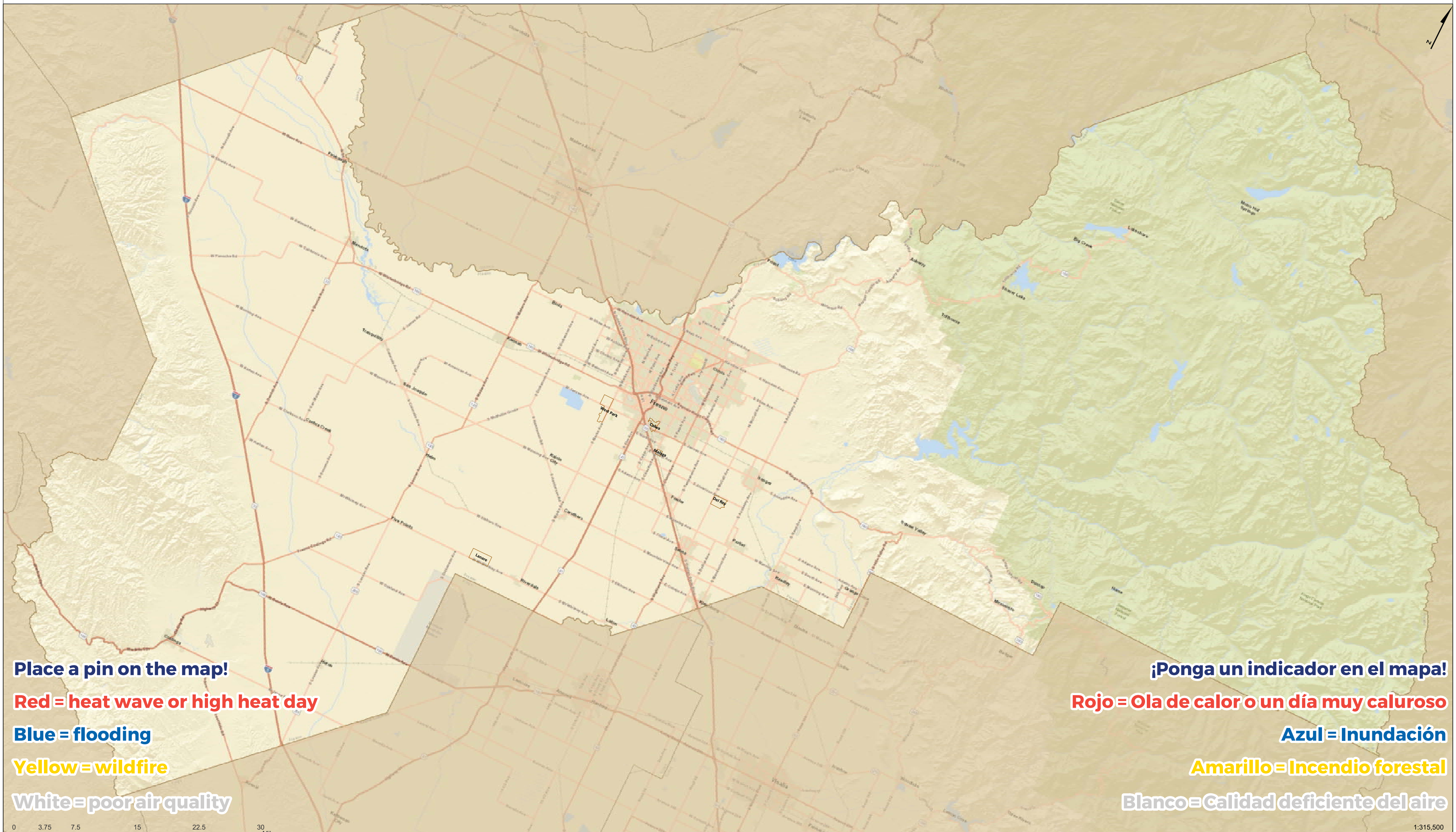
Fresno Council of Governments

wsp

VRPA TECHNOLOGIES, INC.

Has a weather event or other condition ever affected your ability to travel or required you to evacuate? Where?

¿Ha afectado algún evento climático u otra condición su habilidad de viajar o que haya tenido que evacuar? ¿En dónde?



Fresno County Regional Transportation Network Vulnerability Assessment

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Fresno Council of Governments

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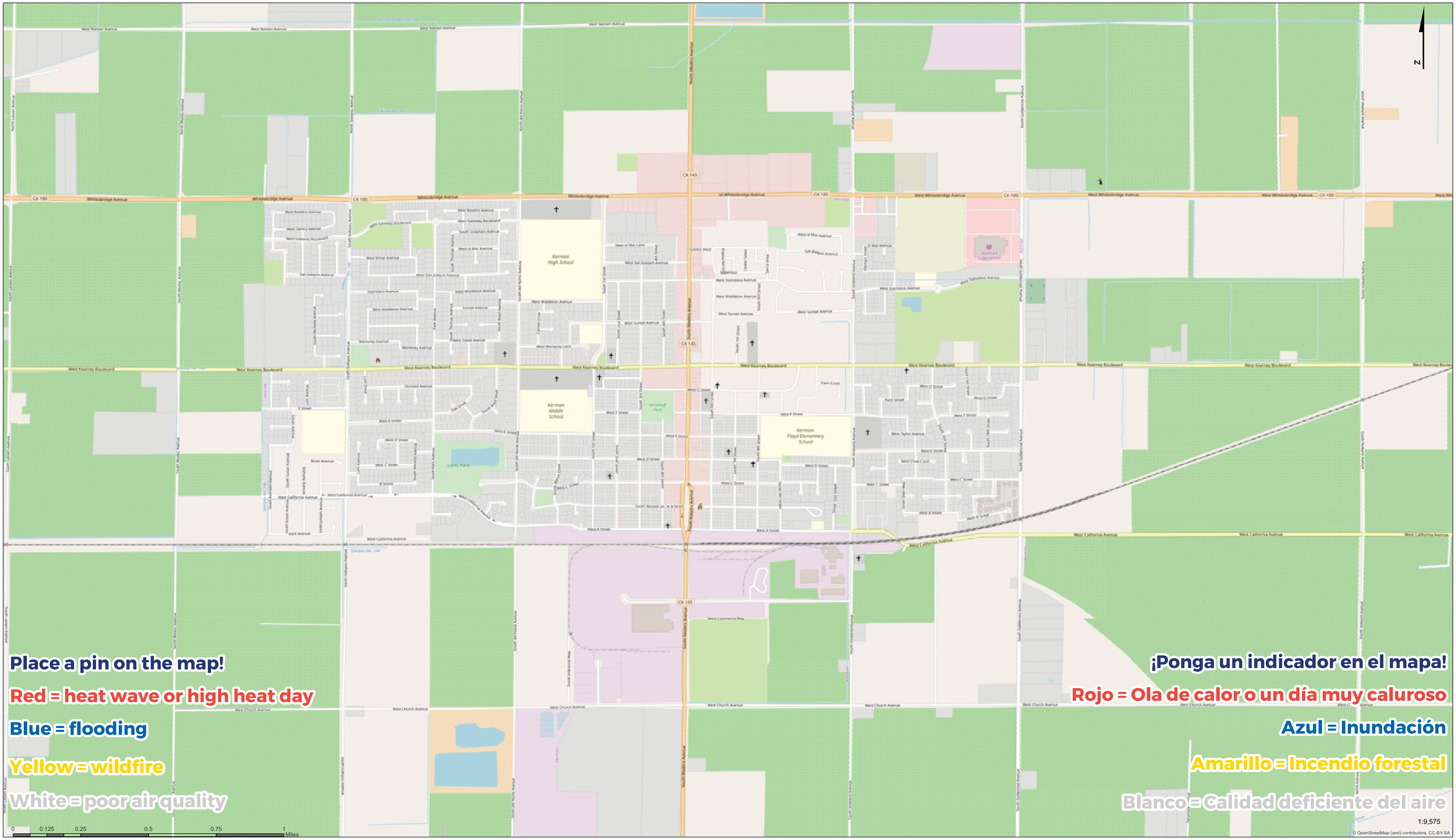

Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

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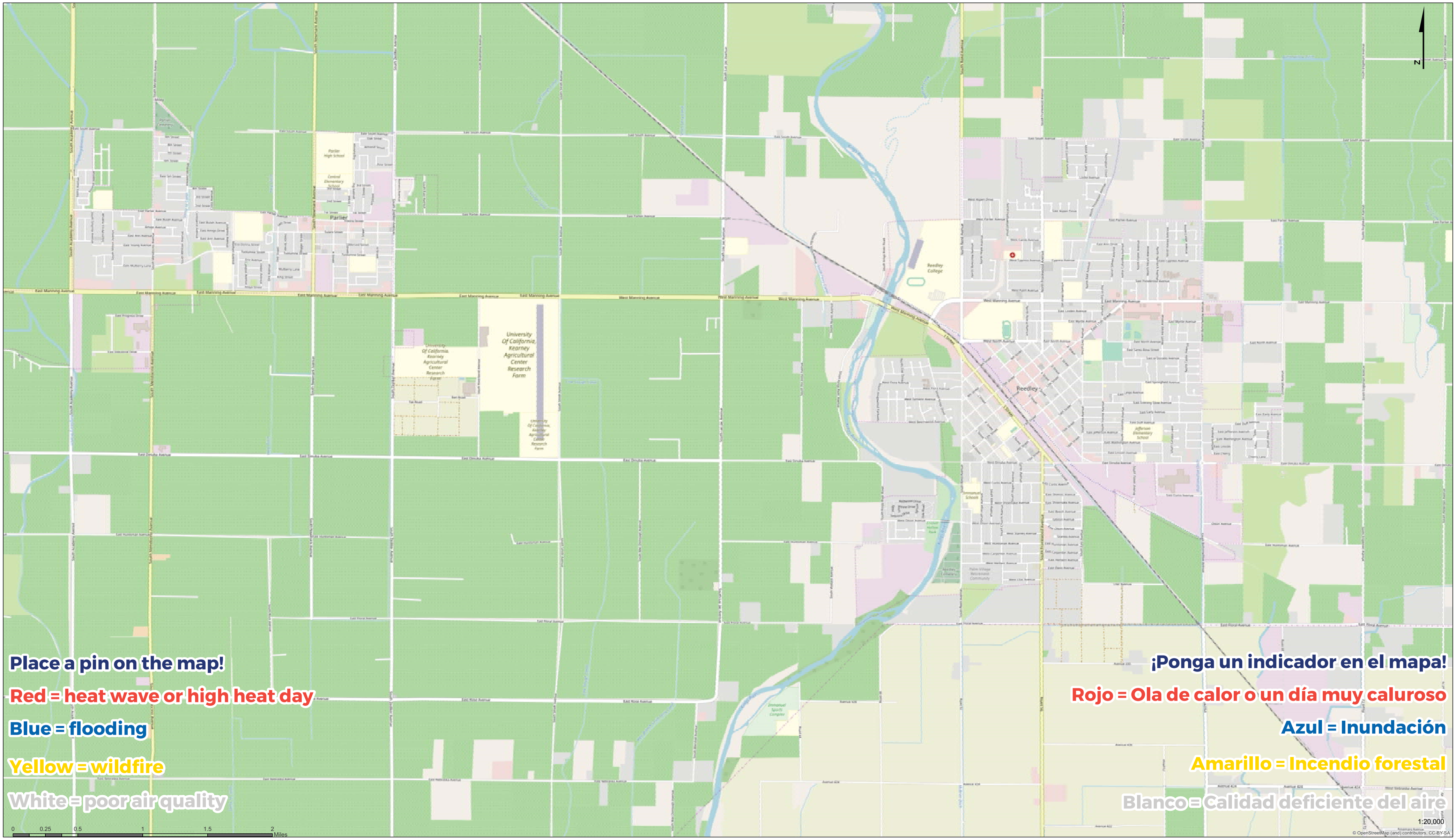

Fresno County Regional Transportation Network Vulnerability Assessment

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Fresno Council of Governments WSP VRPA TECHNOLOGIES INC.

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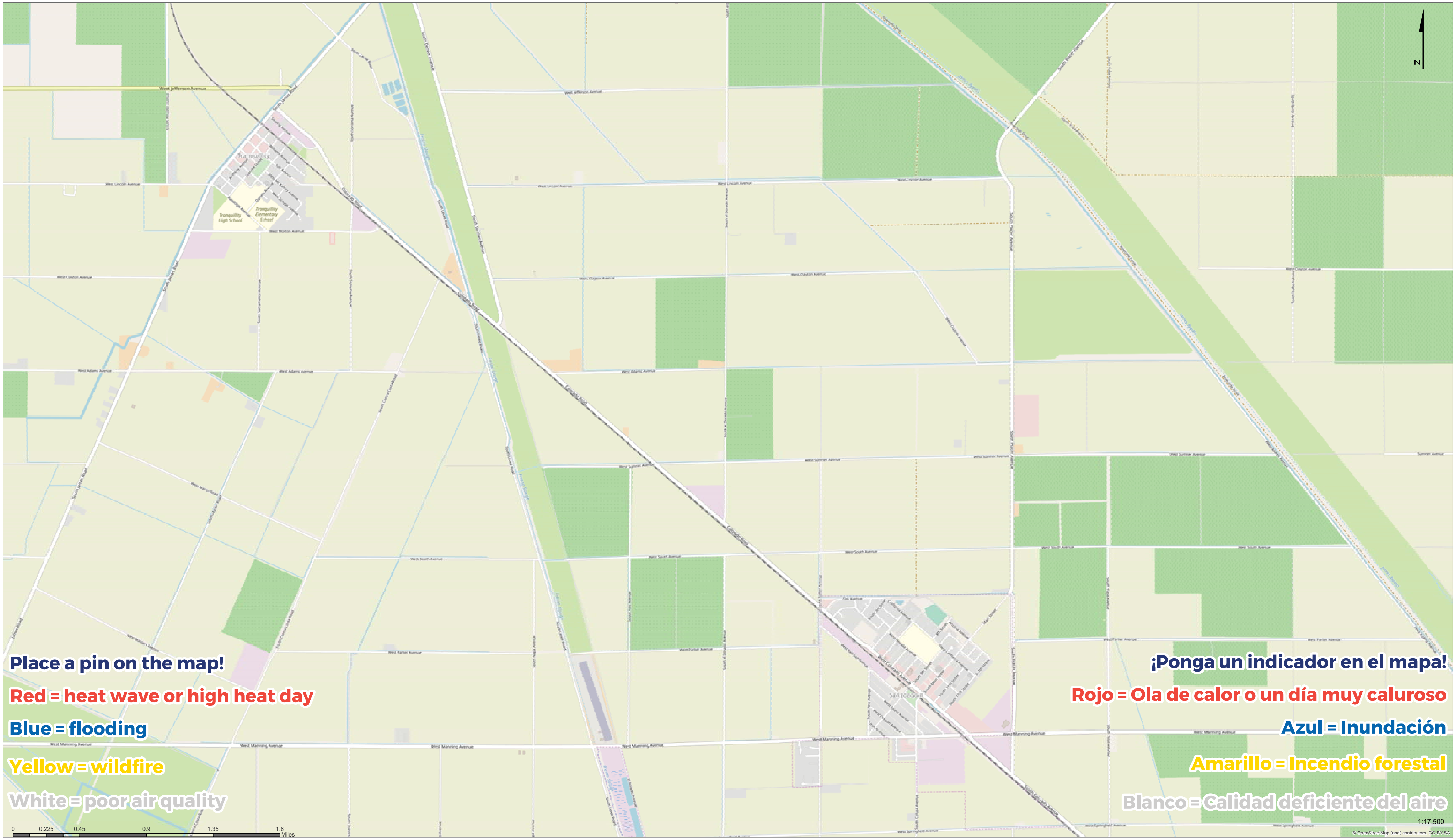


Fresno County Regional Transportation Network Vulnerability Assessment

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Fresno Council of Governments

Pop-up Event Survey Results

Pop-up event surveys were available for dissemination at short, but meaningful interactions with the public that allowed their feedback to be incorporated into the Transportation Network Vulnerability Assessment (TNVA) while ultimately reaching a significantly higher number of residents than a traditional public workshop. Pop-up events allowed the TNVA Project Team to engage with the public at events of interest to them. The TNVA Team worked with Fresno COG staff and the Vulnerability Assessment Working Group (VAWG) to provide materials for dissemination at high-volume events in Fresno County. Such locations included:

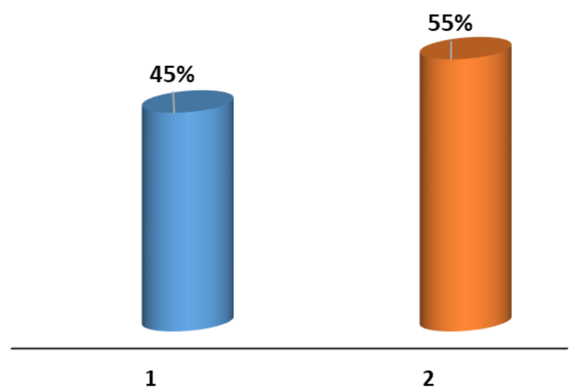
- ✓ Kerman Almond Festival
- ✓ Reedley Street Faire
- ✓ San Joaquin Carnival
- ✓ Fresno Grizzlies July 4th baseball game

The TNVA Team prepared the surveys to reflect the questions desired for the development of the TNVA, while also presented in a format and language easily understood by the general public. The survey consisted of a series of multiple choice, priority ranking and open ended questions, which was available to survey participants in both English and Spanish. Participants were able to provide input on the survey questions by selecting their preferred answer and submitting their completed survey to TNVA Team staff that was present at the pop-up event. Answers from all surveys have been totaled and are graphically displayed below. Numbers in parentheses following each survey question correspond to the total number of responses received for each question. In some cases, survey respondents may have selected more than one answer per question. A total of one hundred seventy-eight (178) surveys were completed by all pop-up event attendees.

1. Have weather events or conditions ever affected your travel or required you to evacuate?

1. Yes
2. No

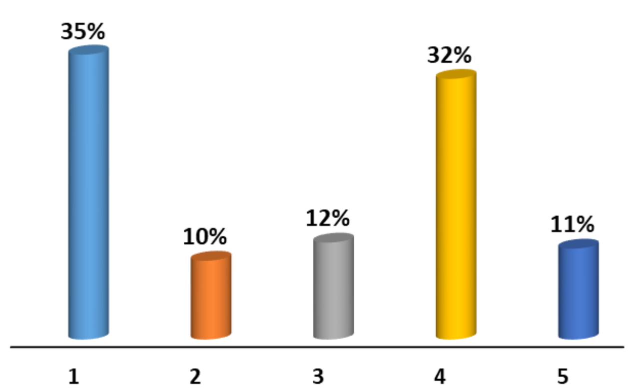
(175 Responses)



2. If yes to the above, "What type of event or condition?"

1. Heat wave or extreme heat day
2. Flooding
3. Wildfire
4. Poor Air Quality
5. Other

(134 Responses)

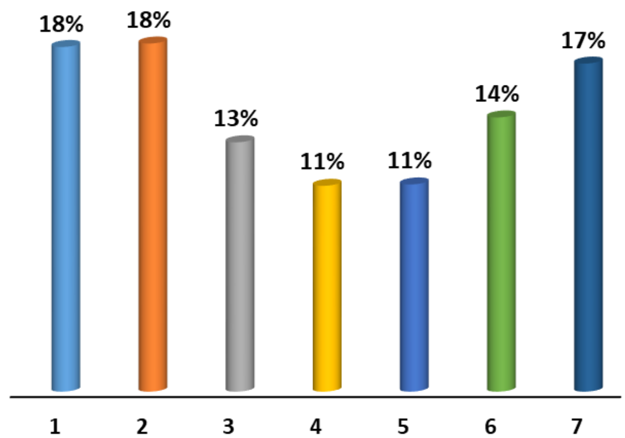


If yes to above, "Tell us about the event(s). How did it affect your travel?" (Please describe below)

- ✓ When it's too hot we avoid running errands usually wait until the night. I have two children with asthma, so the air quality is something really keep an eye on.
- ✓ Know individual affected by wildfire. Lost everything.
- ✓ Bad roads too many potholes, dangerous driving conditions.
- ✓ Not able to take outside due to bad air quality. Extreme heat days- need cooling centers.
- ✓ It's too hot outside, my children have health conditions that prevent them from traveling to far.
- ✓ Flooding affects my commute to work, when the freeway is bad causes traffic jams and detours.
- ✓ The road – Manning Ave. in Reedley has a lot of cracks and potholes. Flooding when it rains.
- ✓ Morning, the fog is too dense and the street signs are not visible; dust waves also block the view.
- ✓ A lot of smoke up SR-41, hard to see.
- ✓ Walks around community , difficult to breathe.
- ✓ Extreme heat affects travel times and destinations.
- ✓ Due to having prior existing health conditions, I am extremely susceptible to major heat/weather changes.
- ✓ It is really hot sometimes and there aren't many places with shade. Places in Reedley need serious remodeling, especially Citizens Park.
- ✓ The bus stop is way to exposed and the heat made me feel sick.
- ✓ Flooding on Manning Ave. Need drainage system.
- ✓ It is too hot at Reedley High School. I believe there should be more trees planted.
- ✓ Poor air quality has required me to stay indoors.
- ✓ The area was blocked off which affected going and coming to work every day.
- ✓ My children were born premature so days with poor air quality we limit our travels.
- ✓ It affected because of the heat wave, the wildfires, the bad air quality.
- ✓ The weather is too hot.
- ✓ The heat has stopped me from walking with my dog to parks. Even at work I don't walk to lunch because of how it is. My allergies have also expanded all while the quality of air has been extremely harmful.
- ✓ I kept stopping every time I walked. It is really hot.
- ✓ Too hot, not enough shade.
- ✓ When driving down Dinuba Ave and Manning Ave, roads get really flooded. Needs a sewage system to drain water and also City needs to plant more trees for shade to combat high heat.
- ✓ Weather too hot to walk, no shade.
- ✓ Less likely to want to travel, or spend time outdoors.
- ✓ The heat made me feel ill.
- ✓ Flooded streets, have transportation buses and shaded bus stop areas.
- ✓ Due to the poor air quality, my twins asthma kicked in, they ended up in the ER to get a breathing treatment.
- ✓ Wildfire- evacuated/couldn't get to work
- ✓ Do not like going out when air quality is bad
- ✓ Street maintenance needed.
- ✓ Family forced to evacuate.
- ✓ Unable to work extended hours/normal shift
- ✓ Heavy traffic, blocked roads, car wreck.

3. What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least concerning)

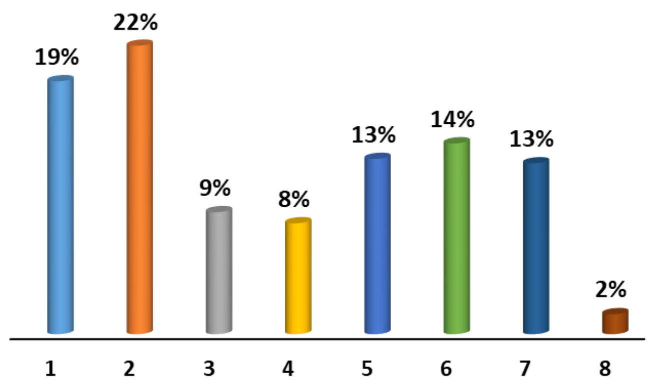
1. Longer and more severe droughts
2. Heat waves and higher temperatures
3. Heavy rains and flooding
4. Landslides and erosions
5. Subsidence (land sinking from groundwater use)
6. Wildfires
7. Lower air quality



(800 Responses)

4. Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)

1. Create more comfortable and shaded transit stops
2. Tree plantings along roadways and sidewalks
3. Improved flood control
4. Better evacuation planning and communications
5. Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) particularly for elderly or disabled people
6. Public transit service to cooling centers on high heat days
7. Better management of flammable vegetation near roadways and structures
8. Others



(600 Responses)

5. What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation? (Please describe)

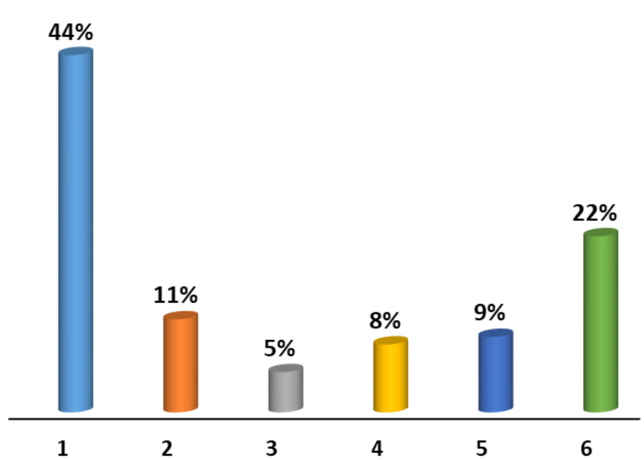
- ✓ Shorter stops per trip.
- ✓ Do research to see how the residents can be helped.
- ✓ More shade, plant more trees.
- ✓ More buses or options provided by the City.
- ✓ Road conditions.
- ✓ More shade at rest stops.
- ✓ More information.
- ✓ More public transportation, van pools.
- ✓ Providing more transportation for families that need it.
- ✓ Bring more buses for transportation.
- ✓ Expand coverage of public transit.
- ✓ Better roads.
- ✓ Cleaner air.
- ✓ Accessible transportation accommodating passenger need access to common needs. Lessens wait time to board or if bus over filled. Common courtesy - how long will next bus coming or shuttle route.
- ✓ Hydrogen cell/electric car.
- ✓ Fix roads instead of constantly patching them.
- ✓ Roads have too many potholes. Dangerous driving conditions.
- ✓ High-Speed rail needs to be continued; avoids pollution. Change school buses to electric.
- ✓ When building/developing new areas "connecting the sidewalks." Leaving dirt spaces between developments makes for children to walk on the road.
- ✓ Transit that moves from city to city.
- ✓ We need to increase lanes of freeway and fix our terrible roads. Fossil fuel is in good supply.
- ✓ A better organized call center for public transportation.
- ✓ Better organization with heat centers in small towns like ours.
- ✓ Having more cooling centers.
- ✓ Cooling centers. Shade.
- ✓ More shade. Provide more transportation so we don't wait so long.
- ✓ More taxis.
- ✓ Better drainage system to clear out water.
- ✓ Increased shaded areas and opportunities for hydration out in the community.
- ✓ More clean air transportation, also more wildfire control since it affects the pollution in the valley.
- ✓ Better road conditions, they are worn down including the lines on them. Can't see the potholes or line in rain.
- ✓ Have free transportation available in serve weather for elderly and those with children.
- ✓ Fresno can improve on offering public transit options.
- ✓ Improved flood control.
- ✓ More cooling shelters.
- ✓ Send people out to bus stops to see what it is like.
- ✓ Sandbags for rain.
- ✓ Somehow, someway, mitigate the impact of asphalt and concrete on the Valley's heat levels.
- ✓ Cut back on idling and fast food drive thru.
- ✓ By putting structures for shade at bus stops.
- ✓ More public transportation to reduce the use of personal vehicles that create pollution.
- ✓ More bus transportation, different times during the day.
- ✓ Implement transportation between central valley towns.
- ✓ Clean up roadsides.

- ✓ Increased shading, popular idea is to install solar panel overhangs in large parking lots to both increase shade for cars and decrease power usage/billing .
- ✓ Making sure that we have lots of shade and cooling areas would be helpful. Provide transportation to those areas. Have more awareness pieces to the population especially for programs that are available to them.
- ✓ Add sewage system/drainage on Dinuba Ave and Manning Ave to not cause flooding. Plant more trees along sidewalk.
- ✓ Sometimes there are flooded areas that make us have to reroute, better street drainage.
- ✓ Make markers on the road more visible. Stop signs need to have LED lights during heavy rain/fog.
- ✓ More water storage. They waste reservoir water to keep the water from overflowing.
- ✓ Increase public transportation.
- ✓ More cooling centers.
- ✓ Shelters/cooling centers. Shade at stops. Water parks.
- ✓ More access to transportation at quicker intervals.
- ✓ Have a cooling system at the community center or build a pool near the community center for all in the community. Fix potholes in the streets.
- ✓ Electric vehicles. Run off – floodwater capture.
- ✓ More indoor facilities to bike or walk.
- ✓ Shorter intervals during extreme heat days.
- ✓ Free transportation during severe heat waves.
- ✓ More shades at bus stops, or any public transportations.
- ✓ Reduce fuel emission.
- ✓ Sustainable option. Bike/walk-ability.
- ✓ More buses, shorter intervals.
- ✓ Invest in repairs on streets.
- ✓ Shorter wait times at bus stops.
- ✓ Grants to fix air conditioning.
- ✓ Stronger air pollution control.
- ✓ More shades and transportation solutions.
- ✓ More awareness- more programs that serve the entire population.
- ✓ Plant trees.
- ✓ More frequent shade in places for public transportation.

6. What are your primary modes of transportation? (Check all that apply if you use multiple modes to reach your destination?)

1. Drive alone of with family
2. Carpooling
3. Taking a Taxi or rideshare (Uber/Lyft)
4. Public transit (bus, train)
5. Biking
6. Walking

(322 Responses)



If biking, "How long do you bike to get to your destination or next mode of transportation (like a transit stop)?"

- 2-3 hours/day
- 10 minutes
- 1 mile
- 1 mile
- ½ hour
- 30 minutes
- When weather is nice, 30 minutes
- Less than 5 miles
- 1 hour for recreation
- I bike just to exercises and go to the park
- 1 hour
- 3 miles
- 5 miles
- 3-4 miles

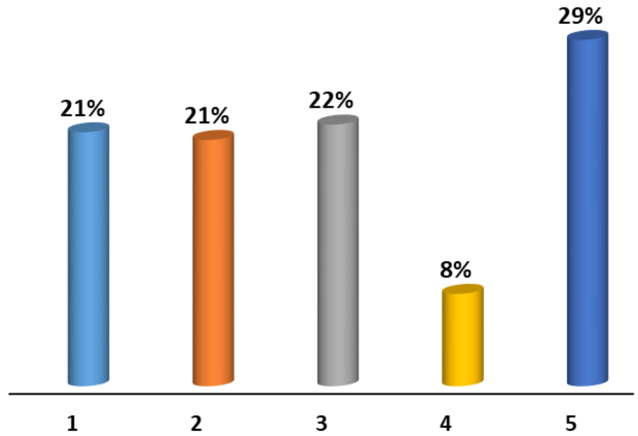
If walking, "How long do you walk to get to your destination or next mode of transportation (like a transit stop)?

- Usually up to 1 mile
- ½ mile
- 1 or 1 ½ mile
- 30 minutes, not enough shade
- 4 hours, every day through town
- 30-35 minutes
- 20 minutes
- 1 mile a day
- 20-35 minutes
- At least a mile
- 20 minutes in spring and fall. Too hot in summer. Too cold and wet winter's
- 2 miles/day
- ½ hour
- 25-30 minutes
- 1 hour
- 25 minutes
- When weather is nice, 30 minutes
- If weather permits, 30 minutes
- 30 minutes
- Only 15-20 minutes due to heat
- 1 hour for recreation
- 10 minutes
- 10 minutes or 15 minutes
- 30 minutes
- 30 minutes
- 4 kilometers
- 30 mins
- 30 mins
- 3 miles
- 30-60 mins
- ¼ mile
- 1 mile
- ¼ of mile
- 2-3 miles
- 1-2 miles
- 2 miles
- 1 mile
- 1 mile

7. What was your household income before taxes in 2018?

1. Less than $15,000
2. $15,000 to $24,999
3. $25,000 to $35,999
4. $36,000 to $49,999
5. $50,000 or more

(156 Responses)



APPENDIX B

Online Survey Materials

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment *(Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno)*

Community Survey *(Encuesta Comunitaria)*

We need your help shaping the Fresno region's future!*(¡Necesitamos su ayuda para dar forma al futuro de la región de Fresno!)*

The Fresno Council of Governments is identifying where the region's transportation network is vulnerable to potential impacts of climate change. These impacts could include increased temperature, more extreme heat days, flooding, drought, and wildfires. This effort is called the Fresno County Regional Transportation Network Vulnerability Assessment. The goal of this assessment is to find solutions that will benefit the entire Fresno County community and improve transportation in the region. *(El Consejo de Gobiernos de Fresno está identificando los lugares donde la red de transportación de la región es vulnerable a impactos potenciales a causa del cambio climático. Estos impactos podrían incluir incremento de temperatura, días de calor extremo, hundimiento, sequia, e incendios forestales. Este esfuerzo es conocido como la Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno. La meta de esta evaluación es el encontrar soluciones que beneficiarán a la comunidad entera del Condado de Fresno y mejorar la transportación en la región.)*

Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, how you use the transportation system to get around, and what transportation improvements you would like to see locally in response to climate change, to create a resilient regional transportation network. *(Por favor complete esta encuesta anónima para informarnos cuáles son los impactos del cambio climático que más le preocupan, como utiliza el sistema de transporte para navegar, y que tipo me mejoras de transporte le gustaría ver localmente en respuesta al cambio climático, para crear una red sólida de transporte regional.)*

1. What zip code do you live in? *(¿Cuál es el código postal donde vive usted?)*

2. Have weather events or conditions such as high heat, flooding, or wildfire ever affected your travel or required you to evacuate? *¿Han afectado eventos climáticos o condiciones como temperaturas altas, hundimientos, o incendios forestales su viaje o que haya que tenido que evacuar?*

- ◯ Yes *(Si)*
- ◯ No *(No)*

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment *(Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno)*

3. If yes, What type of event or condition?*(En caso de responder Si a lo de arriba, ¿Que tipo de evento o condición?")*

- ◯ Heat wave or extreme heat day (Ola de calor o día de calor extremo)
- ◯ Flooding (Inundación)
- ◯ Wildfire (Incendio forestal)
- ◯ Poor air quality day (Día con mala calidad de aire)
- ◯ Other (please specify) (Otros (Por favor describalo abojo)

4. Tell us about the event(s) or conditions noted above in Question 3. How did it affect your travel? *Cuéntenos sobre el/los evento(s)o condiciones mencionada en la pregunta de arriba. ¿Cómo afectó su viaje?")*

5. How could better transportation have helped you? *(¿Cómo le podría haber ayudado un mejor sistema de transporte?)*

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment *(Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno)*

6. How concerned are you about the impacts of climate change? For example, increases in extreme temperatures, drought, flood risk, and wildfires. *(¿Qué tan preocupado está por los impactos del cambio climático? Por ejemplo, aumentos en temperaturas extremas, sequía, riesgo de inundaciones e incendios forestales.)*

- ◯ Very *(Mucho)*
- ◯ Somewhat *(Un Poco)*
- ◯ Not at All (Para Nada)

7. Do you think climate change will impact your life directly?(¿Crees que el cambio climático afectará tu vida directamente?)

- ◯ Yes, Please Explain Below *(Si, por favor explique abajo)*
- ◯ No *(No)*
- ◯ Not Sure (*No estoy seguro)*

If Yes, Please Explain (En caso afirmativo, explíquelo porfavor)

8. What impacts from climate change are you most concerned about? (Please rank in order of importance where 1 is the most important and 7 is the least.) *(¿Cuáles son los impactos por el cambio del clima que más le preocupan? (Favor de clasificar lo siguiente en orden de importancia, en donde el 1 es de más preocupación y el 7 es el que menos le preocupe))*

- Longer and more severe droughts *(Sequias más severas y alargadas)*
- Heat waves and higher temperatures *(Olas de calos y temperaturas altas)*
- Heavy rains and flooding *(Fuertes lluvias e inundaciones)*
- Landslides and erosion *(Derrumbes y erosión)*
- Subsidence (land sinking from groundwater use) *(Subsidencia (hundimiento de las tierras debido al uso del agua subterránea))*
- Wildfires *(Incendios forestales)*
- Lower air quality *(Mala calidad de aire)*

9. Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Choose all that apply) *(¿Cuál de las siguientes mejoras de transporte son de más importancia para combatir el clima extremo y los cambios climáticos? (Marca todas las opciones que aplican))*

- [ ] Create more comfortable and shaded transit stops *(Crear más paradas de transito cómodas y con sombra)*
- [ ] Tree plantings along roadways and sidewalks *(Plantar árboles en el camino de las carreteras y las banquetas)*
- [ ] Improved flood control *(Mejorar el control de inundaciones)*
- [ ] Better evacuation planning and communication *(Mejores planes de planeación y evacuación)*
- [ ] Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.), during high heat or other extreme weather events, particularly for elderly or disabled people. *(Expandir servicio y disponibilidad de transportación a demanda (tal como el viaje en grupo, paratránsito, etc.), durante los días de calor extremo o otro evento de clima extremo, particularmente para mayores de edad o personas discapacitadas.)*
- [ ] Public transit service to cooling centers on high heat days *(Convertir sitios de servicio de transporte público en centros de enfriamiento en días muy calurosos)*
- [ ] Better management of flammable vegetation near roadways and structures *(Mejor manejo de la vegetación inflamables cerca de las carreteras y estructuras)*
- [ ] Other (please specify) (Otros (especificar))

10. What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation? *(¿Que cree usted que la región de Fresno puede hacer para prepararse para los impactos del cambio climático referente al transporte?)*

11. What are your primary modes of transportation? (You can choose more than one if you use multiple modes to reach your destination). *(¿Que son sus modos de transporte primarios? (Puede elegir más de una opción si usted utiliza múltiples modos para llegar a su destino).*

- ☐ Driving alone or with family *(Manejando solo o con su familia)*
- ☐ Public transit (bus, train) *(Transporte público (camión, tren))*
- ☐ Carpooling *(Viaje en grupo)*
- ☐ Biking *(Bicicleta)*
- ☐ Taking a taxi or ride share (Uber/Lyft) *(Tomando un Taxi o un viaje compartido (Uber/Lyft))*
- ☐ Walking *(Caminando)*

If biking or walking, "How long do you bike to get to your destination or next mode of transportation (like a transit stop)?" (Si la respuesta es bicicleta o caminando, "¿Cuánto le toma para llegar a su destino o a su siguiente forma de transporte (como una parada del autobús)?")

12. What is your age? *(¿Cuál es tu edad?)*

- ○ Under 18 years *(Menores de 18 años)*
- ○ 18 to 24 years *(18 a 24 años)*
- ○ 25 to 44 years*(25 a 44 años)*
- ○ 45 to 64 years *(45 a 64 años)*
- ○ 65 years and over *(65 años y más)*

13. How many cars does your household have? *(¿Cuántos carros tiene en su hogar?)*

14. What was your household income before taxes in 2018? *(¿Cuál fue el ingreso de su hogar antes de impuestos en el 2018?)*

- ○ Less than $14,999 *(Menos de $14,999)*
- ○ $15,000 to $24,999 *($15,000 a $24,999)*
- ○ $25,000 to $35,999 *($25,000 a $35,999)*
- ○ $36,000 to $49,999 *($36,000 a $49,999)*
- ○ $50,000 or more *($50,000 o más)*

15. How many people are there in your household?*(¿Cuántas personas hay en su hogar?*

16. How would you describe yourself? *(¿Cómo te describirías a ti mismo?)*

- ◯ American Indian or Alaska Native (*Indio Americano o Nativo de Alaska)*
- ◯ Asian *(Asiático)*
- ◯ Black or African American *(Negro o Afroamericano)*
- ◯ Hispanic, Latino, or Spanish origin *(Origen Hispano, Latino o Español)*
- ◯ Middle Eastern or North African *(Oriente Medio o Norte de África)*
- ◯ Native Hawaiian or other Pacific Islander *(Nativo de Hawái o de otras islas del Pacífico)*
- ◯ White or Caucasian *(Blanco o Caucásico)*
- ◯ Prefer not to say *(Prefiero no decir)*
- ◯ Other (please specify) (Otros (especificar)

Online Survey Results

The Transportation Network Vulnerability Assessment (TNVA) Team augmented the pop-up event in-person survey with an online community survey. The survey consisted of a series of multiple choice, priority ranking and open ended questions, which was available to survey participants in both English and Spanish. The survey was accessible through the Fresno Council of Governments (Fresno COG) Senate Bill (SB) 1 Planning Studies webpage and was available from May through July 2019. A notification concerning the online survey's availability to the public was distributed as follows:

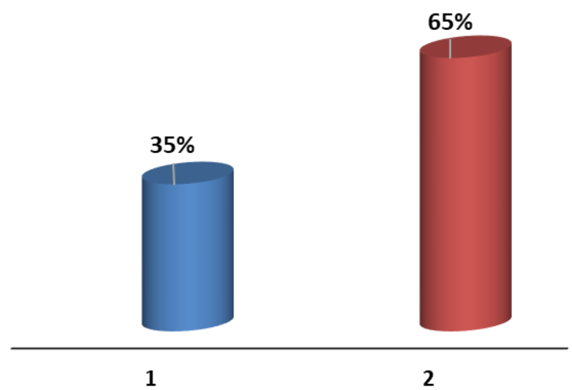
- ✓ By email to the TNVA Stakeholder Database.
- ✓ By email to an expanded Fresno County database.
- ✓ To the Fresno COG newsletter database.
- ✓ Postings to Fresno COG's Facebook and Twitter accounts.
- ✓ Via the California Safe Routes Partnership E-Newsletter.

The Project Team prepared the surveys to reflect the questions desired for the development of the TNVA, while ensuring that the surveys were in a format and language easily understood by the general public. Participants were able to provide input on the survey questions by selecting their preferred answer and submitting their completed surveys online. Answers from all surveys have been totaled and are graphically displayed below. Numbers in parentheses following each survey question correspond to the total number of responses received for each question. In some cases, survey respondents may have selected more than one answer per question. A total of sixty-three online surveys were completed by participants.

1. Have weather events or conditions such as high heat, flooding, or wildfire ever affected your travel or required you to evacuate?

1. Yes
2. No

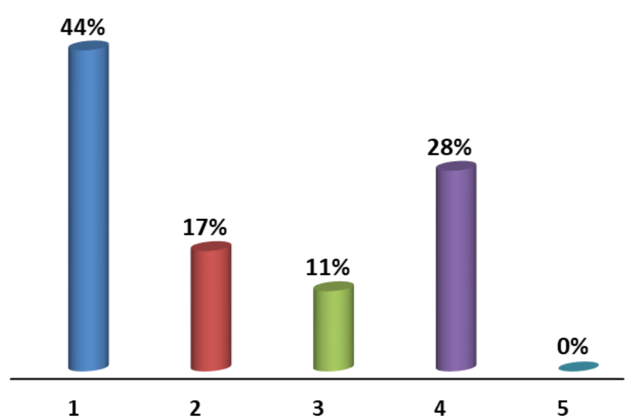
(60 Responses)



2. If yes to the above, "What type of event or condition?"

1. Heat wave or extreme heat day
2. Flooding
3. Wildfire
4. Poor Air Quality
5. Other

(18 Responses)



3. Tells us about the event(s) or conditions noted above in Question 2. How did it affect your travel?"

- Heat and poor air quality routinely prevents me from riding my bike to work or walking to lunch or dinner.
- During high heat days I try to avoid travel. This was especially true when I didn't have air conditioning or the air conditioning in my car was not working well. Poor air quality also prohibits travel. I have a young child and try to keep him inside when the air quality is bad for sensitive audiences. I enjoy walking to the store about a mile from my house with him, but when it's too hot or the air is bad I have to use my car instead.
- Power was reduced to minimum use in the area. A/C and fans weren't available to use to cool off. Older folks suffered from heat stroke.
- Stayed home because did not feel going outside was good for the kids because of how hot it was.
- Rough fire evacuation.
- Can't go outside when it's too hot.
- I don't want to be outside or go outside when it is hot.
- Had to seek a different mode of travel.
- The A/C failed at home. I have a medical condition and had to go to a hotel.
- Major flooding On Cedar between Tulare Ave and Kings Canyon in the City of Fresno. Flooding at the corner of Chestnut and Olive, cars couldn't get past the flooding.
- Heavy rain and backed up storm drains caused flooding which in turn kept us from plans to travel. Read reports of other vehicles that stalled due to flooding.
- Air was so bad my wife had an asthma attack.
- Decided not to travel.
- There is times when our health conditions worsen and this occurs during bad air quality days.
- There was a downpour in Clovis earlier this year that was so heavy that I could not park my car in front of my home. The street was flooded up over the curb. I have lived there for 30 years, and I had never seen so much water on the street.
- Myself and my children could not breathe. FAX is our only transportation.

4. How could better transportation have helped you?

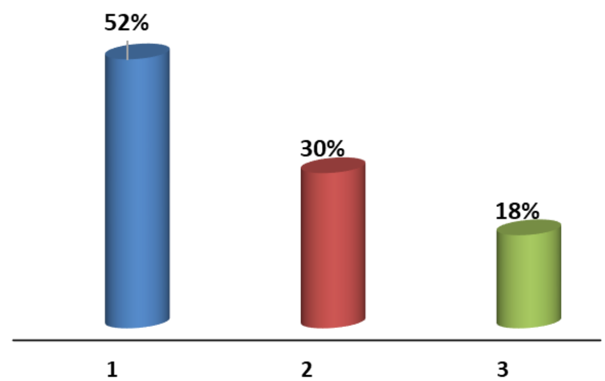
- Strategically landscaped trails and bike lanes providing shade to locally decrease temperature and heat absorption by pavement, while also locally increasing photosynthesis.
- A better tree canopy would help manage walking when the weather is warm. A transportation network that is designed to support improved air quality would also help. If we have better air quality, more people will be inclined to walk, bike or take transit to their destinations.
- Fresno needs to be a transit district! Cities with less than half of our population have up to 5 times as many buses!
- Having public transportation closer to my house.
- An efficient public transportation system could have taken older folks to cooling stations in areas that were not impacted by heat wave.
- While direct transportation is always desirable above transferring on a bus, I don't think it could have.
- Better infrastructure for older parts of the City of Fresno.
- Public transportation should be more frequent (NOT EVERY 1-2 HOURS!) and we should have more accessible routes for low-income communities.

- ✓ Better design of roadways and drainage could have kept the roads safe for travel.
- ✓ Convert all buses, city and county vehicles to electric.
- ✓ Having a choice of affordable transportation with air conditioning.

5. How concerned are you about the impacts of climate change? For example, increase in extreme temperatures, drought, flood risk, and wildfires?

1. Very
2. Somewhat
3. Not at all

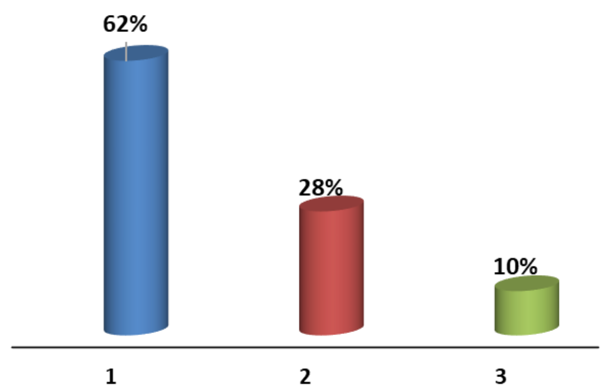
(50 Responses)



6. Do you think climate change will impact your life directly?

1. Yes (Please explain below)
2. No
3. Not sure

(50 Responses)



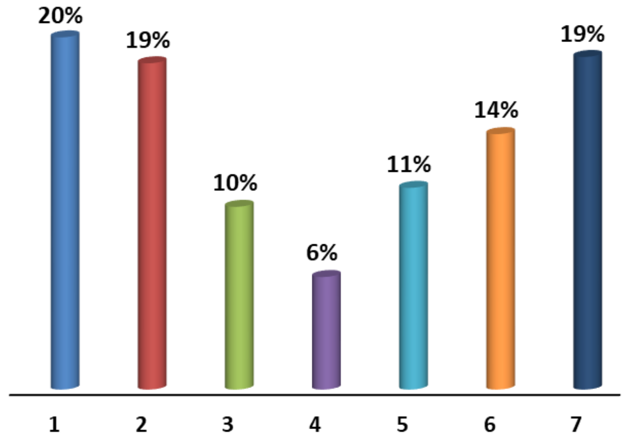
If yes to the above, please explain.

- ✓ I've already been impacted by higher food costs due to drought, increased urban flooding due to more intense storms which can impact travel routes (good city planning here has limited flood damage), higher utility costs (especially water).
- ✓ Less water availability because storage isn't available at higher elevations where more rain and less snow is falling.
- ✓ I fear that the city will become a desert and unlivable.
- ✓ If climate change results in warming climates and extreme weather, it will impact my quality of life by limiting my travel options. When it's too hot, we have to stay inside. When it's raining, trees start to fall and roadways flood. Most people think climate change is a distant/future issue, but I think we are starting to see weather patterns change. Our city wasn't designed to accommodate heavy rains, it was built for a mild climate.
- ✓ More hot days in Fresno.
- ✓ Fresno is a dry area that is susceptible to wildfire and the smoke effects my breathing and asthma problem.

- ✓ The higher temperatures affect daily routines and they restrict your resources for cooling down.
- ✓ Economic impact, weather, drought, etc.
- ✓ Disruption is happening all over our world; it would be presumptuous to think it won't impact me or my family in some ways.
- ✓ Extremes in weather events.
- ✓ Climate is one of the greatest attributing factor to our everyday livelihood. The weather is our go-to for the daily routine activities.
- ✓ Poorer air quality which may lead to respiratory diseases.
- ✓ Less efficient travel. Available working hours and days may be limited by extreme weather.
- ✓ It leads ultimately to an ice age. Not that the heat is desirable, or the fresh water shifting.
- ✓ Increased costs, lower quality of life.
- ✓ Drought.
- ✓ I use multiple forms of transportation. flooding impacts my area, can't use my car. Extreme heat impacts when I walk or bike (air pollution, heat). Heat and rain impacts at bus stops with no shelter (heat strokes).
- ✓ Rising temperatures will lead to much higher energy bills.
- ✓ I think everything will get more expensive and my electric bill will go up a lot.
- ✓ It is an existential threat to all living systems and humanity in particular. The viability of human existence is under direct threat.
- ✓ It will affect agriculture, water supply, days spent outdoors in the heat, increased air pollution due to increased temperatures, etc. All this will affect me - but in ways I cannot now predict.
- ✓ We have a higher probability of health issues.
- ✓ Increased ozone in the air from high temperatures. Summers are hotter the past 5 years. Drought has affected loss of trees, both indigenous trees and trees homeowners have allowed to die. The saying, "Don't frown on brown", was very destructive as many people allowed their yards to blight. Instead, they should have kept trees and shrubs alive. Trees and shrubs help clean our air. People must be encouraged to plant and nurture trees in their yards. Fresno let many trees die. Instead, Fresno must plant trees to clean our air.
- ✓ I actually have been impacted by wildfire, bad air quality days, and now extreme storms. Or house had never had hail and this past season or garden for hail 3 times, making it difficult for us to plan to grow our own food. Our family's asthma has gotten worse over the years and so has our health, we used to be able to go walk summer or winter nights, but now the air quality is bad most days we can't take the risk.
- ✓ My family has asthma. Longer and hotter summer season; more ozone and other pollution. impact family with asthma and heart conditions. Won't want to spend time outdoors and minimal activity. Increased PG&E bill.

7. What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most important and 7 is the least)

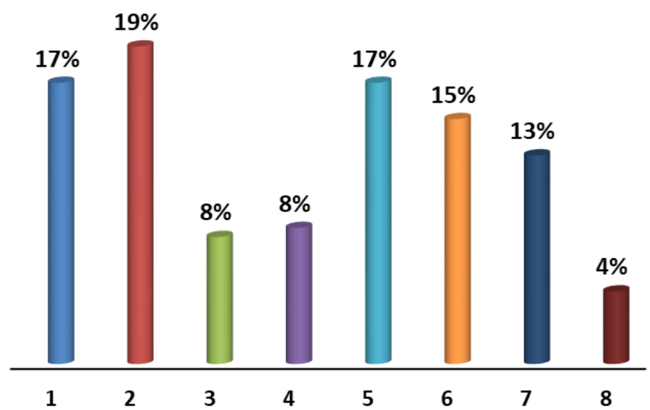
1. Longer and more severe droughts
2. Heat waves and higher temperatures
3. Heavy rains and flooding
4. Landslides and erosions
5. Subsidence (land sinking from groundwater use)
6. Wildfires
7. Lower air quality



(313 Responses)

8. Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)

1. Create more comfortable and shaded transit stops
2. Tree plantings along roadways and sidewalks
3. Improved flood control
4. Better evacuation planning and communications
5. Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) during high heat or other extreme weather events, particularly for elderly or disabled people
6. Public transit service to cooling centers on high heat days
7. Better management of flammable vegetation near roadways and structures
8. Others (Please specify)



(184 Responses)

If others, please specify.

- ✓ Alleviating traffic by creating more inner city highways (timed lights) and educate the public on how and when to use them. Herndon has become a bit of a joke now. What's the point of accelerating to 50 mph just to hit every light? Definitely not countering climate change by burning more fuel.
- ✓ Our freeways (especially SR-41) have waist high dry weeds for most of the summer. I am concerned about the fire risk this presents. I am also concerned about vulnerable residents dying from heat stroke or severe asthma. If there is something we can do to extend quality and length of life, we absolutely should invest in climate change mitigation efforts.
- ✓ Rideshare and carshare programs.
- ✓ Create a transit district! It is ridiculously embarrassing to have Visalia transit running routes in the national parks when it should be FAX!
- ✓ Provide a faster, more efficient transportation system to get between major urban centers and rural outliers.
- ✓ Regulation of heavy transit pollution or more mitigation efforts for the people that live near the freeways because we will all benefit.
- ✓ Electric vehicles for school buses, city buses, short distance delivery/service trucks, more frequent bus schedules.
- ✓ More efficient public transit; technology to tell you when transit will arrive.

9. What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation? (Please describe)

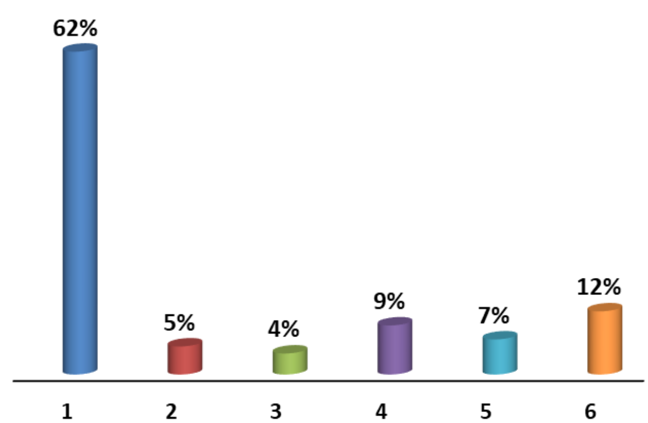
- ✓ Increase service.
- ✓ I believe SGMA (sustainable groundwater management act) nailed this one on the head, however, I think you're asking the wrong question here unless you believe we've passed the point of no return. The greatest effort should be put into prevention and that itself will relieve some of the stress of mitigation. We're not bordered by an ocean that's actively eating our shorelines, so I think we need to be thinking about how we can decrease consumption and lower emissions.
- ✓ Improve the highway system to ensure that there are fewer stop signs and lights where vehicles idle for long periods.
- ✓ Carpool lanes along 99 and 41, more electric charging stations, carshare programs in the urban core.
- ✓ increase water storage for irrigation.
- ✓ More energy efficient transportation.
- ✓ Invest more money in planting trees, maintaining trees and improving irrigation systems. Invest in shade structures at bus stops and benches. There are grants for more trees, but no funding for tree care or major irrigation upgrades. Without the operations and maintenance funding, it is hard to expand the canopy. Fresno could also continue to market bus routes to grow ridership.
- ✓ Plant more and more trees.
- ✓ Consider it in all planning exercises and use real incentives to encourage change.
- ✓ More frequent headways and comfortable stops.
- ✓ Invest in clean vehicle technology and infrastructure.
- ✓ Promote electric and flex fuel “Green” vehicle.
- ✓ Zero Emission Vehicles.

- ✓ Create an app that shows bus locations in real time.
- ✓ Introduce additional green technology. Provide an intercity, high capacity transit system that is 100% zero emissions. Provide faster and more reliable intercity transit so that multi-car ownership is not mandatory.
- ✓ Better weed control and enhanced public transit service.
- ✓ Prevention strategies.
- ✓ Increase number and hours of cooling centers.
- ✓ Invest in an all-electric future. Put community first! Make sure people can get to work no matter what time they need to be there.
- ✓ Implement and apply for money for technology that is zero or low emissions in all of our major economic sectors.
- ✓ Offer more options in travel. More bicycle lanes.
- ✓ Have eco-friendly buses that run every 15-20 minutes and provide more options for different routes across town.
- ✓ Electric vehicles. Strict regulations on large 18-wheel trucks. Air monitors placed at industrial and warehouse sites to record affected air quality from large trucks. Have a warning system for Fresno residents to know when the air quality is dangerous. Sirens going off, TV and other social media alerts.
- ✓ Get expert advice. Conduct regional planning. Do not rely on the County or city governments to come up with reasonable county-wide climate adaptation plans.
- ✓ Contain the growth of cities and promote smart growth and infill development.
- ✓ Make it more attractive for communities to get out of their cars and commute or ride public transit.
- ✓ Build better roads and maintain them.

10. What are your primary modes of transportation? (You can choose more than one if you use multiple modes to reach your destination?)

1. Drive alone of with family
2. Carpooling
3. Taking a Taxi or rideshare (Uber/Lyft)
4. Public transit (bus, train)
5. *5.* Biking
6. Walking

(74 Responses)



If biking or walking, "How long do you bike/walk to get to your destination or next mode of transportation (like a transit stop)?"

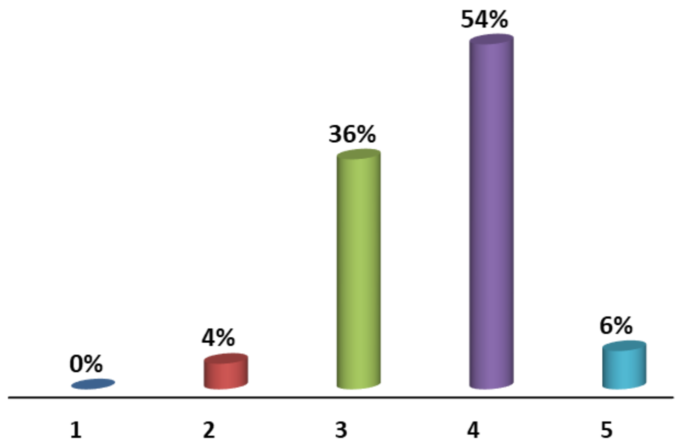
- ✓ When I bike to work its 12 miles...part trail, part bike lane, part dangerous road lacking bike lanes. When I walk to my destination I typically don't walk more than 1 mile each direction.
- ✓ Typically, about 1/2 to 3/4 mile. If the weather is nice, I can easily walk up to 1.5 miles one way to reach my destination.
- ✓ 10-20 min
- ✓ 15-30 minutes

- ✓ 10 minutes
- ✓ 5 min, but the wait in the heat is about 15min
- ✓ Fifteen minutes
- ✓ 6 to 10 blocks
- ✓ We have an electric car we use for in-town transportation. I ride my bike on the rare days the air is good. I have asthma since moving here in 2003.

11. What is your age?

1. Under 18 years
2. 18 to 24 years
3. 25 to 44 years
4. 45 to 64 years
5. 65 years and over

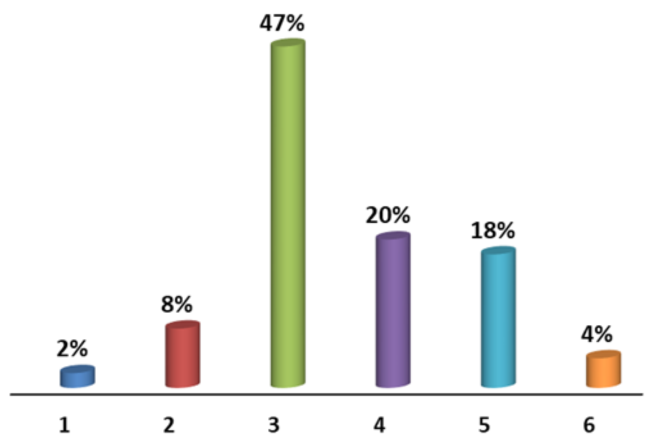
(50 Responses)



12. How many cars does your household have?

1. Zero cars
2. 1 car
3. 2 cars
4. 3 cars
5. 4 cars
6. 5 cars

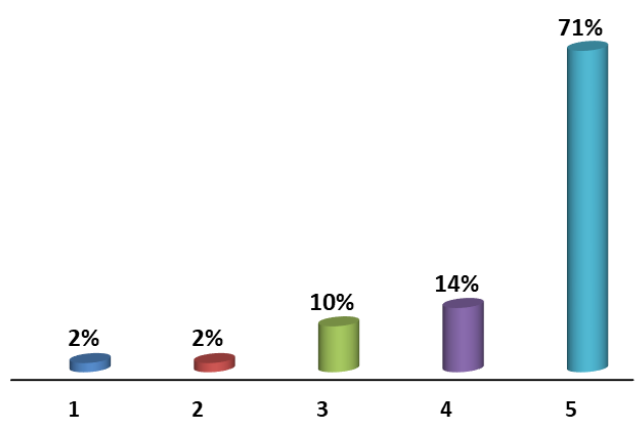
(50 Responses)



13. How many cars does your household have?

1. Less than $15,000
2. $15,000 to $24,999
3. $25,000 to $35,999
4. $36,000 to $49,999
5. $50,000 or more

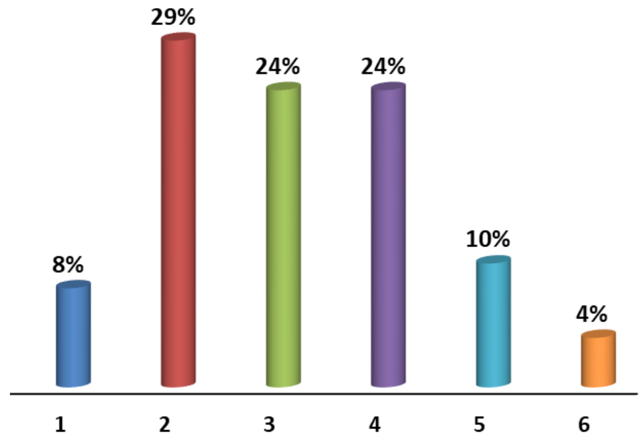
(49 Responses)



14. How many people are there in your household?

1. 1 person
2. 2 people
3. 3 people
4. 4 people
5. 5 people
6. 6 people

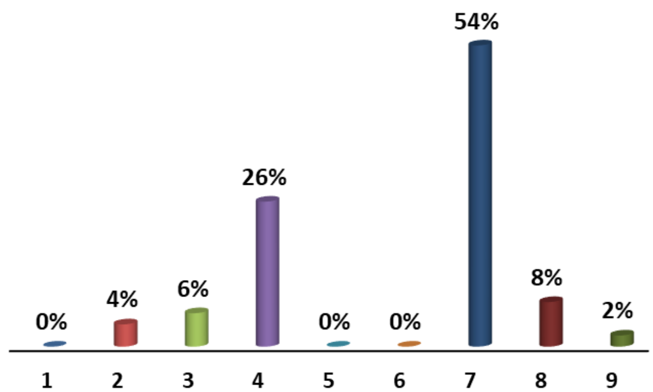
(49 Responses)



15. How would you describe yourself?

1. American Indian or Alaska Native
2. Asian
3. Black or African American
4. Hispanic, Latino, or Spanish origin
5. Middle Eastern or North African
6. Native Hawaiian or other Pacific Islander
7. White or Caucasian
8. Prefer not to say
9. Other (Please specify)

(50 Responses)



APPENDIX C

Stakeholder Interview Questionnaire

FRESNO COG FRESNO COUNTY REGIONAL TRANSPORTATION VULNERABILITY ASSESSMENT: STAKEHOLDER INTERVIEW QUESTIONS

EAST CITIES, WEST CITIES, AND METRO QUESTIONS

1. Describe your role and responsibilities
2. What climate and weather-related impacts currently affect the transportation network or have affected it in the past?
   a. Do you have data on impacts (such injuries, fatalities, outage lengths, costs, geolocations)?
3. What future climate and weather-related impacts are of most concern in your community?
4. What decisions/actions [in design, maintenance, operations] do you need to make that depend on weather and climate?
   a. Which of these are long term (and could therefore be affected by shifts in climate)?
5. What design or maintenance specs/guidance documents do you use for:
   a. For heavy precipitation/heavy streamflow (such as bridges, culverts, and other drainage infrastructure)
   b. For extreme heat standards (such as electrical equipment, outdoor working time windows, pavement, etc.)
   c. For wildfire protections (though this won't apply to most of the municipalities)
   d. Are these documents sufficient, or would it be helpful to have additional resources?
6. Which other agencies/departments do you coordinate with regularly on these matters (e.g., adjacent jurisdictions, county, dam owners, flood control district)? How does that coordination happen?
7. Does your municipality ever have weather-related evacuation events? If so can you briefly describe your agency's role in managing the evacuation and how you coordinate with other agencies?
   a. How could these practices be improved?
8. What are your most pressing climate concerns for the future?
9. Who are/will be the communities/areas most affected by these impacts and changes? How will they be affected?
10. How can FCOG help prepare the transportation network for future climate conditions?
11. What would you like to learn from the vulnerability assessment?
    a. Are there tools and information you currently need, but don't have?
    b. What future time periods that align with planning efforts and/or capital improvement projects?

EJ/CBO QUESTIONS

1. Describe your organization, role and responsibilities
2. Describe the communities your organization serves (socioeconomics, location, etc.)
3. What climate and weather-related impacts are of most concern in your community (or community your organization represents)? Are there any related to travel?
4. Have weather events led to evacuations in the communities you represent (for example, due to wildfire)? If so, can you describe an example?
5. What needs do your communities have in terms of addressing these threats, particularly regarding transportation?
6. What are your most pressing climate concerns for the future?
7. Who are/will be the communities/areas most affected by these impacts and changes? How will they be affected?
8. How can FCOG and other agencies help prepare the transportation system for future climate conditions and serve the populations you work with? What transportation solutions would benefit these populations?
9. What would you like to learn from the vulnerability assessment?
    a. Are there tools and information you currently need, but don't have?

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COUNTY OES QUESTIONS

1. Describe your organization, role and responsibilities
2. Can you briefly outline how emergency response is coordinated between your agency and others agencies/stakeholders?
3. How does the coordination work for transportation-related issues such as road closures, detours, evacuations etc.?
4. What climate and weather-related impacts currently affect the transportation network or have affected it in the past?
    a. Do you have data on impacts (such injuries, fatalities, outage lengths, costs, geolocations)?
5. What climate and weather-related impacts are of most concern to you in Fresno County? What keeps you up at night from an emergency services perspective?
    a. How could this be improved?
6. In your view, what are the major vulnerabilities to the transportation system from weather events? What are the specific locations?
7. What longer terms decisions/actions do you need to make that depend on weather and climate (and could therefore be affected by shifts in climate)?
8. What are your most pressing climate concerns for the future?
9. How can FCOG help prepare the transportation network for future climate conditions?
10. What would you like to learn from the vulnerability assessment?
    a. Are there tools and information you currently need, but don’t have?

APPENDIX D

Public Workshop Materials

Fresno COG Transportation Network Vulnerability Assessment

Public Workshop

June 19, 2019

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Introduction

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Who is Fresno COG?

Fresno Council of Governments

Diverse Partners Building a Progressive Future as One Voice

- An association of local governments – members include Fresno's 15 cities and the County of Fresno
- Fresno COG is one of 38 "Councils of Governments" in California and 500+ nationwide
- Develops and updates a variety of transportation plans and allocates certain federal and state transportation funds
- Formed in 1967


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Agenda

- Open House
- Introductory Presentation and Open Questions
- Breakout Session Mapping Exercise
- Interactive Polling
- Conclusion, Next Steps, and Raffle Prize

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Project Purpose

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Caltrans SB 1 Adaptation Planning

- FCOG has been awarded a Caltrans Adaptation Planning Grant through Senate Bill 1 to develop a Fresno County Regional Transportation Vulnerability Assessment

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Project Summary

- Convene regional partners, stakeholders, and the public - we want your input!
- Assess vulnerabilities of the Fresno County transportation system and how these vulnerabilities affect the systems users
- Develop a range of adaptation strategies
- Compile findings into a final report and recommendations for use by FCOG, stakeholders, and the public

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Climate Change Background and Projected Impacts

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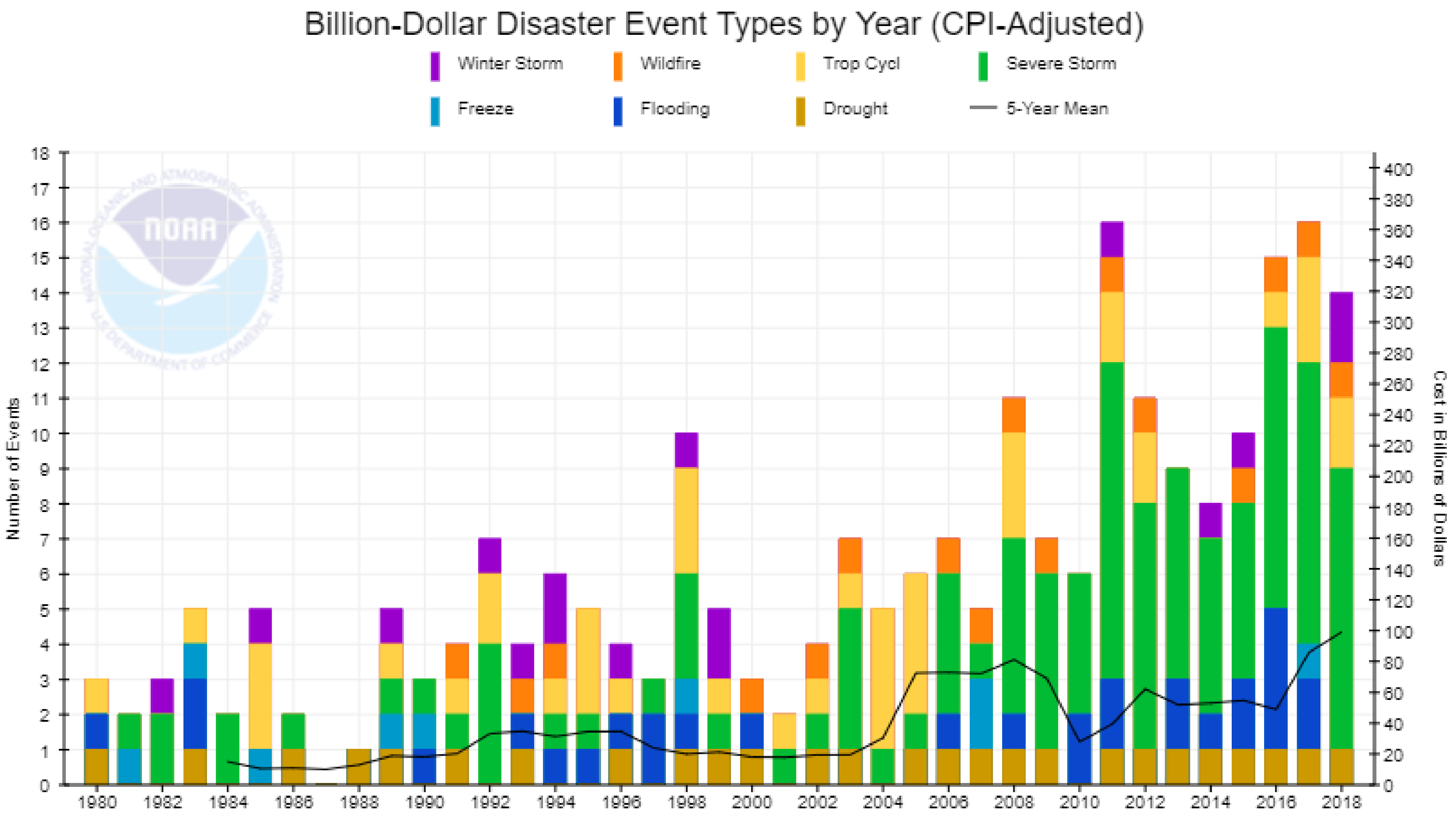
US Billion-Dollar Disasters



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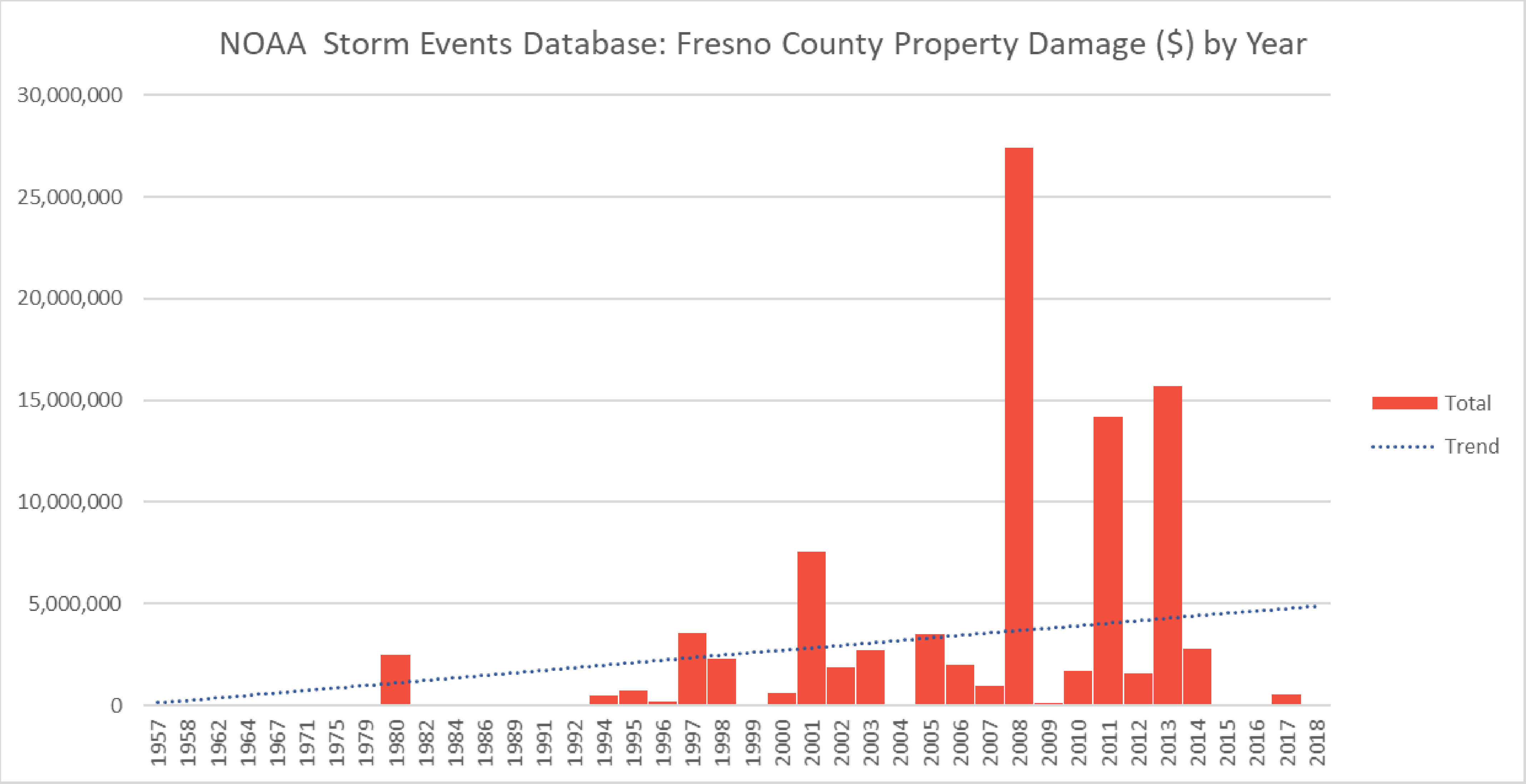
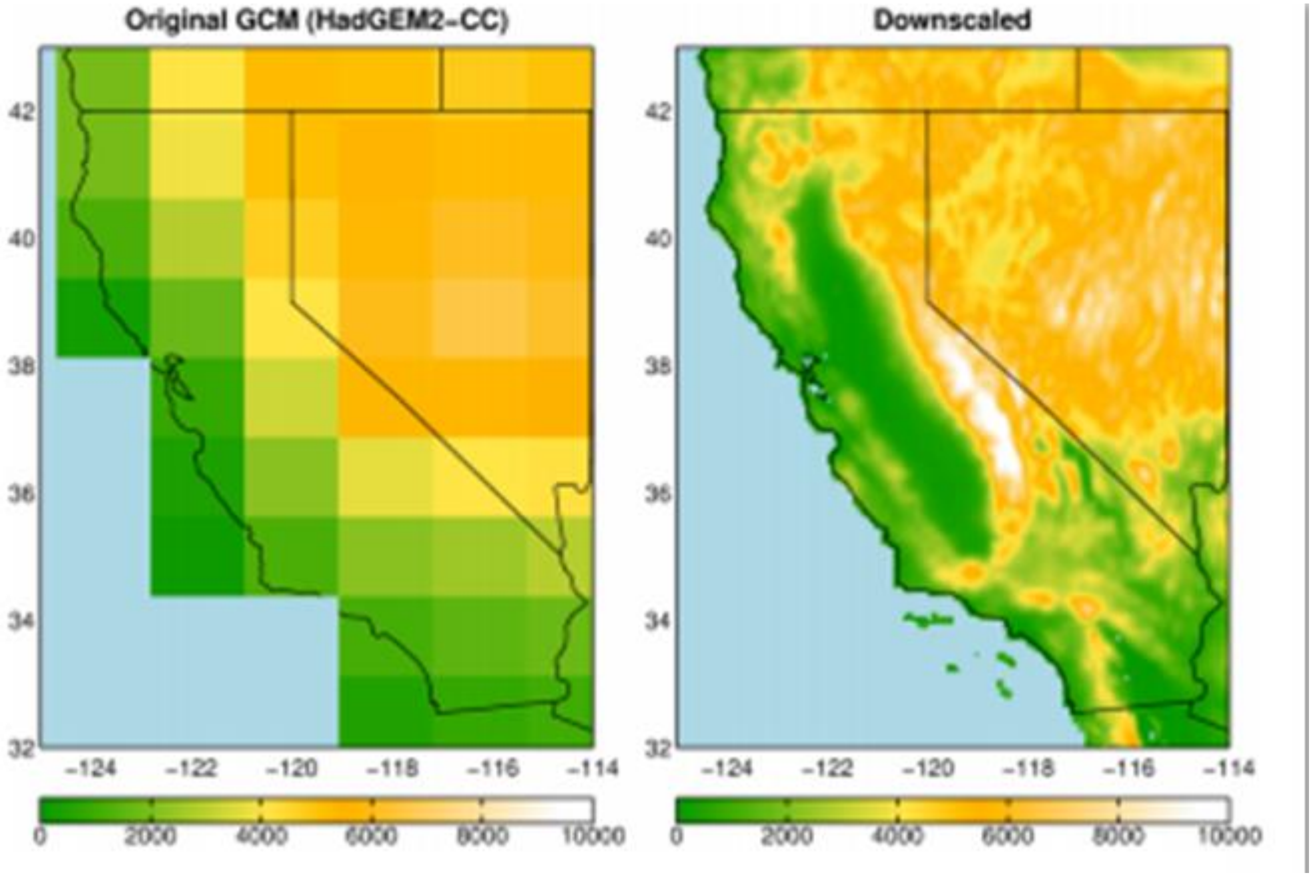
Fresno County Storm Event Property Damage



Climate Research and Models

- Intergovernmental Panel on Climate Change (IPCC) is major research institution
- Global Climate Models (GCM) simulate climate over time, drawing on physics, climatology, and historical climate observations
- Downscaling is process by which climate projections are improved to perform at regional level



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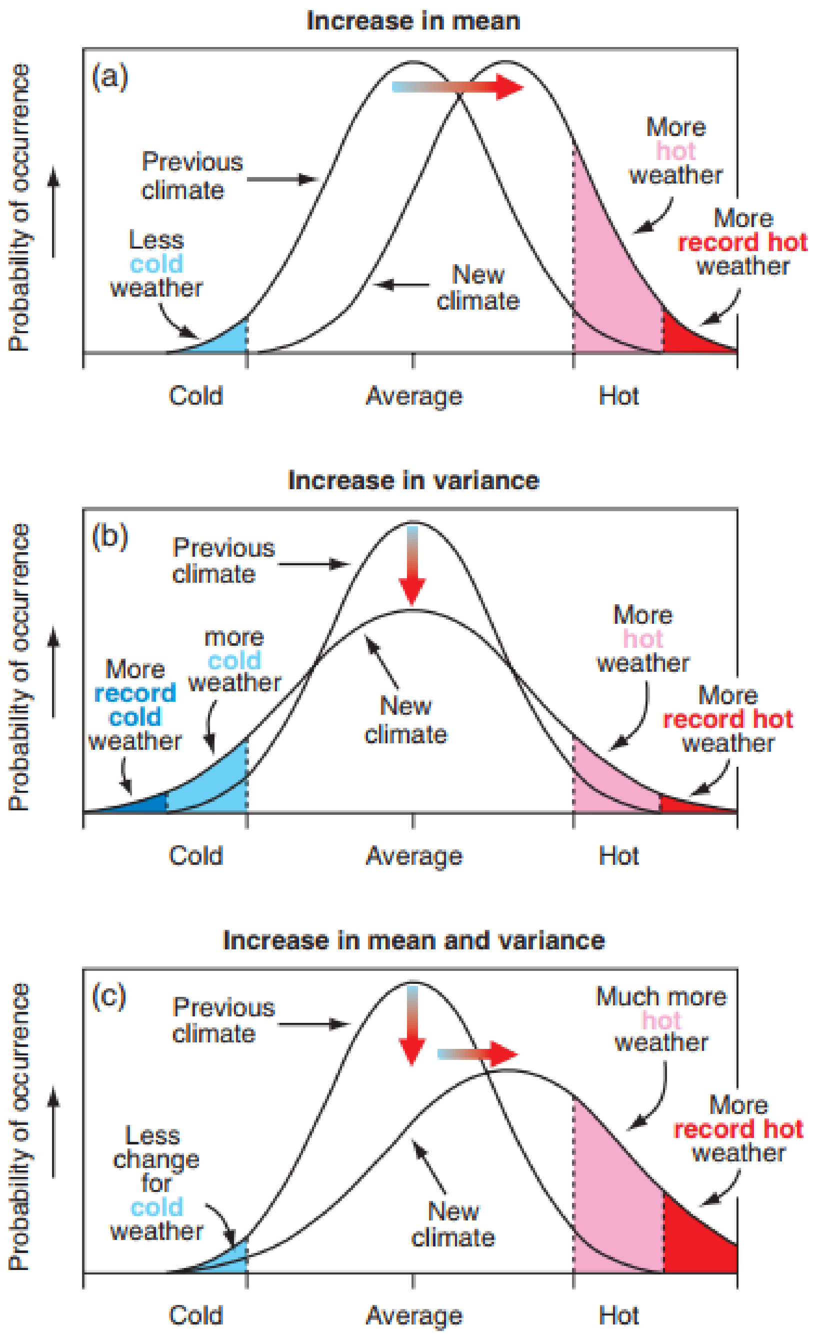
Change, Uncertainty and Implications for Infrastructure Management

- Directional changes
- Increased variance
- Three principal sources of uncertainty in climate projections:
  - Future emissions – different scenarios
  - Model response to GHG atmospheric concentrations
  - Natural variability
- In transportation, decisions about design, risk, etc. often based on historical data and aren't forward looking



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Terminology

- **Climate stressor or hazard**: one element of climate change, like temperature rise or wildfire risk
- **Weather vs. Climate**
  - Weather refers to conditions of atmosphere over short period of time
  - Climate refers to how atmosphere behaves over long period of time (includes averages, variability, and extremes)
  - Climate change refers to shifts in global or regional climate patterns
- **Vulnerability:** the degree to which a system is susceptible to, or unable to cope with, adverse effects
- **Risk:**
  - Potential of gaining or losing something of value
  - Probability x Consequence
  - Consequences can include impacts to communities, infrastructure, and natural systems.
- **Resilience:**
  - Ability to respond and recover from adversity
  - Amount of change a system can undergo without changing state
- **Adaptation:** action to reduce vulnerability or increase resilience

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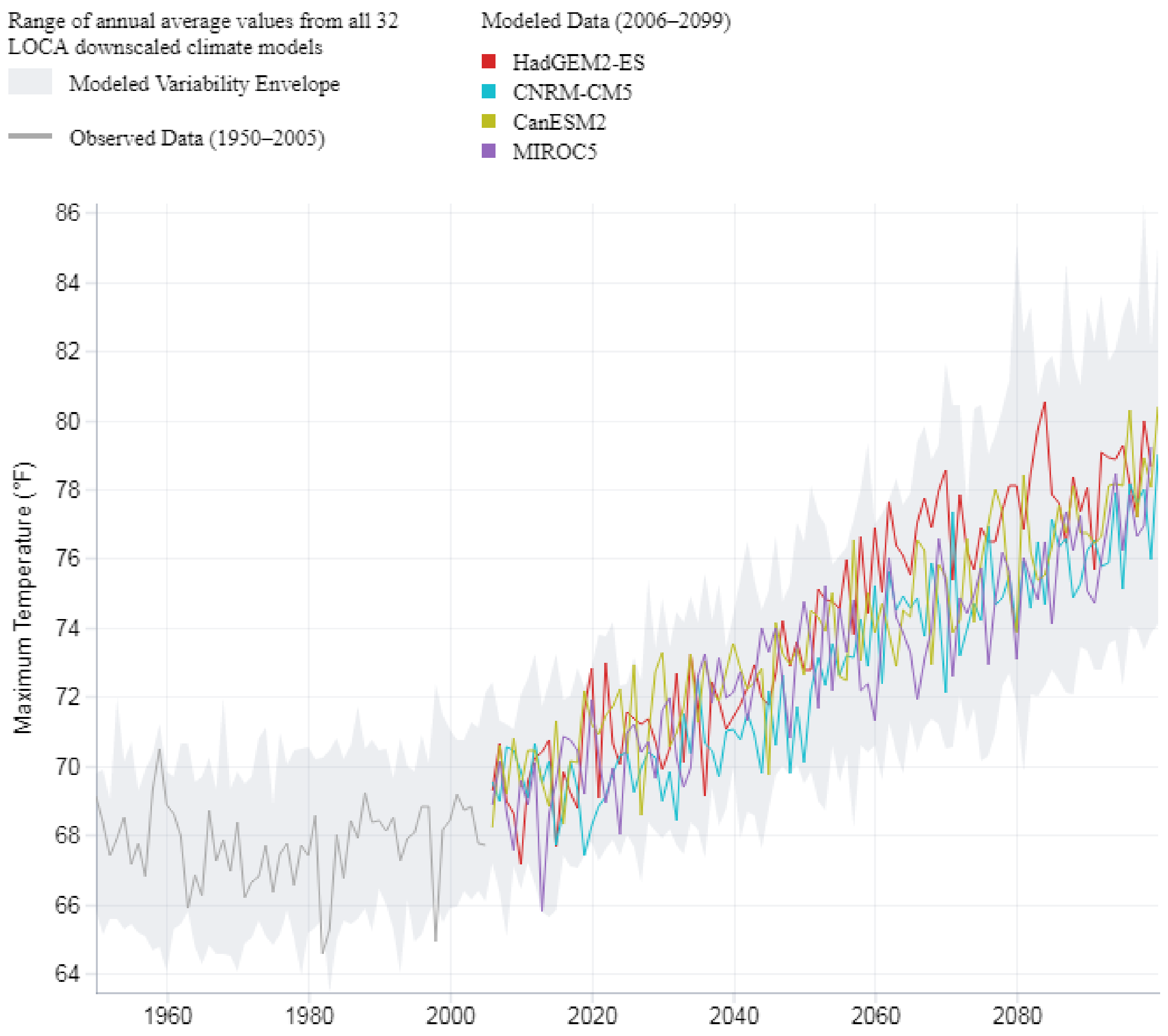
Temperature

- Max and min temperatures expected to increase across Fresno County
- Average max temperature for Fresno County is expected to increase from ~67 °F to ~77 °F by end of century (RCP 8.5, model average)
- Number of extreme heat (>105 °F) days per year in City of Fresno are expected to increase from 7 to ~66 by end of century (RCP 8.5, model average)

Maximum Temperature

Fresno County, California

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



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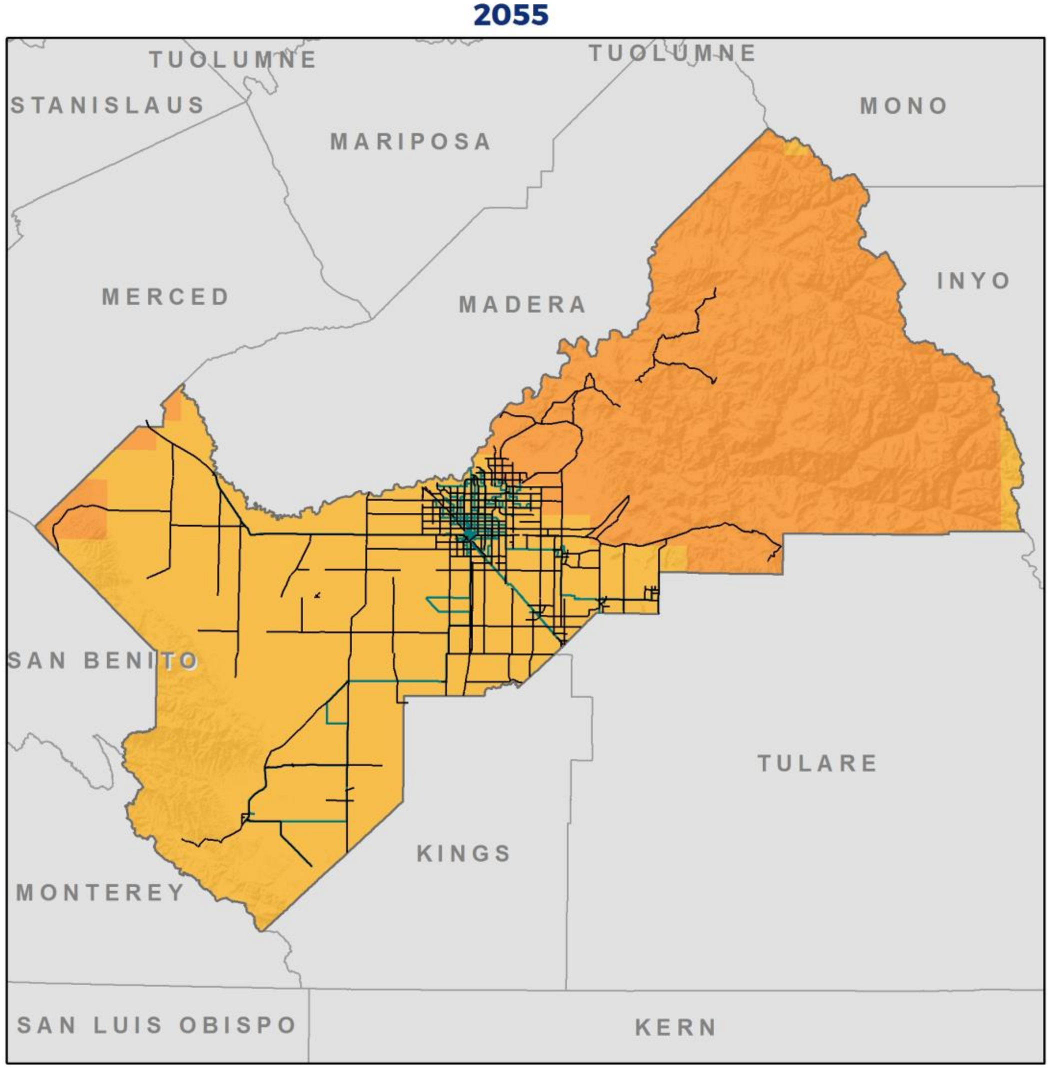
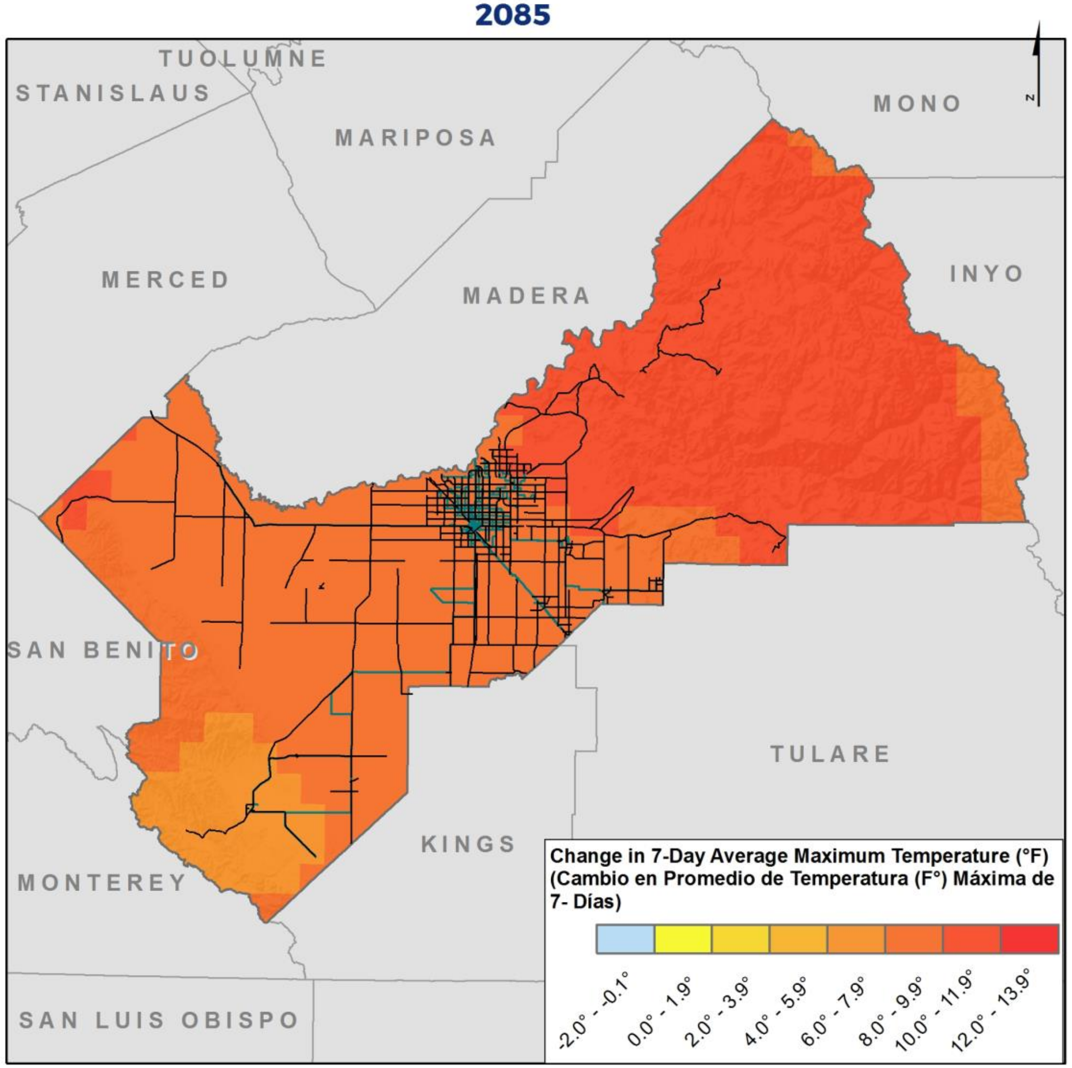
Increase in Average Maximum Temperature over Seven Consecutive Days





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— 2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

— Transit Lines (Líneas de Transito)

Source: CMCC-CMS Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario.

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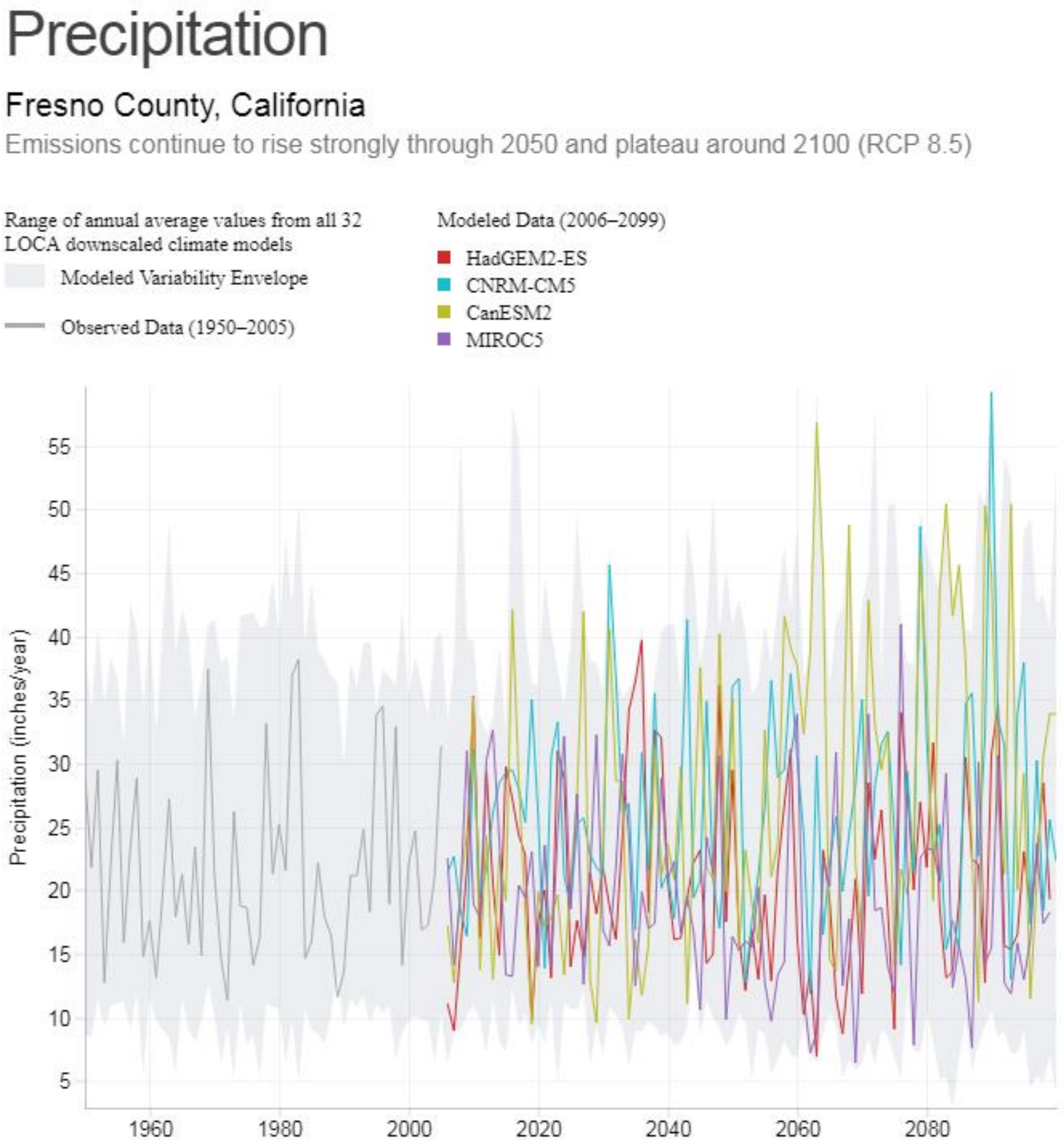
Precipitation

- Precipitation expected to change and become more volatile over the coming century, but projections are uncertain
- Generally, it's expected that both droughts and extreme storm events will become more frequent and severe
- Average precipitation change in Fresno County is expected to increase from ~21 to ~25 inches by end of century



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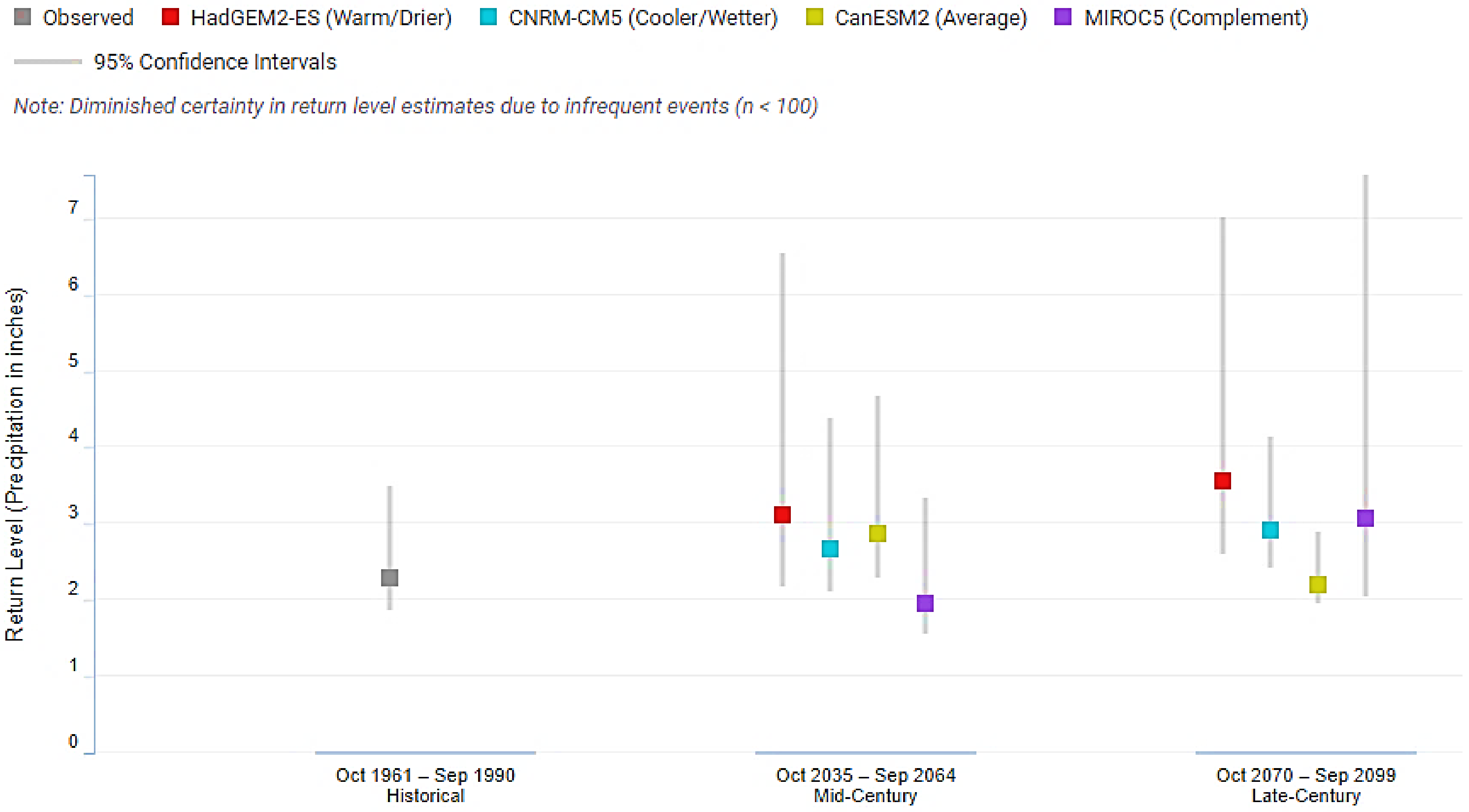
100-Year Precipitation Depth, City of Fresno (RCP 8.5)



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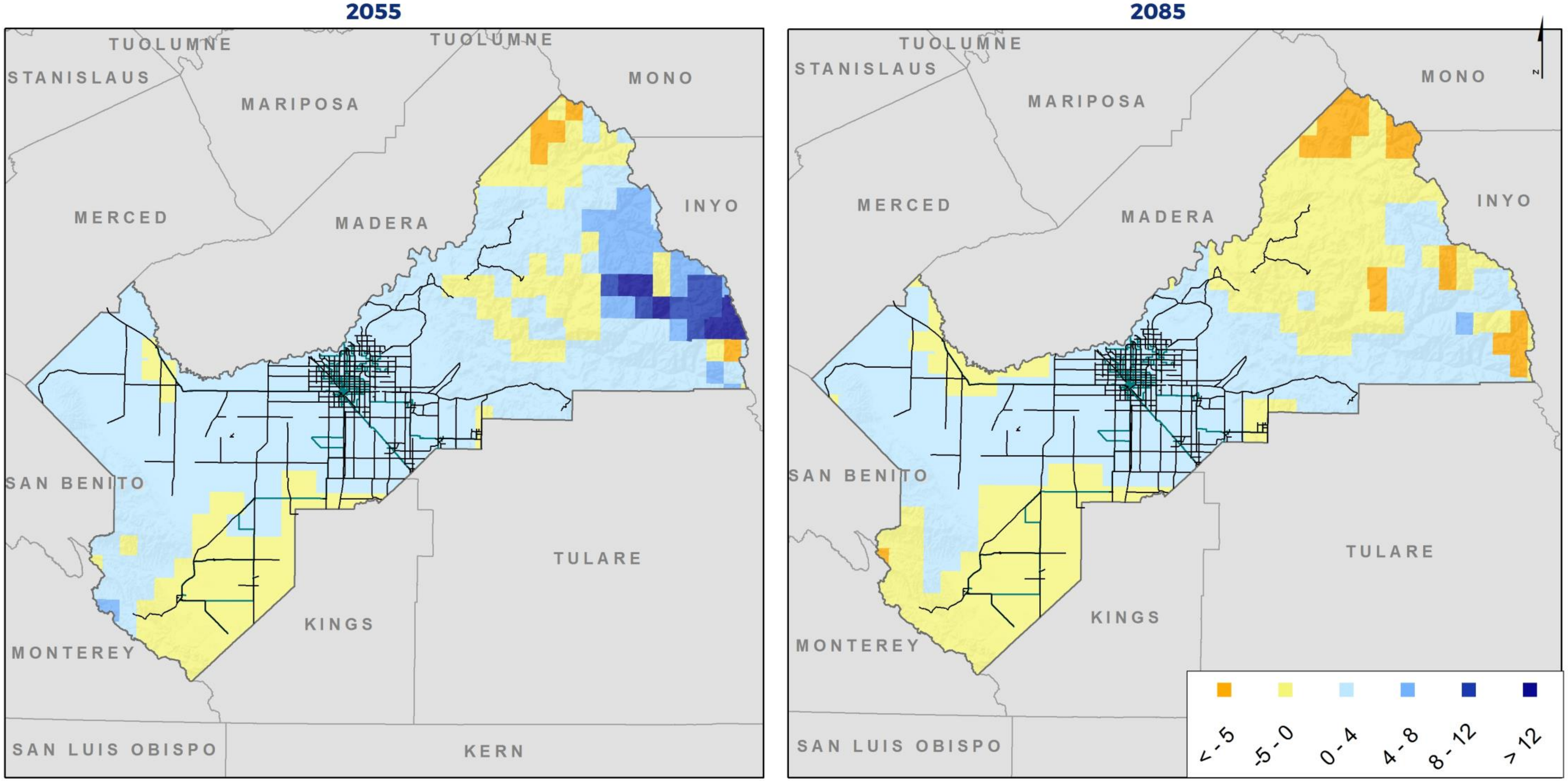
Inches Change in 100-Year Storm Depth



— 2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

— Transit Lines (Líneas de Transito)

Source: CanESM2 Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario. Results should be used with caution.

0 5 10 20 30 40 Miles

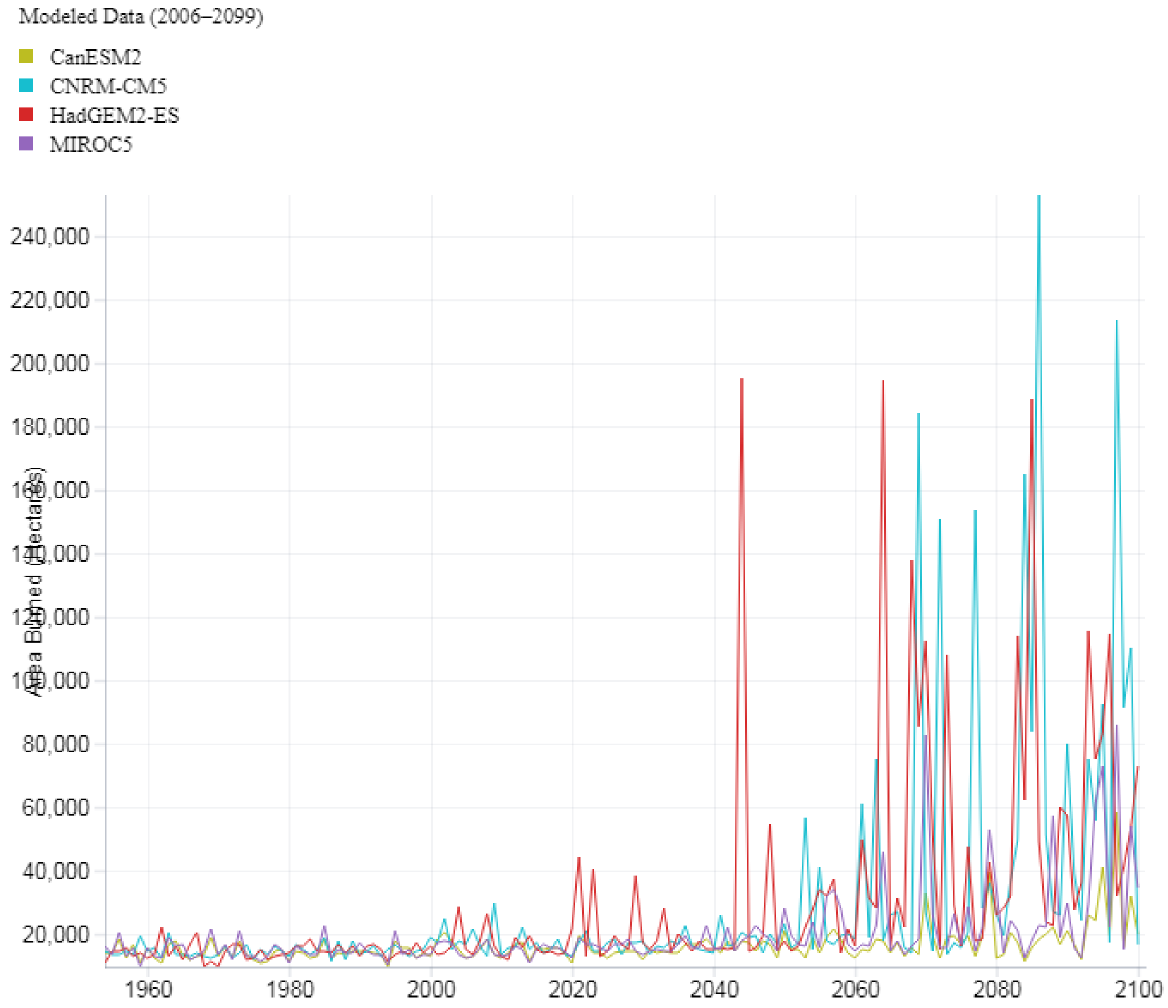
Wildfire

- Wildfire risk is increasing across CA as rising temperatures dry out soils and vegetation
- 172 miles of the State Highway System in Fresno County are projected to be exposed to moderate to very high wildfire risk over the coming century
- Average annual area burned in Fresno County is expected to increase from ~15,000 to ~44,000 hectares by end of century

Annual Average of Area Burned

Fresno County, California

Emissions continue to rise strongly through 2050 and plateau around 2100 (RCP 8.5). Central Population Growth Projections.



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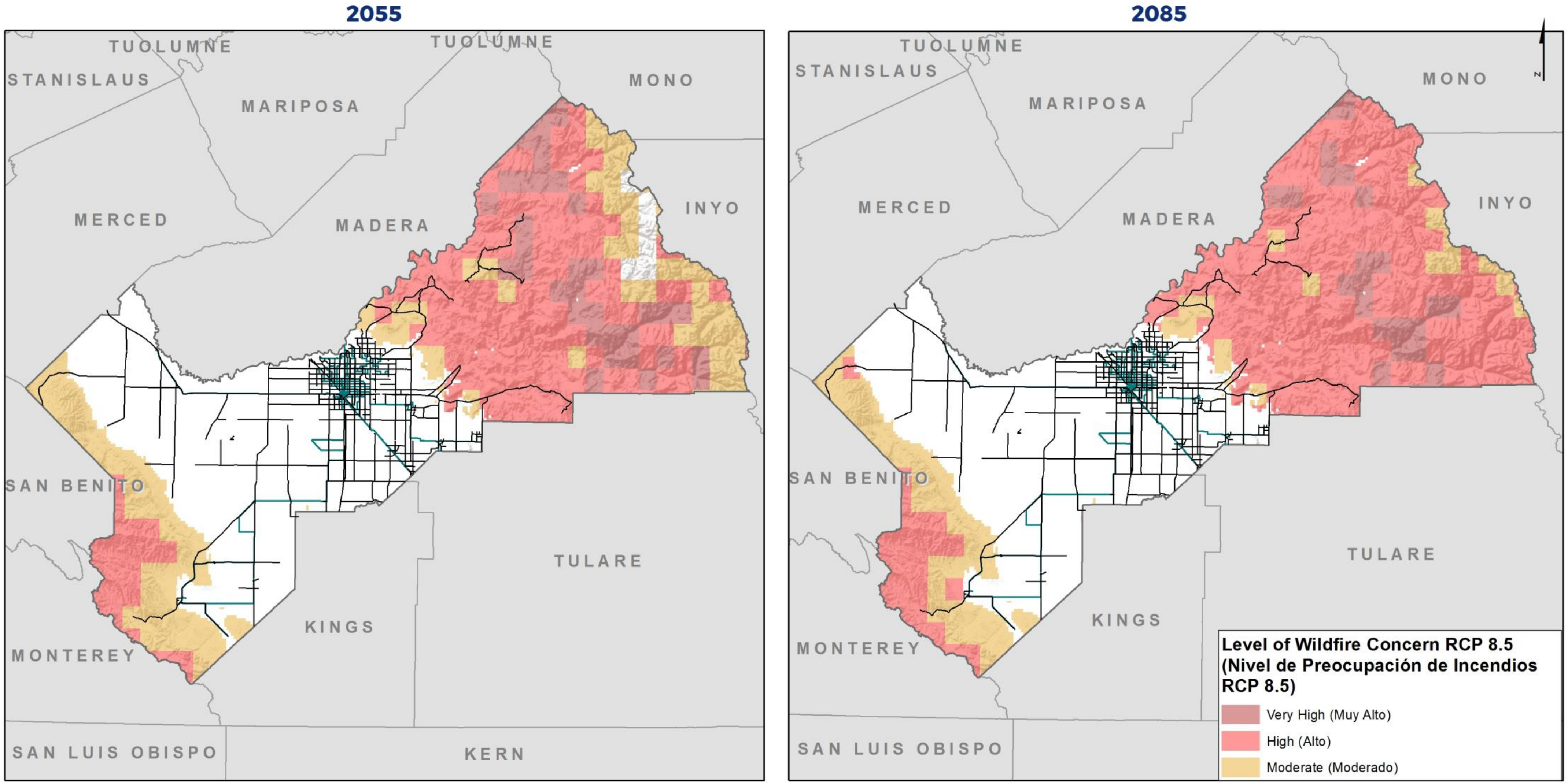
Increase in Wildfire Risk



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— 2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

— Transit Lines (Líneas de Transito)

Source: Amalgamation of three fire models: 1) MC2-EPA Climate Impacts Risk Assessment, USFS, 2) MC2-Applied Climate Science Lab at the University of Idaho, 3) University of California Merced model.

0 5 10 20 30 40 Miles

Example Impacts to the Transportation System and Users

- Pavement cracking and rutting from temperature rise
- Heat related health impacts to users
- Flooding, washouts, and erosion from heavy rain events and runoff
- Damage to roadway infrastructure from wildfire (guardrails, culverts, signage)
- Evacuations and safety threats for users
- Air quality impacts

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Transportation System Resiliency

- Can include design, operations and maintenance, emergency response, transit planning, etc.
- Example adaptation strategies for Fresno County transportation system:
  - Change pavement design standards to reflect future climate
  - Increase drainage infrastructure sizing to accommodate larger, more frequent storm events
  - Cooling measures at transit stops
  - Increase bridge heights to accommodate heavier river flows
  - Evacuation planning
  - Use defensible space to reduce wildfire risk to assets

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Public Outreach Overview

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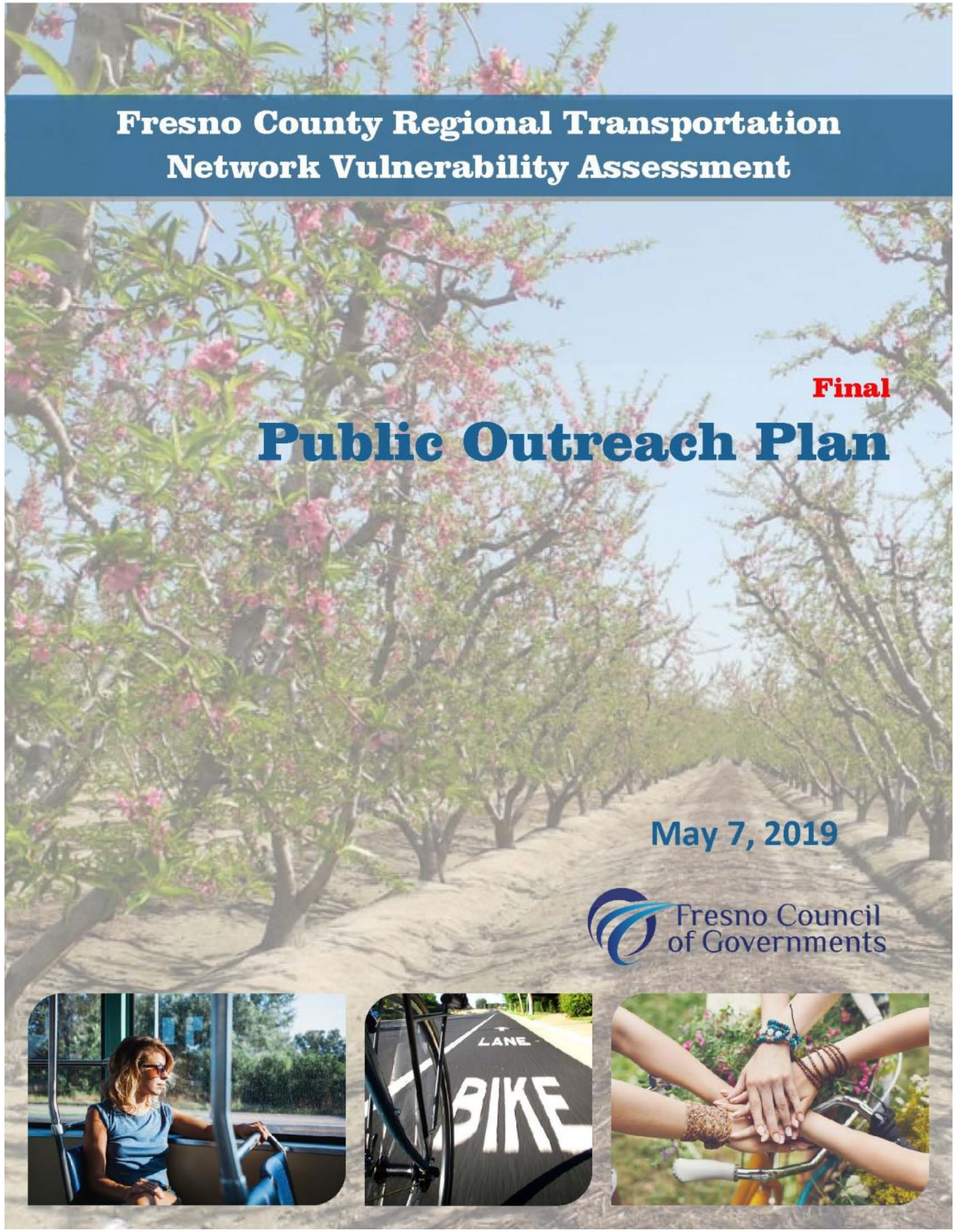
Public Outreach Plan

- Describes how project partners, stakeholders, community members, and the general public will be engaged during the Transportation Network Vulnerability Assessment planning process
- A guide of community involvement activities to be completed
- A living document, easily adjusted if recommended activities are not providing the input needed



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Outreach Activities Completed to Date

- Pop-up Events
- Stakeholder Interviews
- Online Survey

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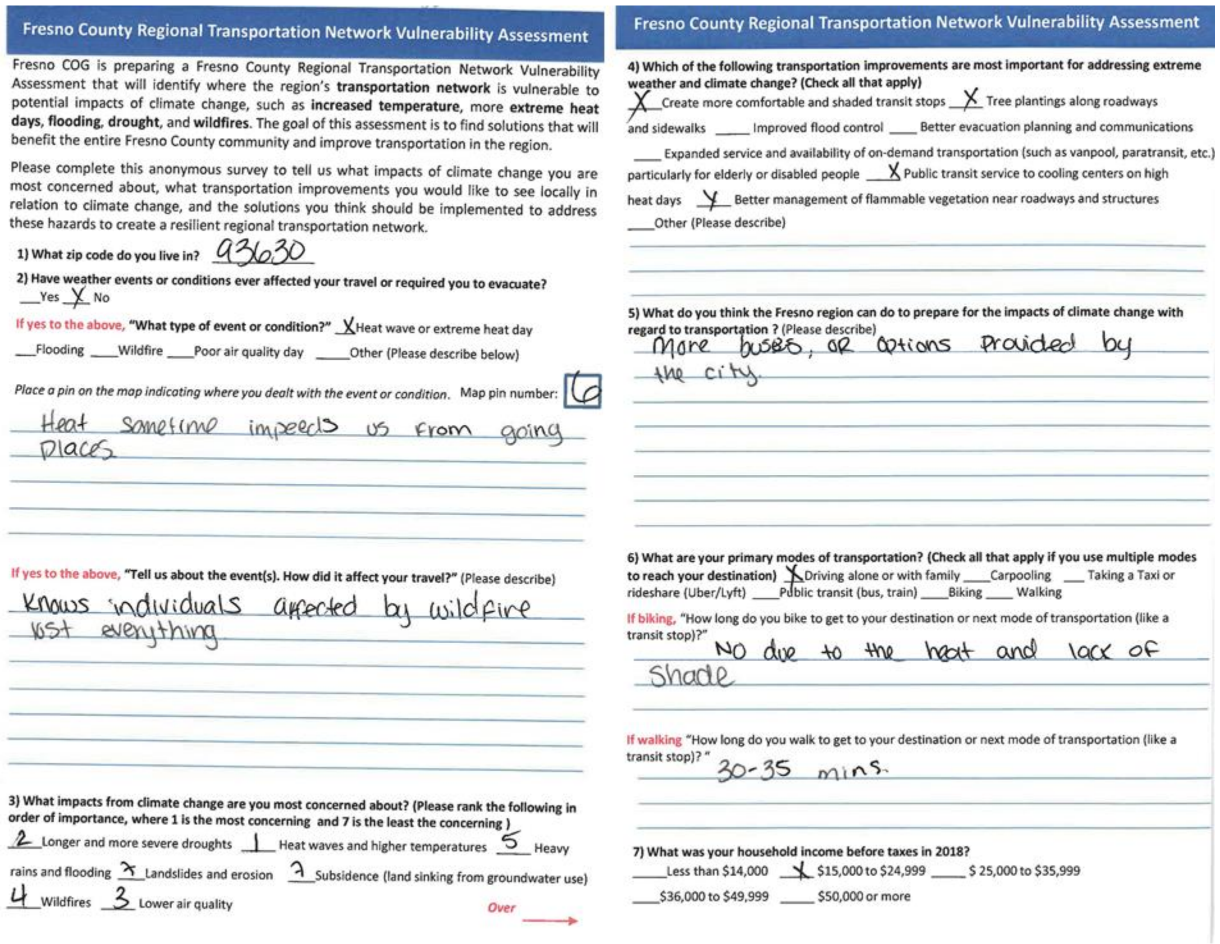
Completed Pop-up Events and Stakeholder Interviews

- Pop-up Events
  - Kerman Almond Festival
  - Reedley Street Faire
  - San Joaquin Carnival
- Stakeholder Interviews
  - City and County planning, engineering and transit staff
  - Fresno County's Office of Emergency Services
  - Community Based Organization representatives



Fresno County Regional Transportation Network Vulnerability Assessment

Fresno COG is preparing a Fresno County Regional Transportation Network Vulnerability Assessment that will identify where the region's **transportation network** is vulnerable to potential impacts of climate change, such as **increased temperature**, more **extreme heat days, flooding, drought**, and **wildfires**. The goal of this assessment is to find solutions that will benefit the entire Fresno County community and improve transportation in the region.

Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, what transportation improvements you would like to see locally in relation to climate change, and the solutions you think should be implemented to address these hazards to create a resilient regional transportation network.

1) What zip code do you live in? 93630

2) Have weather events or conditions ever affected your travel or required you to evacuate?
__Yes X No

If yes to the above, **"What type of event or condition?"** X Heat wave or extreme heat day __Flooding __Wildfire __Poor air quality day __Other (Please describe below)

Place a pin on the map indicating where you dealt with the event or condition. Map pin number: 6

Heat sometime impeeds us from going places

If yes to the above, **"Tell us about the event(s). How did it affect your travel?"** (Please describe)

Knows individuals affected by wildfire lost everything

3) What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least the concerning)
2 Longer and more severe droughts 1 Heat waves and higher temperatures 5 Heavy rains and flooding 7 Landslides and erosion 7 Subsidence (land sinking from groundwater use) 4 Wildfires 3 Lower air quality

Over

Fresno County Regional Transportation Network Vulnerability Assessment

4) Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)
X Create more comfortable and shaded transit stops X Tree plantings along roadways and sidewalks __Improved flood control __Better evacuation planning and communications __Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) particularly for elderly or disabled people X Public transit service to cooling centers on high heat days X Better management of flammable vegetation near roadways and structures __Other (Please describe)

5) What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation ? (Please describe)

More buses, or options provided by the city.

6) What are your primary modes of transportation? (Check all that apply if you use multiple modes to reach your destination) X Driving alone or with family __Carpooling __Taking a Taxi or rideshare (Uber/Lyft) __Public transit (bus, train) __Biking __Walking

If biking, "How long do you bike to get to your destination or next mode of transportation (like a transit stop)?"

No due to the heat and lack of shade

If walking "How long do you walk to get to your destination or next mode of transportation (like a transit stop)?"

30-35 mins.

7) What was your household income before taxes in 2018?
__Less than \$14,000 X \$15,000 to \$24,999 __\$ 25,000 to \$35,999 __\$36,000 to \$49,999 __\$50,000 or more

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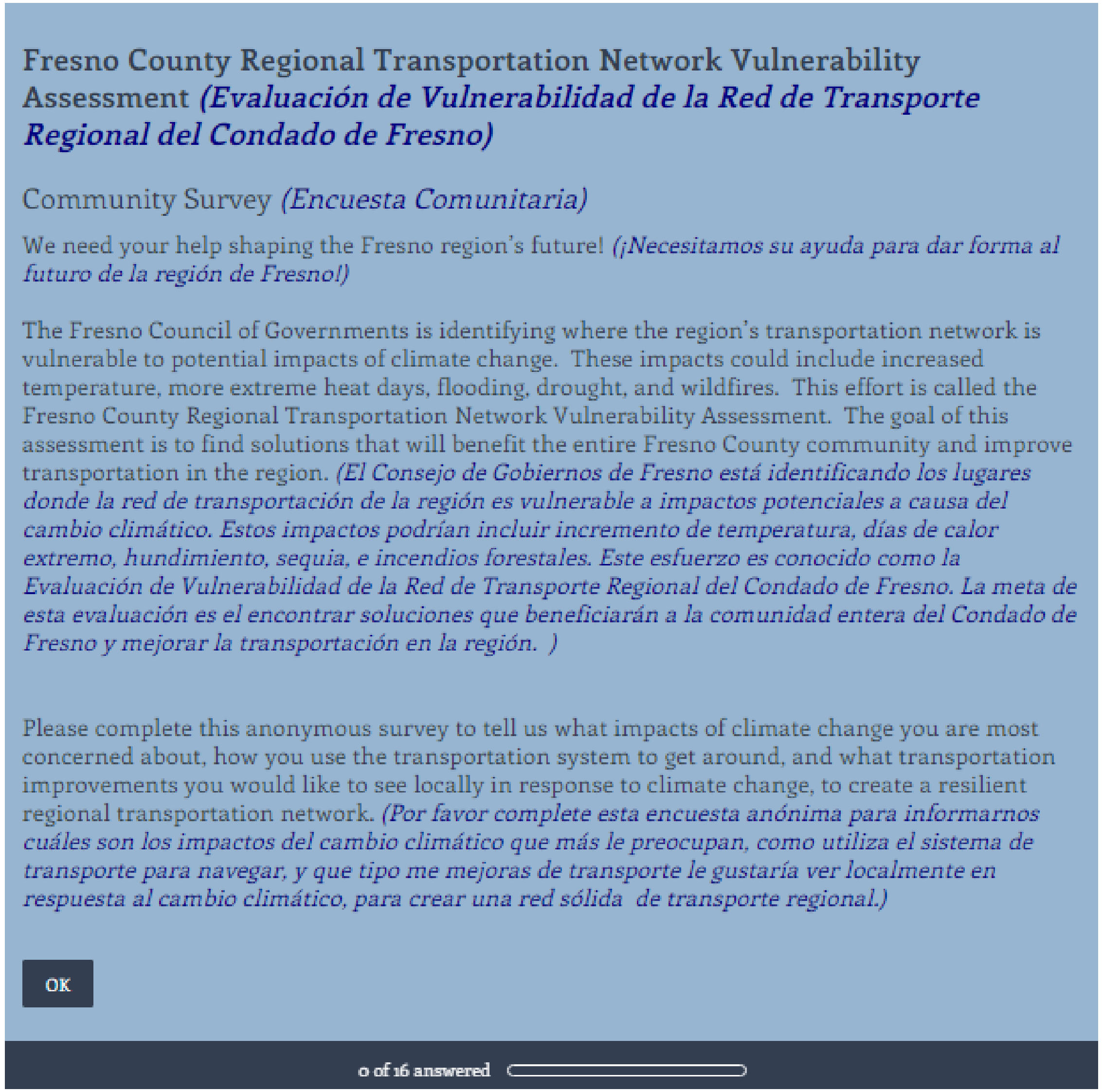
Online Survey

- Online survey instrument allows for participants to respond in English and Spanish
- Available on Fresno COG's website or by visiting https://www.surveymonkey.com/r/FresnoTNVA
- Addresses what impacts of climate change participants are most concerned about, how they use the transportation system to get around, and what transportation improvements they would like to see locally in response to climate change, to create a resilient regional transportation network.



Fresno County Regional Transportation Network Vulnerability Assessment *(Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno)*

Community Survey *(Encuesta Comunitaria)*

We need your help shaping the Fresno region's future! *(¡Necesitamos su ayuda para dar forma al futuro de la región de Fresno!)*

The Fresno Council of Governments is identifying where the region's transportation network is vulnerable to potential impacts of climate change. These impacts could include increased temperature, more extreme heat days, flooding, drought, and wildfires. This effort is called the Fresno County Regional Transportation Network Vulnerability Assessment. The goal of this assessment is to find solutions that will benefit the entire Fresno County community and improve transportation in the region. *(El Consejo de Gobiernos de Fresno está identificando los lugares donde la red de transportación de la región es vulnerable a impactos potenciales a causa del cambio climático. Estos impactos podrían incluir incremento de temperatura, días de calor extremo, hundimiento, sequia, e incendios forestales. Este esfuerzo es conocido como la Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno. La meta de esta evaluación es el encontrar soluciones que beneficiarán a la comunidad entera del Condado de Fresno y mejorar la transportación en la región.)*

Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, how you use the transportation system to get around, and what transportation improvements you would like to see locally in response to climate change, to create a resilient regional transportation network. *(Por favor complete esta encuesta anónima para informarnos cuáles son los impactos del cambio climático que más le preocupan, como utiliza el sistema de transporte para navegar, y que tipo me mejoras de transporte le gustaría ver localmente en respuesta al cambio climático, para crear una red sólida de transporte regional.)*

OK

0 of 16 answered

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Questions

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Breakout Session

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Thank you for your time!

Please feel free to reach out with any questions and comments.

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Team Contacts

- **Meg Prince**, FCOG Project Manager, MPrince@fresnocog.org
- **Tim Grose**, Consultant Project Manager, Timothy.Grose@wsp.com
- **Georgiena Vivian**, Collaboration and Community Engagement Lead, gvivian@vrpatechnologies.com

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Fresno COG Evaluación de Vulnerabilidad de la Red de Transporte Taller Público

June 19, 2019

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Introducción

¿Quién es Fresno COG ?

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Diversos Socios Construyendo un Futuro Progresivo como Una sola Voz

- Una asociación de gobiernos locales - sus miembros incluyes 15 ciudades de Fresno y el Condado de Fresno
- Fresno COG es uno de los 38 “Concilios de Gobierno” en California y 500+ en toda la nación
- Desarrolla y actualiza una variedad de programas de transporte y distribuye ciertos fondos de transporte federal y estatal
- Formado en 1967

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Agenda

- Casa Abierta
- Presentación de Introducción y Preguntas de Respuesta Abierta
- Sesión en Grupos y Ejercicio de Mapeo
- Votación interactiva
- Conclusión, Pasos a Seguir, y el Premio de la Rifa

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Propósito del Proyecto

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Planificación de Adaptación del SB 1 de Caltrans

- FCOG se le ha otorgado un Subsidio de Planificación de Adaptación Caltrans por medio del Proyecto de Ley 1 del Senado para desarrollar una Evaluación de Vulnerabilidad del Transporte Regional en el Condado de Fresno

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Resumen del Proyecto

- Reunir partidos regionales, partidos interesados, y el público - ¡Queremos su participación!
- Evaluar las vulnerabilidades del Sistema de Transporte del Condado de Fresno y cómo es que estas vulnerabilidades afectan a los usuarios del sistema
- Desarrollar un rango de estrategias de adaptación
- Reunir resultados en un reporte final tanto como recomendaciones para el uso de FCPG, interesados, y el público

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Contexto de los Cambios Climáticos e Impactos Proyectados

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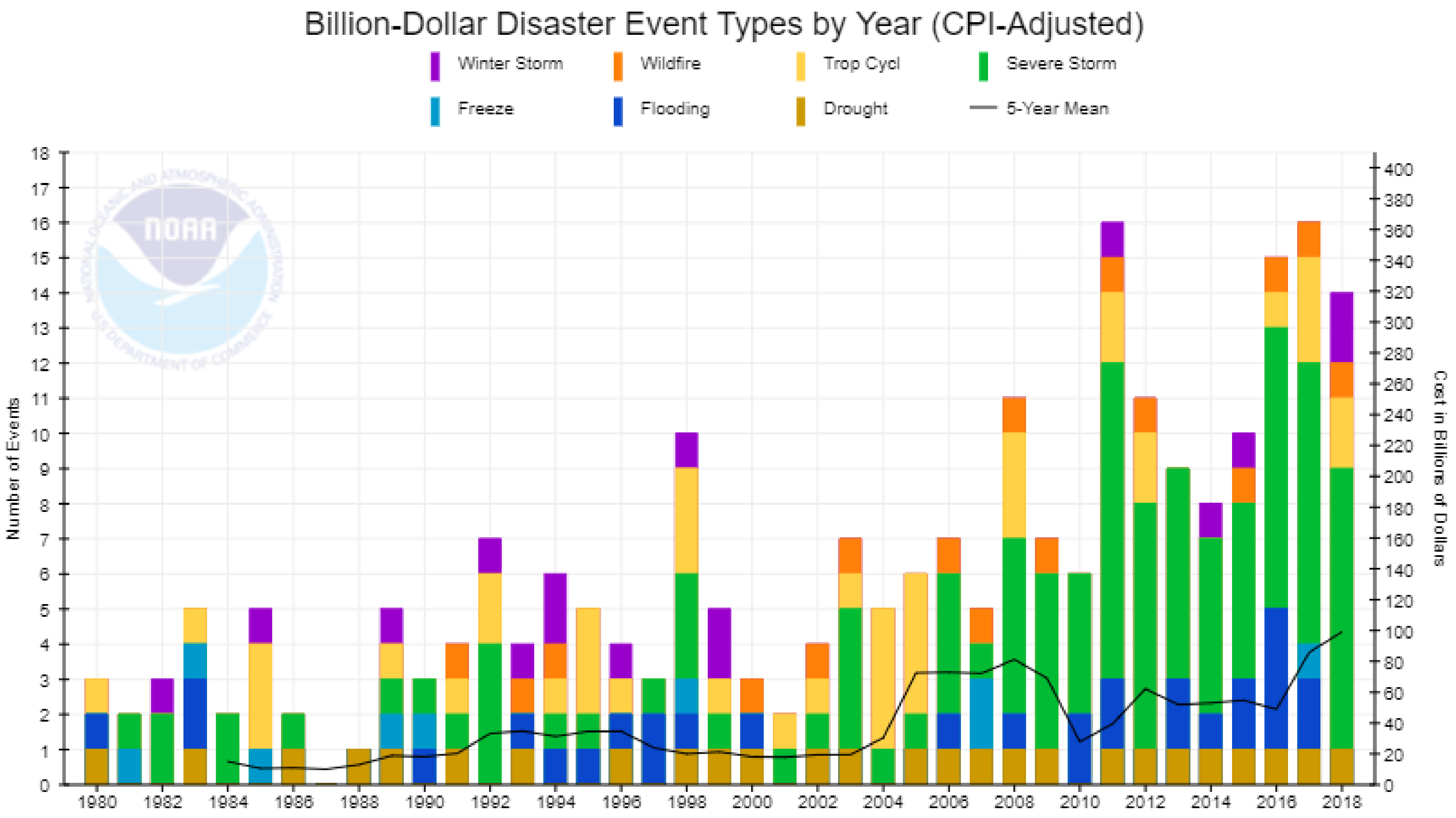
Desastres en Billones de Dólares – en EUA



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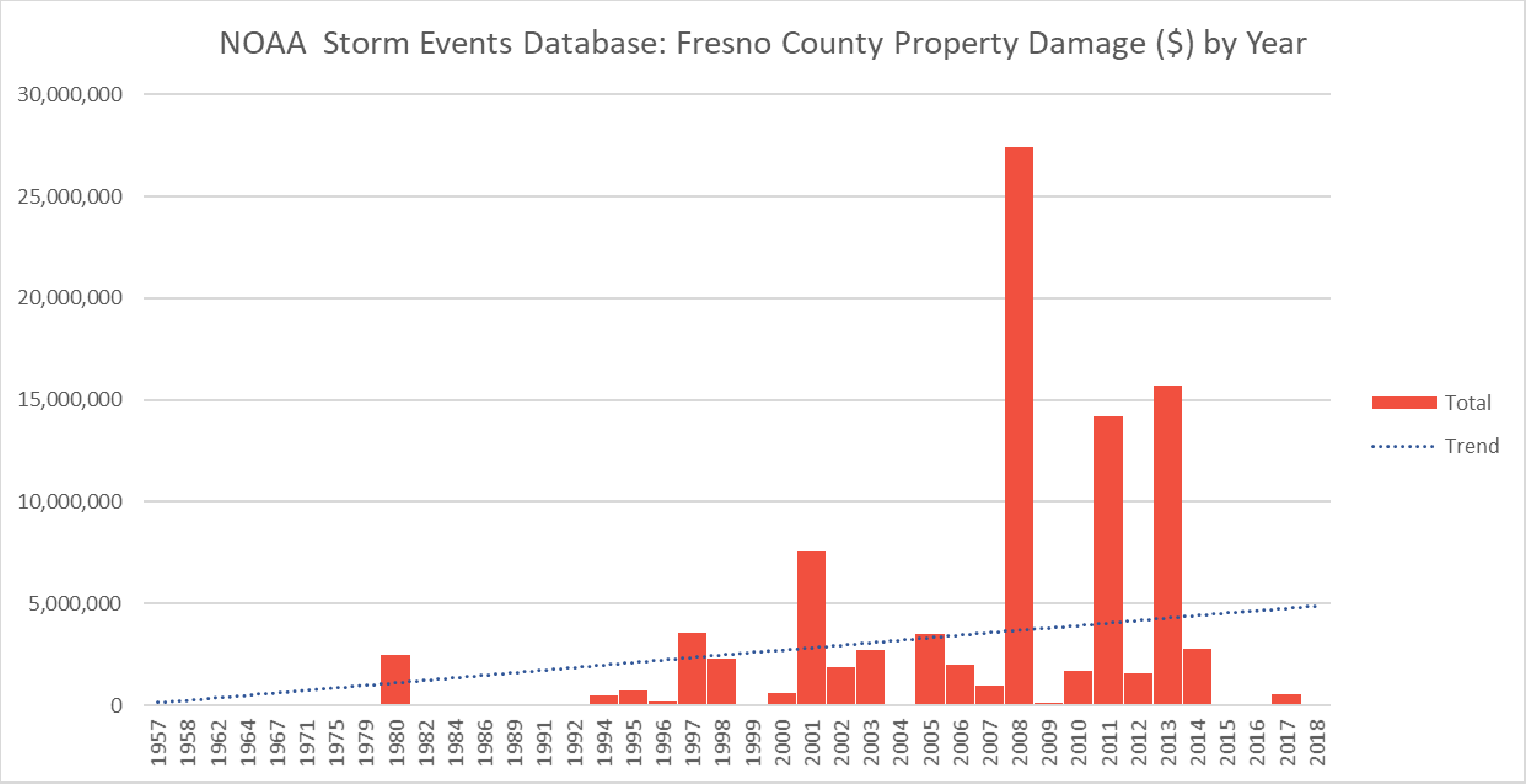
Daños de Propiedad por Eventos de Aguas Pluviales en el Condado de Fresno



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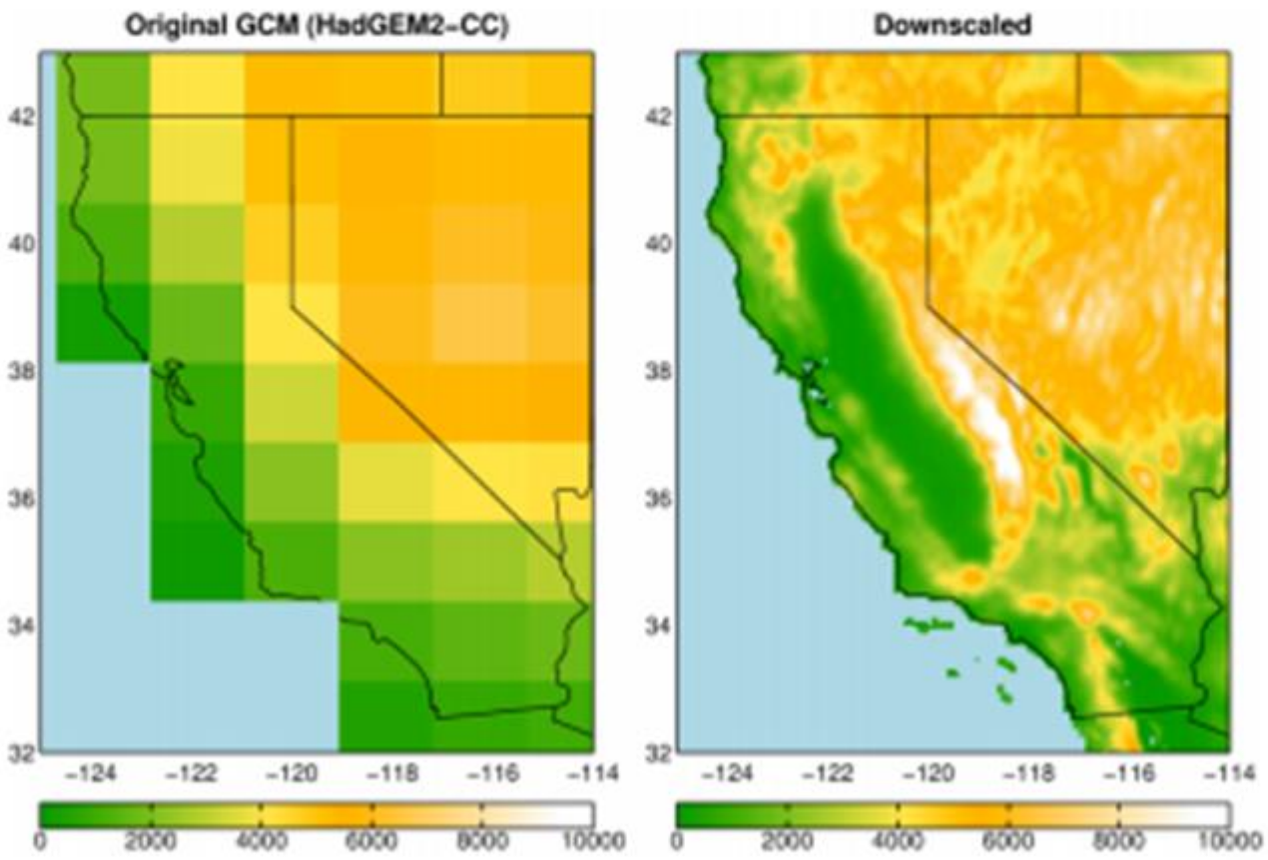
Investigación del Clima y Modelos

- Panel Intergubernamental en el Cambio Climático (IPCC) es una institución de investigación principal
- Modelos Climáticos Globales (GCM) Imitan el clima a lo largo del tiempo, basándose en la física, climatología, y observaciones climáticas históricas
- Reducción de escala es un proceso por el cual las proyecciones climáticas son mejoradas para funcionar a nivel regional



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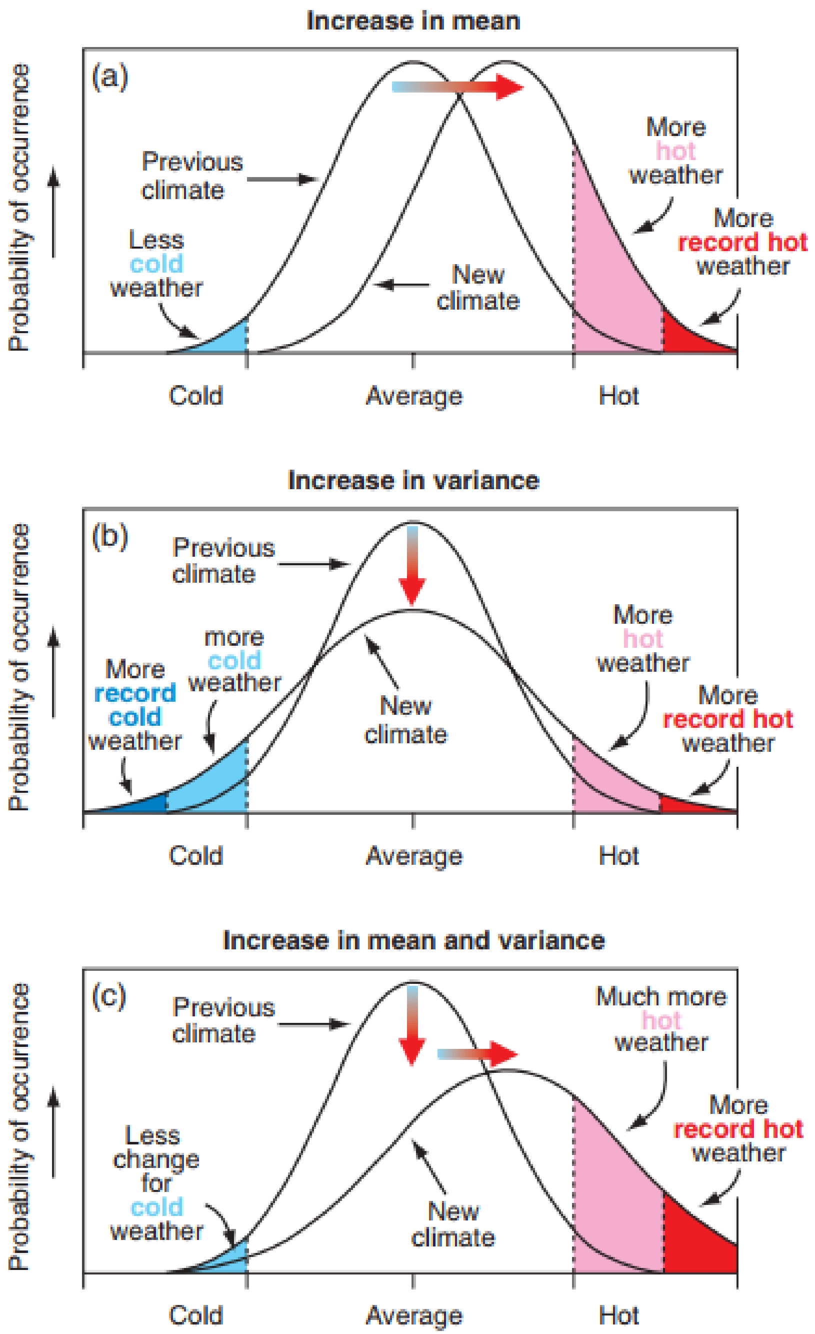
Cambio, Incertidumbre e Implicaciones para el Manejo de Infraestructura

- Cambios direccionales
- Aumentar variación
- Tres fuentes principales de incertidumbre en proyecciones climáticas:
  - Emisiones futuras – diferentes escenarios
  - Respuesta modelo a concentraciones atmosféricas GHG
  - Variabilidad natural
- En transporte, decisiones sobre el diseño, riesgo, etc., muchas veces basadas en datos históricos y no son progresistas



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Terminología

- Factor estresante climático o riesgo: Un elemento del cambio climático, como los aumentos de temperatura o los riesgos de incendios forestales
- Condiciones Meteorológicas vs. Clima
  - Condiciones meteorológicas se refiere a las condiciones de la atmósfera en un periodo corto del tiempo
  - Clima se refiere a como se comporta la atmósfera en un periodo largo del tiempo (incluye promedios, variabilidad, y extremos)
  - Cambio climático se refiere a cambios globales o patrones climáticos regionales
- Vulnerabilidad: El grado al cual un sistema es susceptible a, o no puede aguantar a, efectos adversos
- Riesgo:
  - Potencial de ganar o perder algo de valor
  - Probabilidad (x) Consecuencias
  - Consecuencia pueden incluir impactos a las comunidades, infraestructura, y sistemas naturales.
- Resistencia:
  - Habilidad de responder y recuperarse de adversidad
  - Cantidad de cambio un sistema puede soportar sin cambiar su estado
- Adaptación: acción para reducir vulnerabilidad o aumentar resistencia

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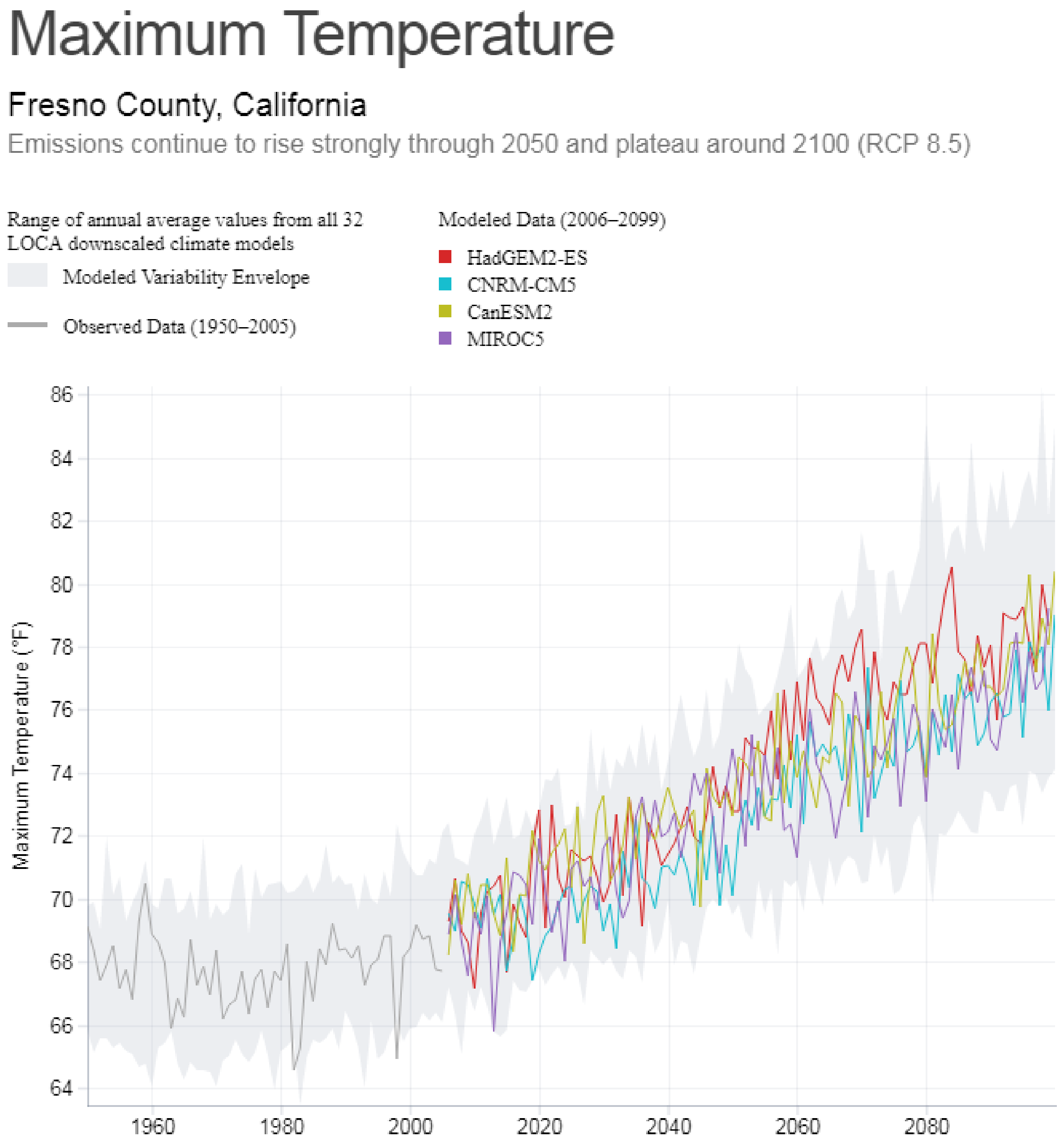
Temperatura

- Temperaturas máximas y mínimas que se espera que aumenten en todo el Condado de Fresno
- Promedio máximo de temperatura para el Condado de Fresno se espera que aumente de ~67 °F a ~77 °F a finales del siglo (RCP 8.5, Promedio modelo)
- Numero de días de calor extremoso (>105 °F)por año en la Ciudad de Fresno se espera que aumenten de 7 a ~66 a finales del siglo (RCP 8.5, Promedio modelo)



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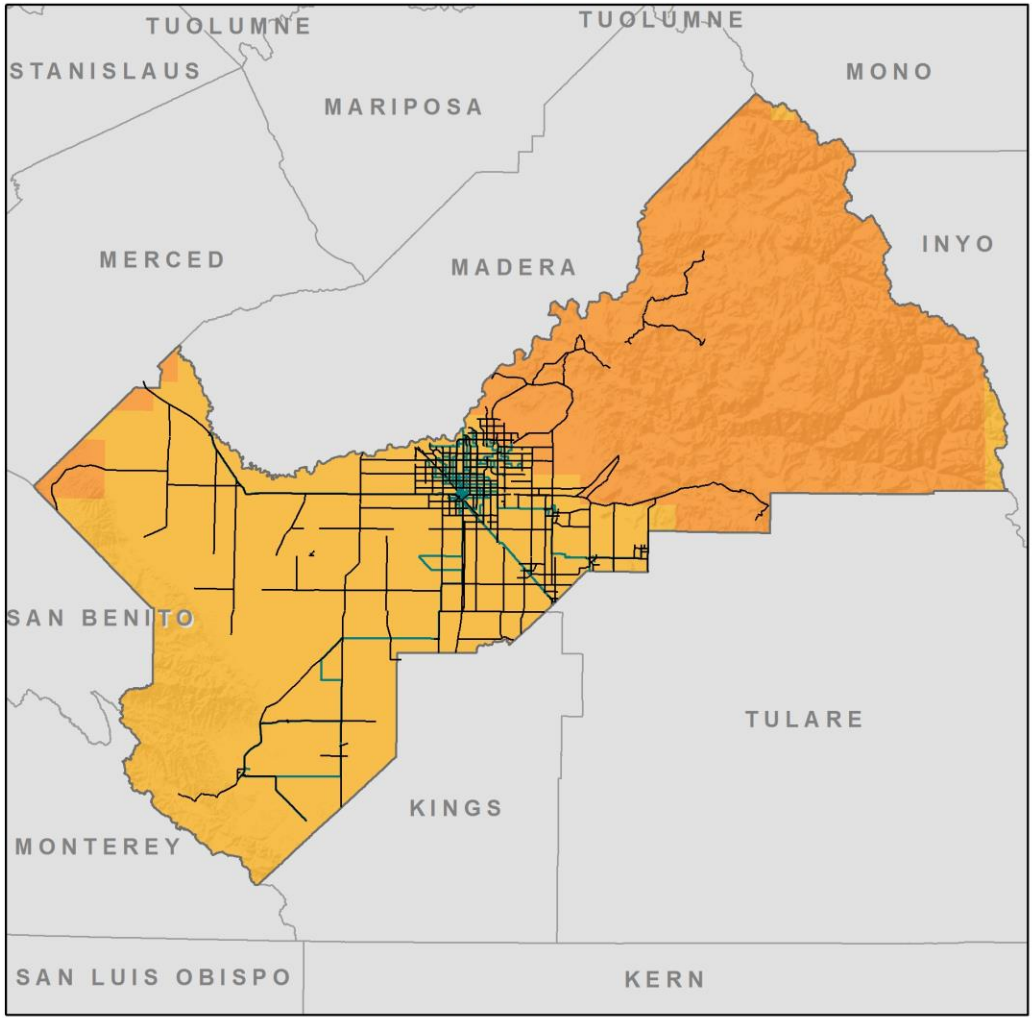
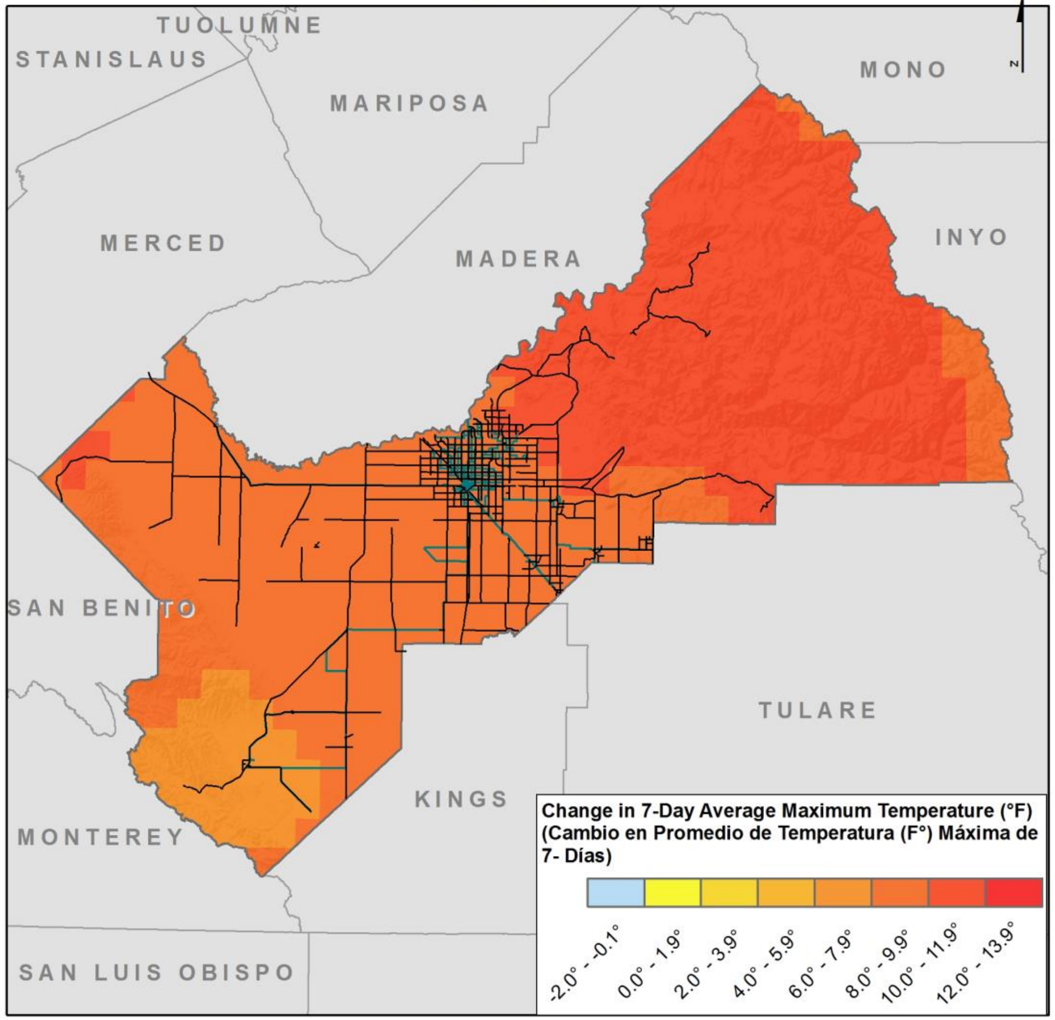
Incremento en Temperaturas Máximas Promedio atreves de Siete Días Consecutivos





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— 2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

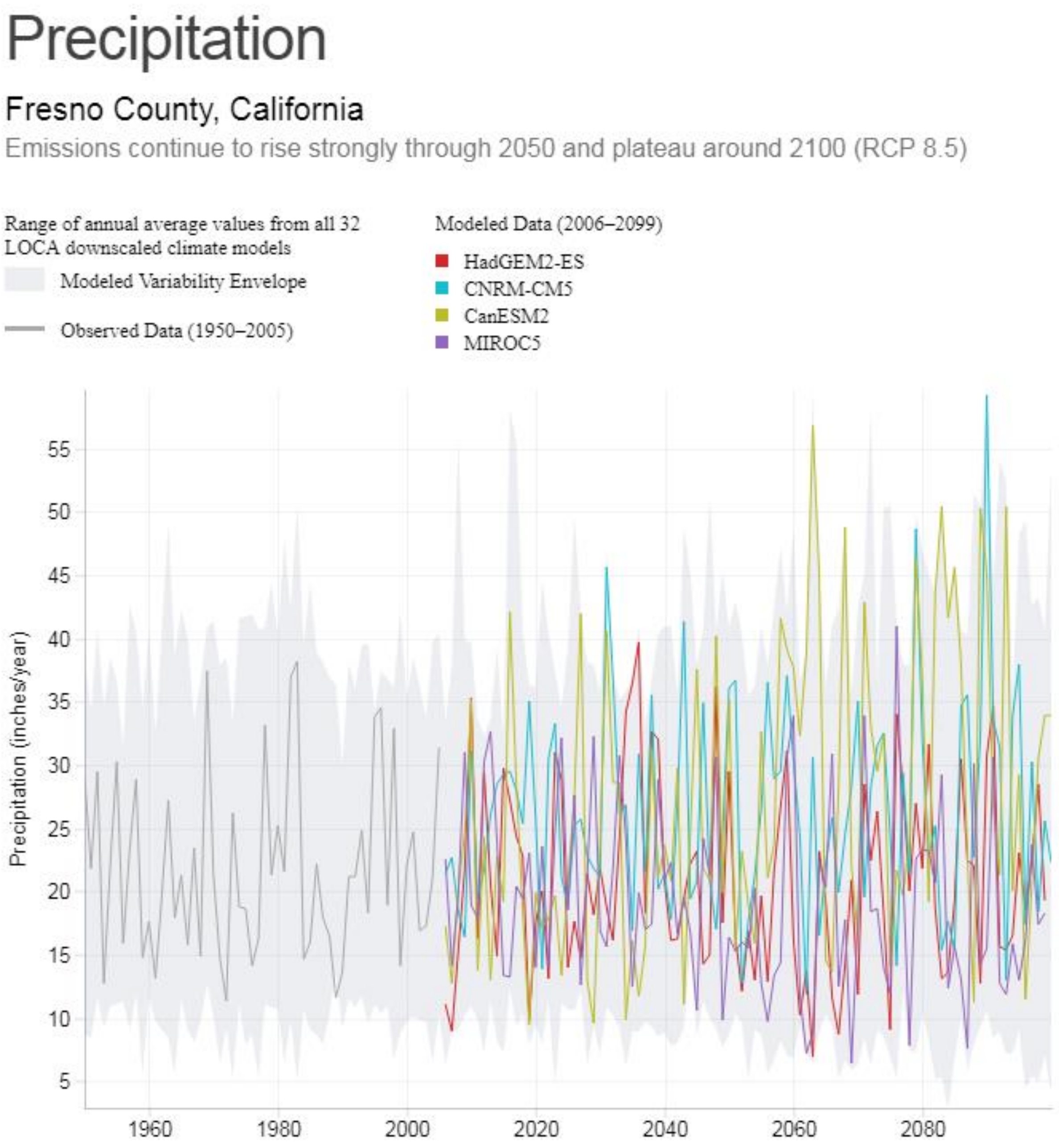
— Transit Lines (Líneas de Transito)

0 5 10 20 30 40 Miles

Source: CMCC-CMS Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario.

Precipitación

- La precipitación se espera que cambie y llegue a ser más volátil en el siguiente siglo, pero las proyecciones son inciertas
- Generalmente, se espera que ambas, sequia y eventos de aguas pluviales extremas sean más frecuentes y severas
- El promedio de precipitación en el Condado de Fresno se espera que aumente de ~21 a ~25 pulgadas a finales del siglo



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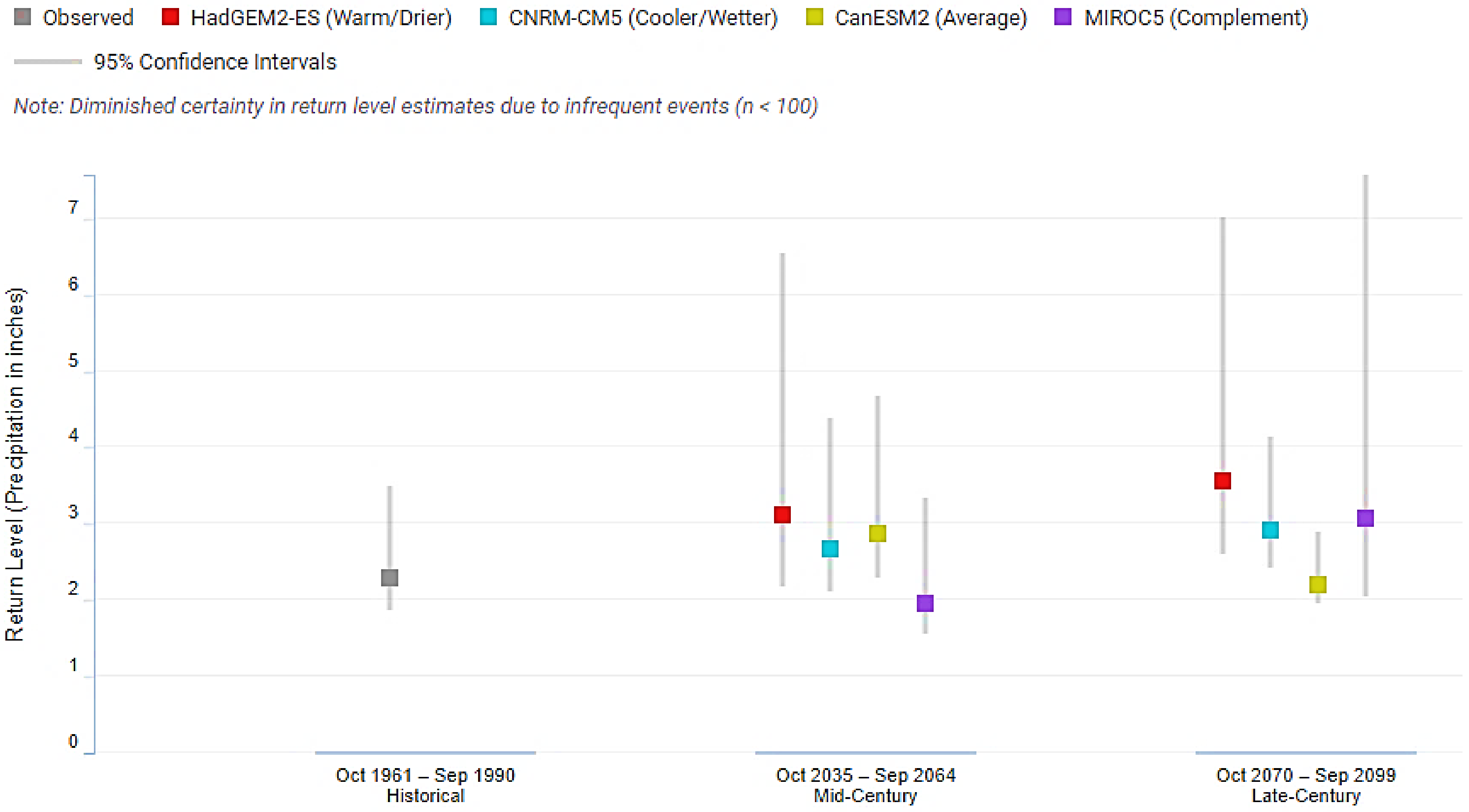
Profundidad de Aguas Pluviales a los 100 años en la Ciudad de Fresno (RCP 8.5)



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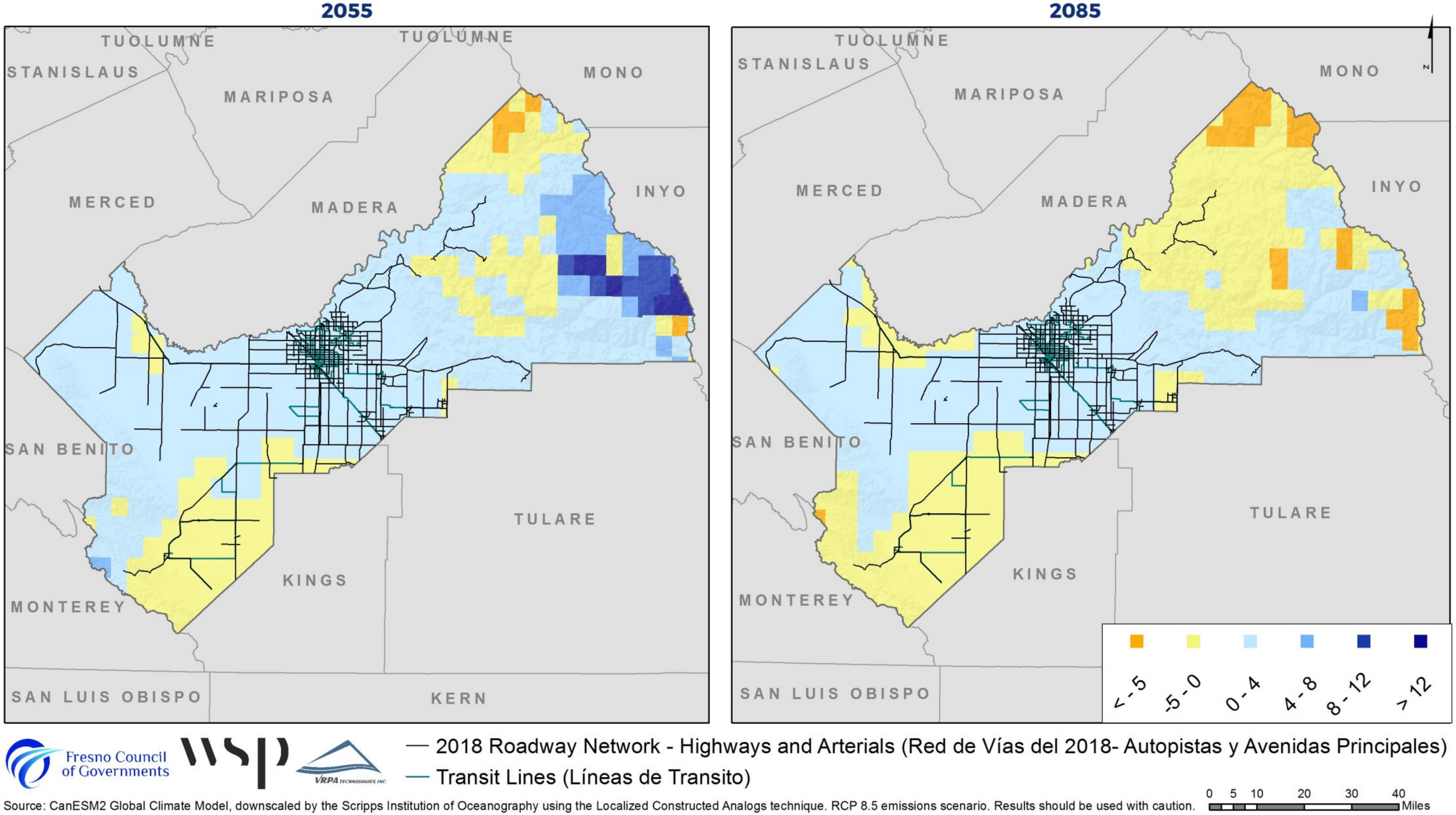
Cambio en Pulgadas de 100- Años de la Profundidad de Aguas Pluviales



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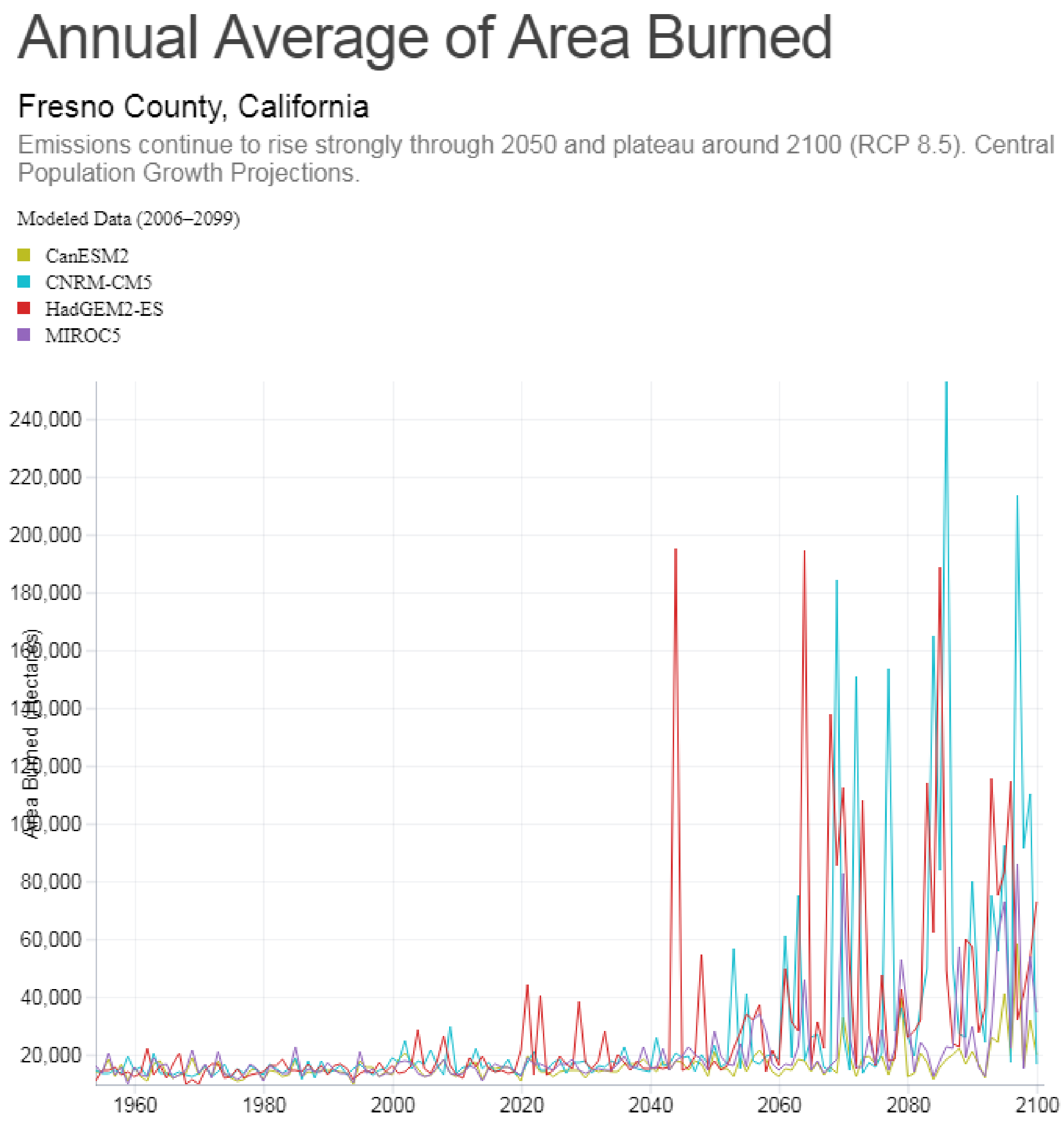
2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

Transit Lines (Líneas de Transito)

Source: CanESM2 Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario. Results should be used with caution.

Incendios Forestales

- El riesgo de incendios forestales esta aumentando a través de CA por causa del incremento en temperaturas que están secando las tierras y la vegetación
- 172 millas del Sistema del Autopista Estatal en el Condado de Fresno se proyecta que estarán expuestas a riesgos de incendios forestales moderados y altos en el próximo siglo
- El Promedio de área quemada anualmente en el Condado de Fresno se espera que aumente de ~15,000 a ~44,000 hectáreas a finales del siglo



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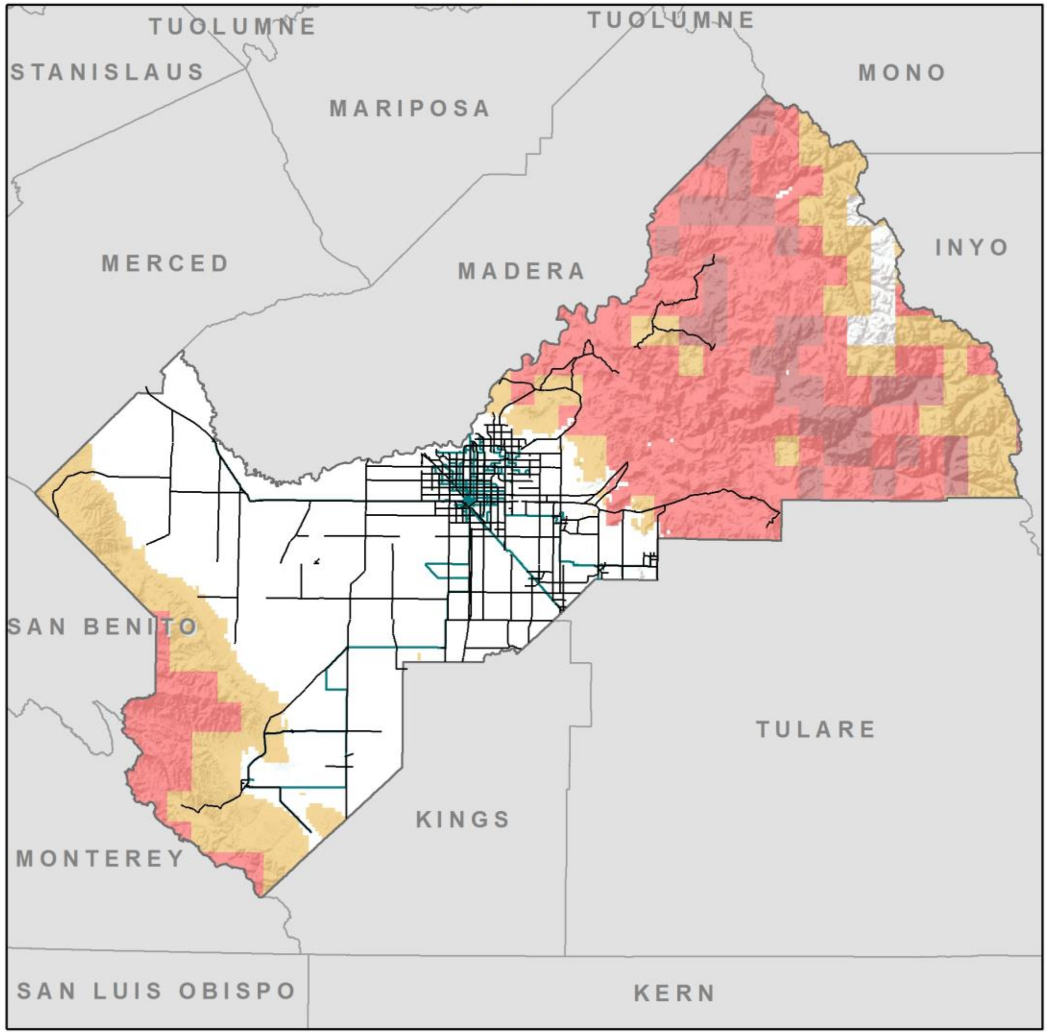
Incremento en Riesgo por Incendios

2055



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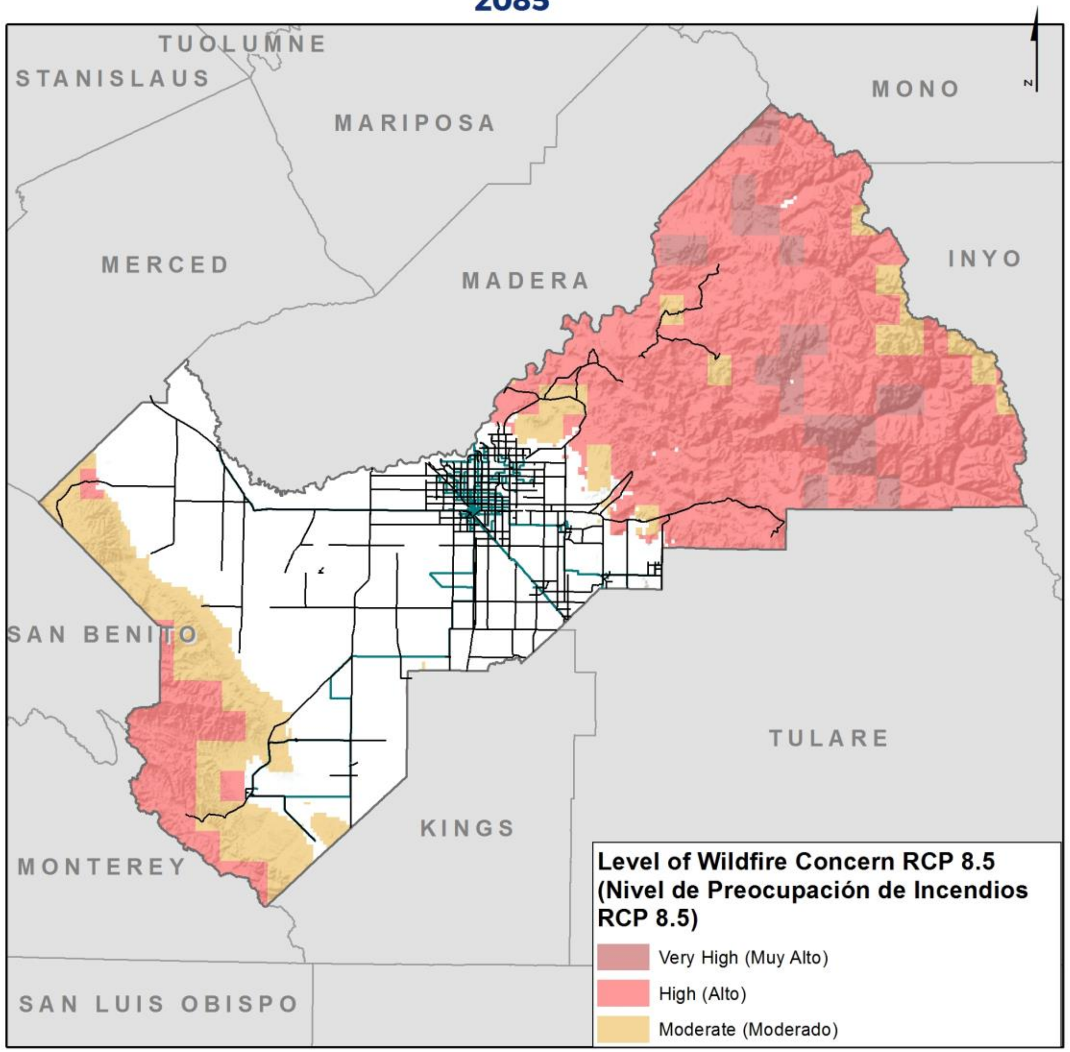

— 2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

— Transit Lines (Líneas de Transito)

Source: Amalgamation of three fire models: 1) MC2-EPA Climate Impacts Risk Assessment, USFS, 2) MC2-Applied Climate Science Lab at the University of Idaho, 3) University of California Merced model.

Ejemplos de Impactos al Sistema de Transporte y Usuarios

- Agrietamiento del pavimento y irregularidades debido al aumento de temperatura
- Impacto de salud relacionados al calor para los usuarios
- Inundaciones, derrumbes, y erosiones debido a los eventos de fuertes lluvias y escorrentía
- Daño al la infraestructura de las carreteras por los incendios forestales (barandales alcantarillas, señalización)
- Evacuaciones y amenazas de seguridad para los usuarios
- Impactos a la calidad del aire

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Resistencia del Sistema de Transporte

- Puede incluir diseño, operaciones y mantenimiento, respuesta de emergencia, planificación de tráfico, etc.
- Ejemplo de estrategias de adaptación para el sistema de transporte del Condado de Fresno:
  - Cambio del diseño de calidad de pavimento para reflejar clima futuro
  - Aumentar infraestructura del drenaje para anticipar eventos de aguas pluviales más grandes y frecuentes
  - Medidas de enfriamiento en las paradas de tránsito
  - Incrementar la alturas de puentes para anticipar flujo más pesados de ríos
  - Planificación de evacuación
  - Utilizar un espacio justificable para reducir el riesgo de incendios forestales a bienes

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Resumen del Alcance Comunitario Público

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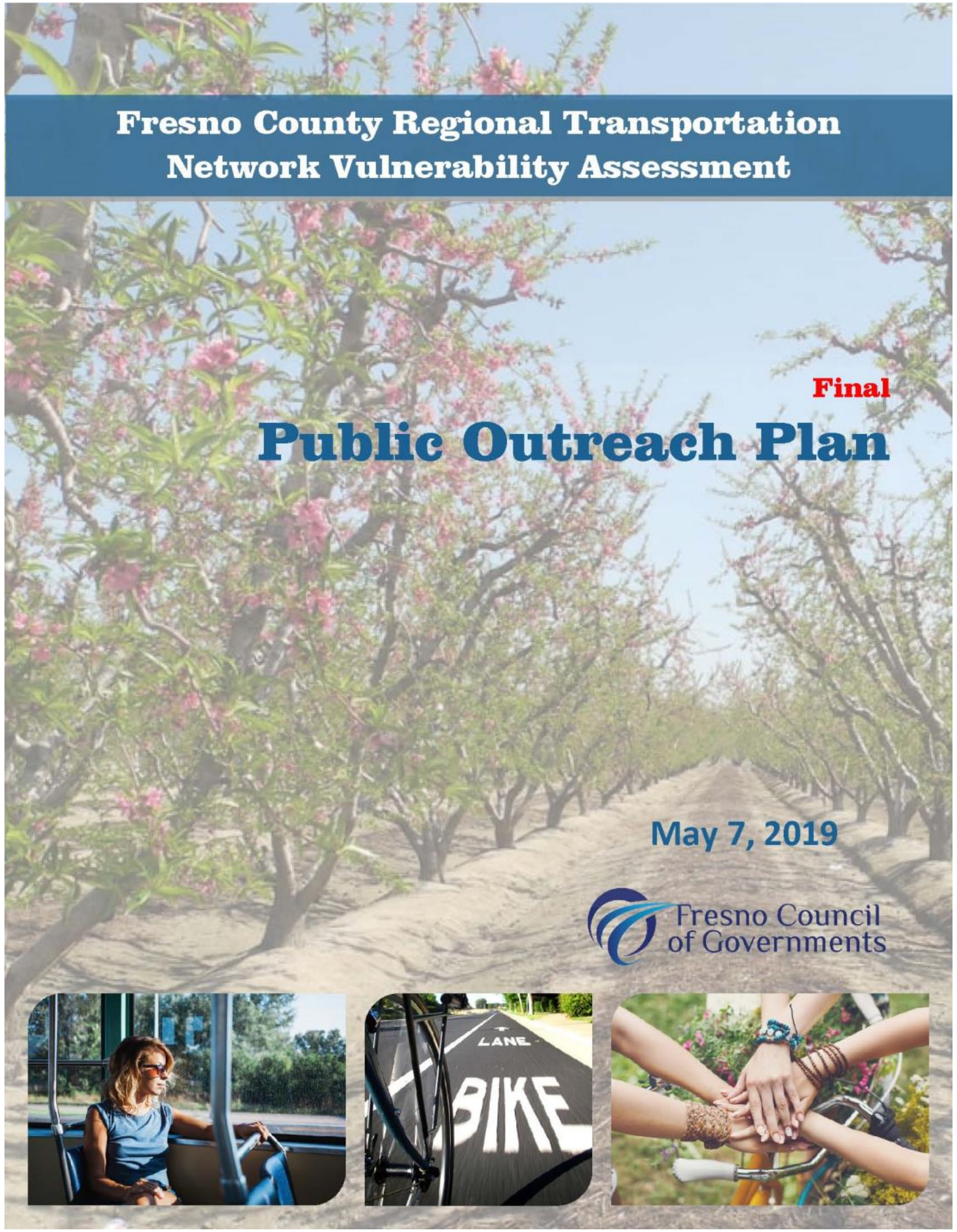
Plan de Alcance Comunitario Público

- Describe como los socios de proyectos, partidos interesados, miembros de la comunidad, y el público en general estarán involucrados durante el proceso de planeación de la Evaluación de Vulnerabilidad de la Red de Transporte
- Una guía de actividades para involucrar a la comunidad será completada
- Un documento activo, fácil de ajustar si las actividades recomendadas no proveen la información necesaria



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Actividades de Alcance Comunitario Completadas Hasta la Fecha

- Eventos de Carpa
- Entrevistas con Partidos Interesados
- Encuesta por Internet

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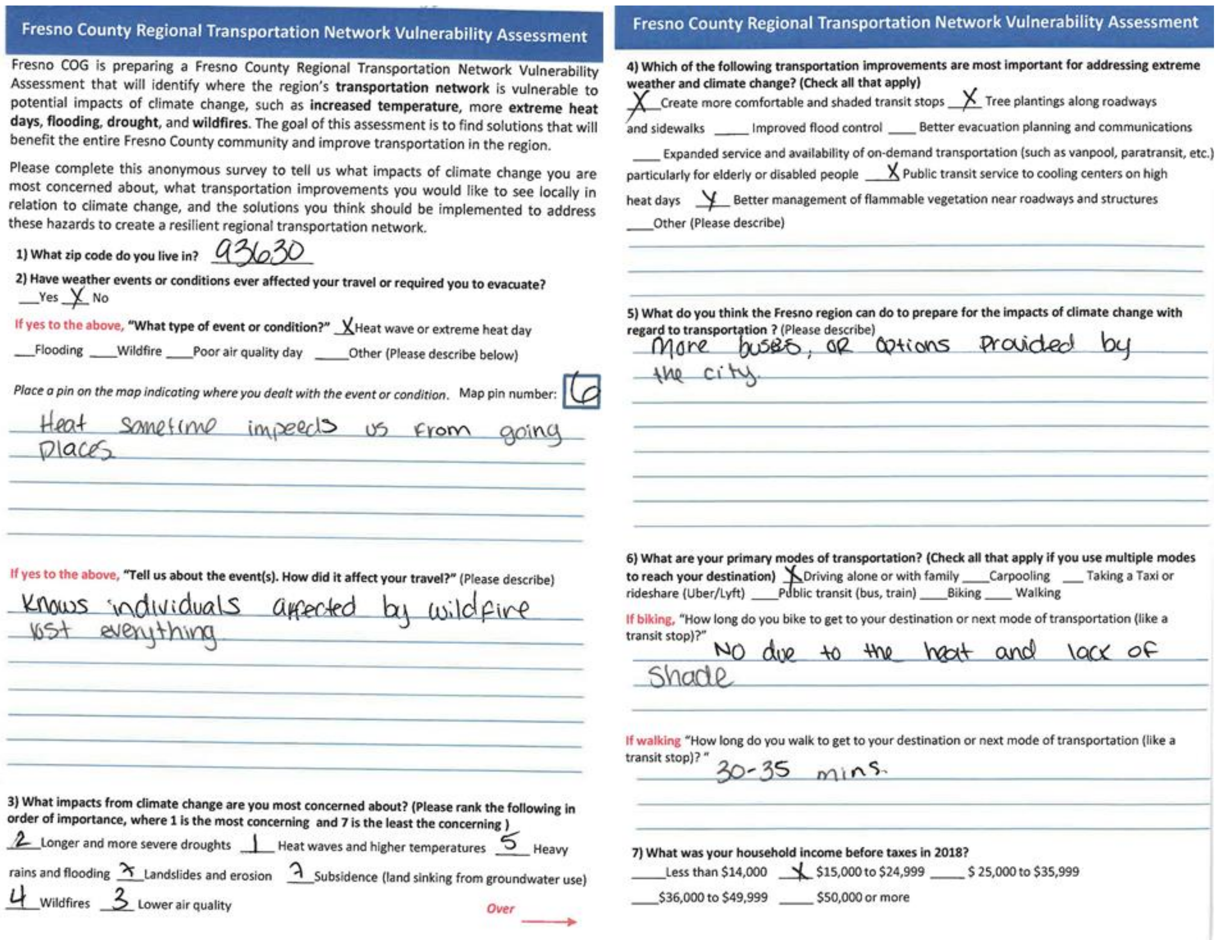
Eventos de Carpa Completados e Entrevistas con Partidos Interesados

- Eventos de Carpa
  - Festival del Almendra de Kerman
  - Feria de Calle en Reedley San Joaquín Carnaval
- Entrevistas con Partidos Interesados
  - Personal del departamento de Planeación de la Ciudad y el Condado, Ingeniería y transito
  - Oficina del Condado de Fresno de Servicios de Emergencia
  - Representantes de Organizaciones Basadas en la Fe



Fresno County Regional Transportation Network Vulnerability Assessment

Fresno COG is preparing a Fresno County Regional Transportation Network Vulnerability Assessment that will identify where the region's **transportation network** is vulnerable to potential impacts of climate change, such as **increased temperature**, more **extreme heat days**, **flooding**, **drought**, and **wildfires**. The goal of this assessment is to find solutions that will benefit the entire Fresno County community and improve transportation in the region.

Please complete this anonymous survey to tell us what impacts of climate change you are most concerned about, what transportation improvements you would like to see locally in relation to climate change, and the solutions you think should be implemented to address these hazards to create a resilient regional transportation network.

1) What zip code do you live in? 93630

2) Have weather events or conditions ever affected your travel or required you to evacuate?
___Yes _X_ No

If yes to the above, **"What type of event or condition?"** _X_ Heat wave or extreme heat day ___Flooding ___Wildfire ___Poor air quality day ___Other (Please describe below)

Place a pin on the map indicating where you dealt with the event or condition. Map pin number: 6

Heat sometime impeeds us from going places

If yes to the above, **"Tell us about the event(s). How did it affect your travel?"** (Please describe)

knows individuals affected by wildfire lost everything

3) What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least the concerning)
_2_ Longer and more severe droughts _1_ Heat waves and higher temperatures _5_ Heavy rains and flooding _7_ Landslides and erosion _7_ Subsidence (land sinking from groundwater use) _4_ Wildfires _3_ Lower air quality

Over →

Fresno County Regional Transportation Network Vulnerability Assessment

4) Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check all that apply)
_X_ Create more comfortable and shaded transit stops _X_ Tree plantings along roadways and sidewalks ___ Improved flood control ___ Better evacuation planning and communications ___ Expanded service and availability of on-demand transportation (such as vanpool, paratransit, etc.) particularly for elderly or disabled people _X_ Public transit service to cooling centers on high heat days _X_ Better management of flammable vegetation near roadways and structures ___Other (Please describe)

5) What do you think the Fresno region can do to prepare for the impacts of climate change with regard to transportation ? (Please describe)

More buses, or options provided by the city.

6) What are your primary modes of transportation? (Check all that apply if you use multiple modes to reach your destination) _X_ Driving alone or with family ___Carpooling ___ Taking a Taxi or rideshare (Uber/Lyft) ___Public transit (bus, train) ___Biking ___ Walking

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30-35 mins.

7) What was your household income before taxes in 2018?
___Less than $14,000 _X_ $15,000 to $24,999 ___ $ 25,000 to $35,999 ___$36,000 to $49,999 ___ $50,000 or more

Encuesta en sitio de internet

- Las encuestas en el sitio de internet les permite a los participantes el responder en Inglés o Español
- Disponible en el sitio de internet de Fresno COG o visitando https://www.surveymonkey.com/r/FresnoTNVA
- Cubre las mayores preocupaciones que tienen los participantes con el impacto de los cambios climáticos, como usan el sistema de transporte para transportarse, y que mejoras en el transporte les gustaría ver localmente como respuesta a los cambios climáticos, para crear una red de transporte regional resistente .

Fresno County Regional Transportation Network Vulnerability Assessment *(Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno)*

Community Survey *(Encuesta Comunitaria)*

We need your help shaping the Fresno region's future! *(¡Necesitamos su ayuda para dar forma al futuro de la región de Fresno!)*

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OK

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Preguntas

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Sesión en Grupos

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¡Gracias por su tiempo!

Si tiene cualquier pregunta o comentario, no dude en contactarnos.

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Información de Contacto del Equipo

- **Meg Prince**, FCOG Project Manager, MPrince@fresnocog.org
- **Tim Grose**, Consultant Project Manager, Timothy.Grose@wsp.com
- **Georgiena Vivian**, Collaboration and Community Engagement Lead, gvivian@vrpatechnologies.com

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Fresno County Regional Transportation Network Vulnerability Assessment

June 19, 2019

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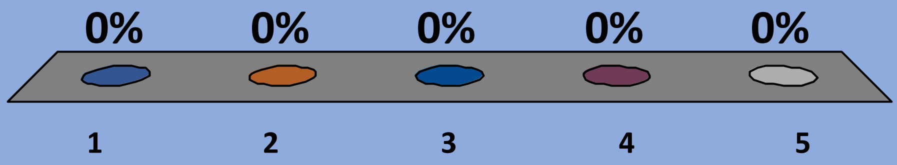
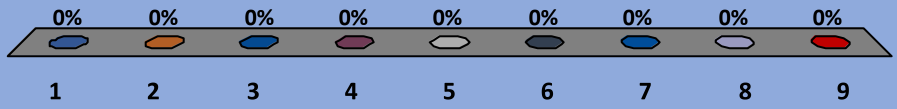
What is your age?

1. Less than 18
2. 18-24
3. 25-44
4. 45-64
5. 65 years and over



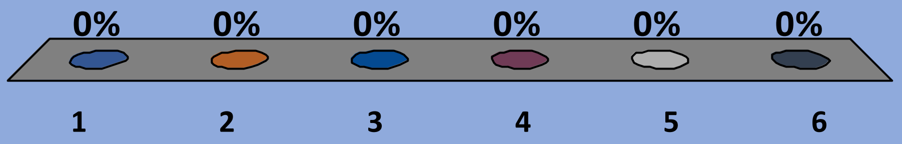
What is your racial or ethnic background?

1. White or Caucasian
2. Hispanic, Latino, or Spanish origin
3. American Indian or Alaska Native
4. Black or African American
5. Asian
6. Middle Eastern or North African
7. Native Hawaiian or other Pacific Islander
8. Other
9. Rather not answer



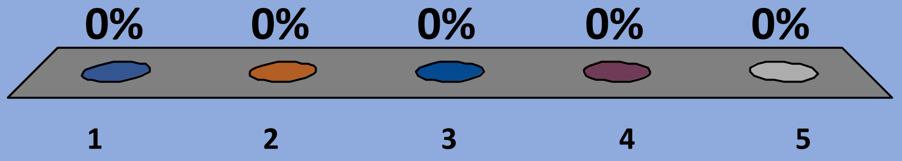
What is your household income?

1. Less than $15,000
2. $15,000 - $24,999
3. $25,000 - $35,999
4. $36,000 - $49,999
5. $50,000 or more
6. Rather not say



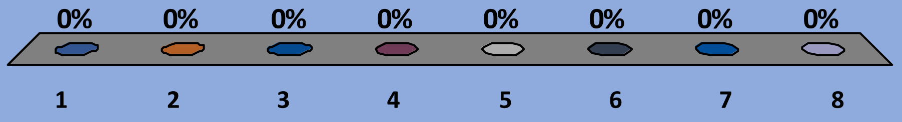
Where do you live?

1. City of Fresno
2. City of Clovis
3. Other City in Fresno County
4. Unincorporated County Area outside of the City of Fresno
5. Outside of Fresno County



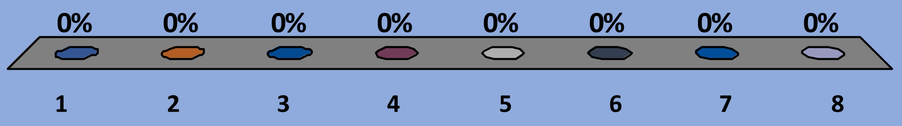
Which of the following subgroups BEST describes you?

1. Elected Official
2. Appointed Official
3. Private Citizen
4. Student
5. Public Agency Staff
6. Community Based Organization/Faith Based Organization
7. Environmental Justice Advocate
8. Other



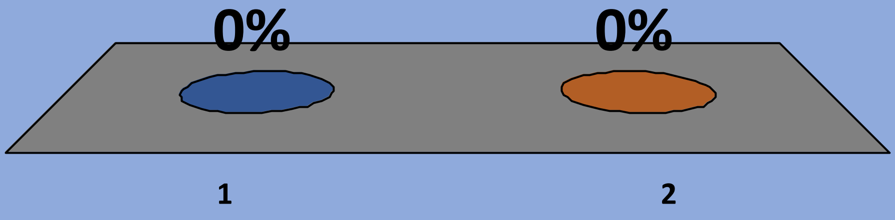
What is your primary mode of transportation?

1. Driving alone or with family
2. Carpooling
3. Taking a taxi or ride share (Uber/Lyft)
4. Public Transit (bus, train)
5. Biking
6. Walking
7. Other
8. I have more than one primary mode of transportation



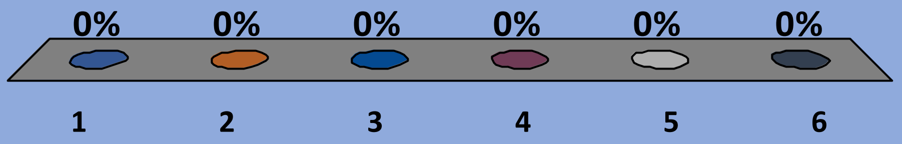
Have weather events or conditions such as high heat, flooding, or wildfire ever affected your travel, or required you to evacuate?

1. Yes
2. No



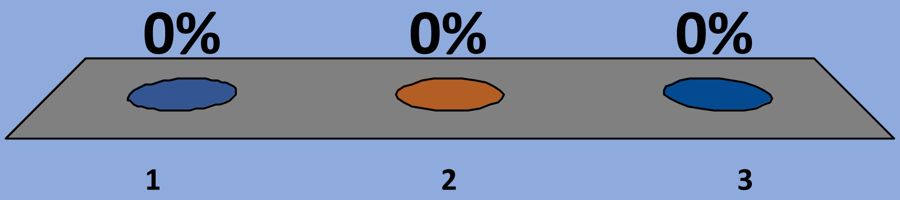
If yes, what type of event or condition?

1. Heat wave or extreme heat day
2. Flooding
3. Wildfire
4. Poor air quality day
5. Other
6. Weather events or conditions have never affected my travel or required me to evacuate



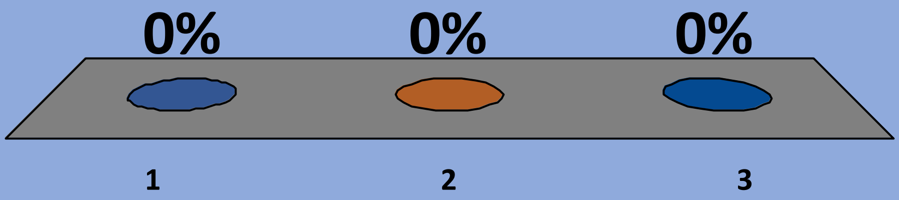
How concerned are you about the impacts of climate change? For example, increases in extreme temperatures, drought, flood risk, and wildfires.

1. Very
2. Somewhat
3. Not at all



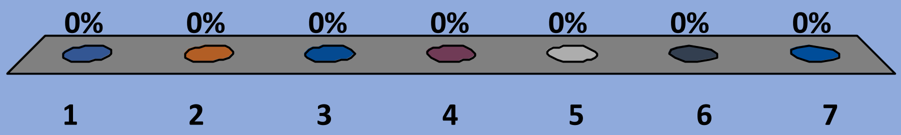
Do you think that climate change will impact your life directly?

1. Yes
2. No
3. Not sure



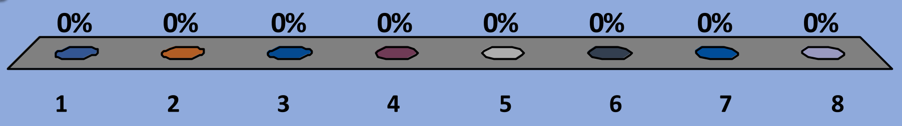
What impacts from climate change are you most concerned about? (Please rank the following in order of importance, where 1 is the most concerning and 7 is the least concerning)

1. Longer and more severe droughts
2. Heat waves and higher temperature
3. Heavy rains and flooding
4. Landslides and erosions
5. Subsidence (land sinking from groundwater use)
6. Wildfires
7. Lower air quality



Which of the following transportation improvements are most important for addressing extreme weather and climate change? (Check All That Apply)

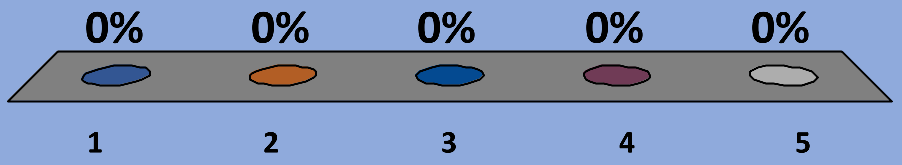
1. Create more comfortable and shaded transit stops
2. Tree planting along roadways and sidewalks
3. Improved flood control
4. Better evacuation planning and communications
5. Expanded service and availability of on-demand transportation during high heat or other extreme weather events, particularly for elderly or disabled people
6. Public transit service to cooling centers on high heat days
7. Better management of flammable vegetation near roadways and structures
8. Other



Meeting Evaluation

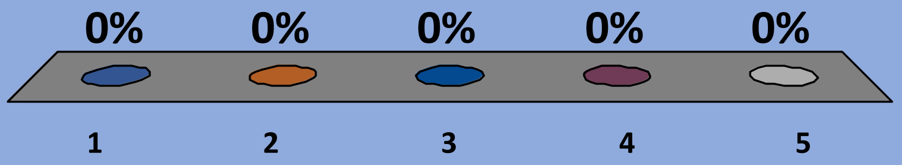
How effective has this meeting been to express your opinions?

1. Not at all effective
2. Not very effective
3. Somewhat effective
4. Effective
5. Very effective



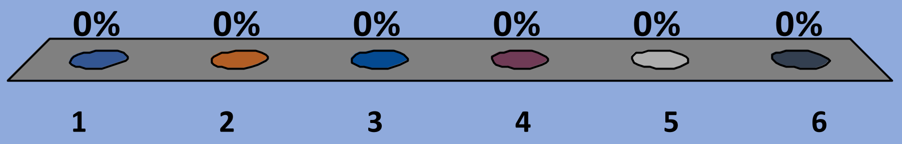
How useful were the clickers to provide your opinion?

1. Not at all effective
2. Not very effective
3. Somewhat effective
4. Effective
5. Very effective



How did you learn about today's workshop?

1. Received a flyer
2. Received an email
3. Newsletter
4. Social Media
5. Word of mouth
6. Other



Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

19 de Junio del 2019

VRPA TECHNOLOGIES, INC.

Fresno Council of Governments

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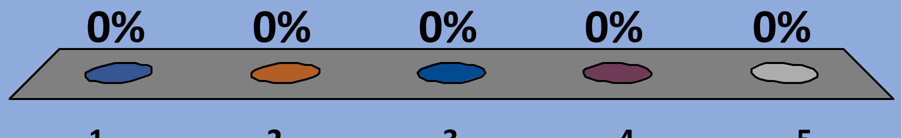
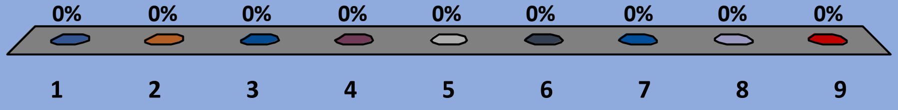
¿Cual es tu edad?

1. Menos de 18
2. 18-24
3. 25-44
4. 45-64
5. Más de 65



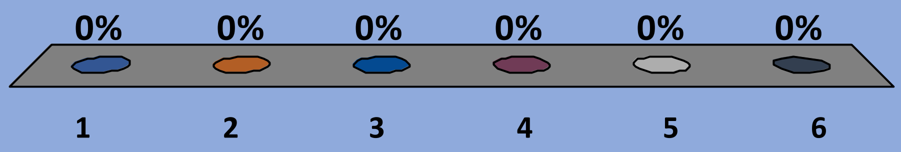
¿Cuál es tu origen racial y étnico?

1. Blanco o Caucásico
2. Origen Hispano, Latino o Español
3. Indio Americano o Nativo del Alaska
4. Negro o Afroamericano
5. Asiático
6. Oriente Medio o Norte de África
7. Nativo de Hawái o de otras islas del Pacífico
8. Otro
9. Prefiero no responder



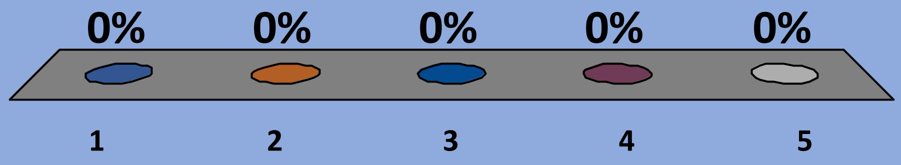
¿Cual es el ingreso de su hogar?

1. Menos de $15,000
2. $15,000 - $24,999
3. $25,000 - $35,999
4. $36,000 - $49,999
5. Más de $50,000
6. Prefiero no responder



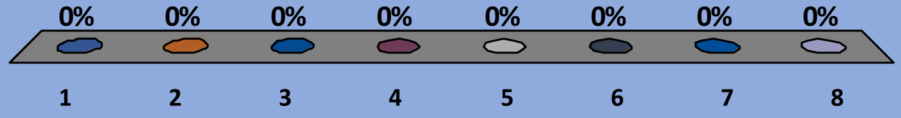
¿Donde vives?

1. Ciudad de Fresno
2. Ciudad de Clovis
3. Otra ciudad del condado de Fresno
4. Área no incorporada del condado fuera de la ciudad de Fresno
5. Fuera del condado de Fresno



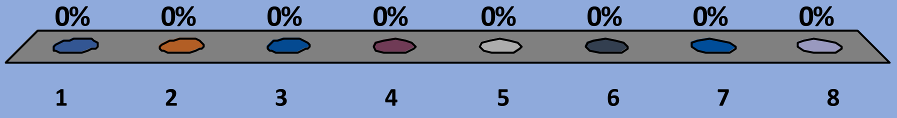
¿Cuál de los siguientes subgrupos te describe MEJOR?

1. Funcionario Oficial
2. Oficial Designado
3. Ciudadano privado
4. Estudiante
5. Personal de la agencia pública
6. Basado en la comunidad Organización/ Organización Basada en la Fe
7. Abogacía de Justicia Ambiental
8. Otro



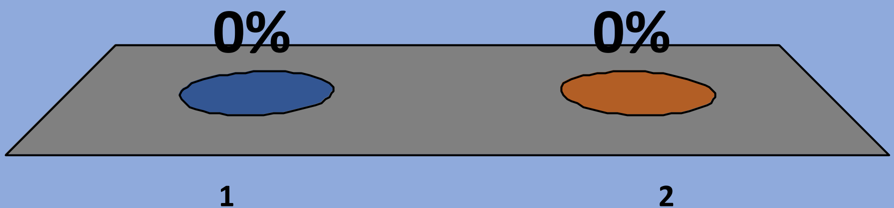
¿Cuáles son sus medios de transporte primarios?

1. Manejando solo o con su familia
2. Viaje en grupo
3. Tomando un Taxi o un viajes compartidos (Uber/Lyft)
4. Transporte público (camión , tren)
5. Bicicleta
6. Caminando
7. Otro
8. Tengo mas de un modo primario de transportación



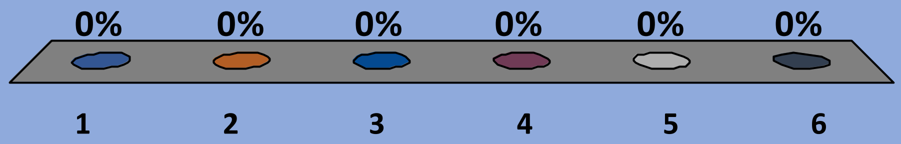
¿Han afectado los eventos climáticos u otras condiciones su habilidad de viajar o que haya tenido que evacuar

1. Si
2. No



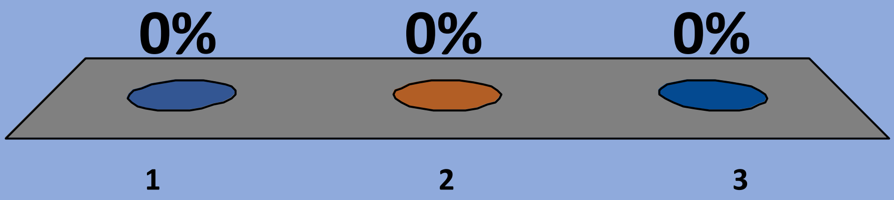
En caso de responder Si , ¿Que tipo de evento o condición?”

1. Ola de calor o día de calor extremo
2. Inundación
3. Incendio forestal
4. Día con mala calidad de aire
5. Otro
6. Eventos meteorológicos o condiciones nunca han afectado mi viaje o me han requerido que evacue



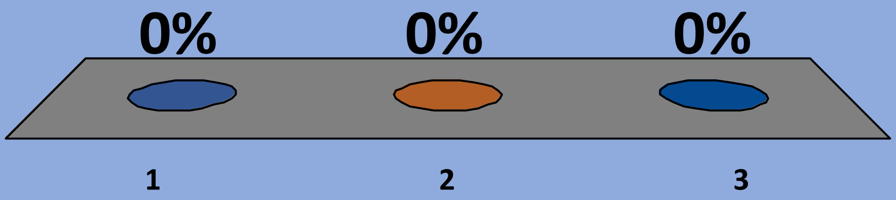
¿Qué tan preocupado está por los impactos del cambio climático? Por ejemplo, aumentos en temperaturas extremas, sequía, riesgo de inundaciones e incendios forestales.

1. Mucho
2. Un Poco
3. Para Nada



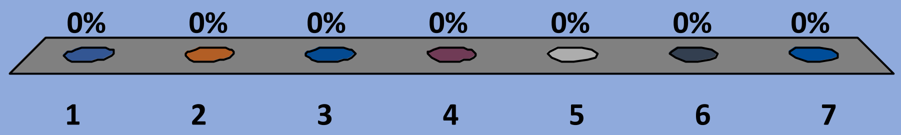
¿Crees que el cambio climático afectará tu vida directamente?

1. Si
2. No
3. No estoy seguro/a



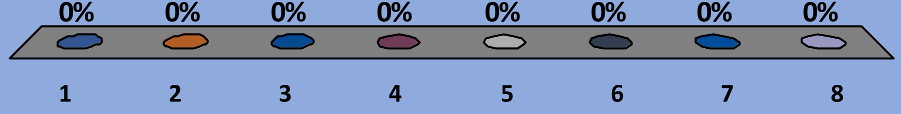
¿Cuales son los impactos por el cambio del clima que más le preocupan? (Favor de clasificar lo siguiente en orden de importancia, en donde el 1 es de más preocupación y el 7 es el que menos le preocupe)

1. Sequias más severas y alargadas
2. Olas de calos y temperaturas altas
3. Fuertes lluvias e inundaciones
4. Derrumbes y erosión
5. Subsidencia (hundimiento de las tierras debido al uso del agua subterránea)
6. Incendios forestales
7. Reduccion de calidad del aire



¿ Cuál de las siguientes mejoras de transporte son de más importancia para combatir el clima extremo y los cambios climáticos? (Marca todas las opciones que aplican)

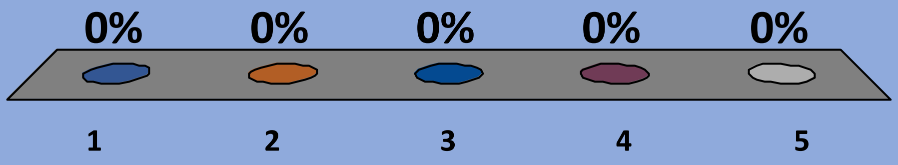
1. Crear más paradas de transito cómodas y con sombra
2. Plantar árboles en el camino de las carreteras y las banquetas
3. Mejorar el control de inundaciones
4. Better evacuation planning and communications
5. Expandir servicio y disponibilidad de transportación a demanda durante los días de calor extremo o otro evento de clima extremo, particularmente para mayores de edad o personas discapacitadas
6. Servicio de transporte público a centros de enfriamiento en días muy calurosos
7. Mejor manejo de la vegetación inflamables cerca de los carreteras y estructuras
8. Otros



Evaluación de la Junta

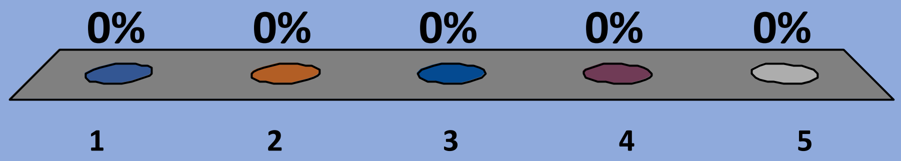
¿Qué tan efectiva ha sido esta reunión para expresar sus opiniones?

1. Nada efectiva
2. No muy efectiva
3. Algo efectiva
4. Efectiva
5. Muy efectiva



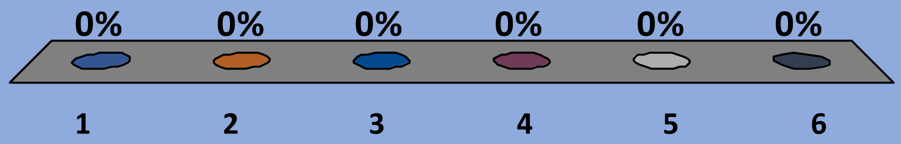
¿Qué tan útiles fueron los aparatos electrónicos para dar tu opinión?

1. Nada efectivo
2. No muy efectivo
3. Algo efectivo
4. Efectivo
5. Muy efectivo



¿Cómo aprendiste sobre el taller de hoy?

1. Recibió un volante
2. Recibe un correo electrónico
3. Boletín
4. Media Social
5. De boca en boca
6. Otro



Fresno County Transportation Network Vulnerability Assessment

Fresno City College Workshop – June 19, 2019

Name:

Email:

Comments:

Visit www.fresnocog.org/project/sb1-planning-studies/ for additional information

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Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

The **Fresno Council of Governments** is preparing a **Fresno County Regional Transportation Network Vulnerability Assessment (TNVA),** funded through Senate Bill 1. The TNVA will identify areas of the region where the multi-modal transportation network is vulnerable to climate change hazards and identify strategies to remedy potential impacts. These responses will be designed to provide additional benefits to the broader community through public health, environmental, equitable, and economic improvements.

The main climate hazards that will be assessed as part of the TNVA are **temperature rise and extreme heat, flooding from extreme precipitation events, and wildfire risk.** In general, projected changes are:

- **High and low temperatures are expected to rise** across Fresno County, and there will be more heat waves and extreme heat days.
- Precipitation projections are uncertain and **precipitation will become even more volatile**, but in general it's expected that both droughts and storm events will become more frequent and severe.
- **Wildfire risk is increasing** as soils and vegetation dry out from temperature rise.

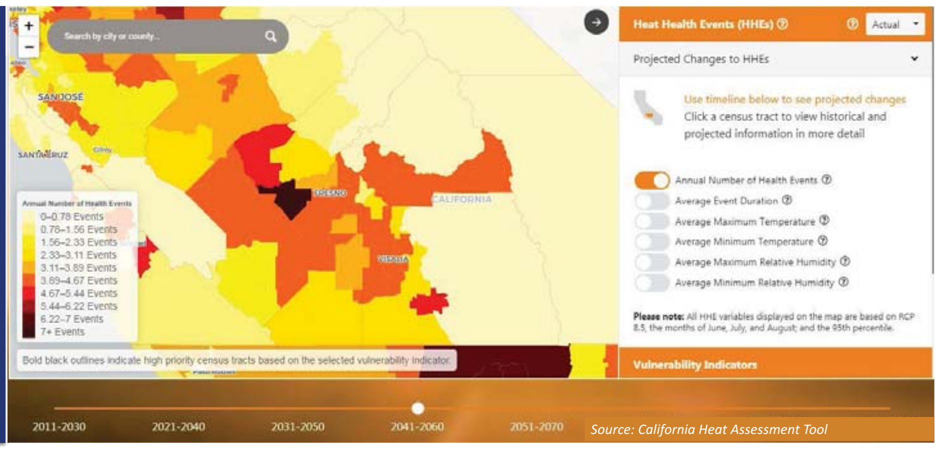
Clovis, CA, photo by David Prasad, Creative Commons License 2.0

Heat Health Events

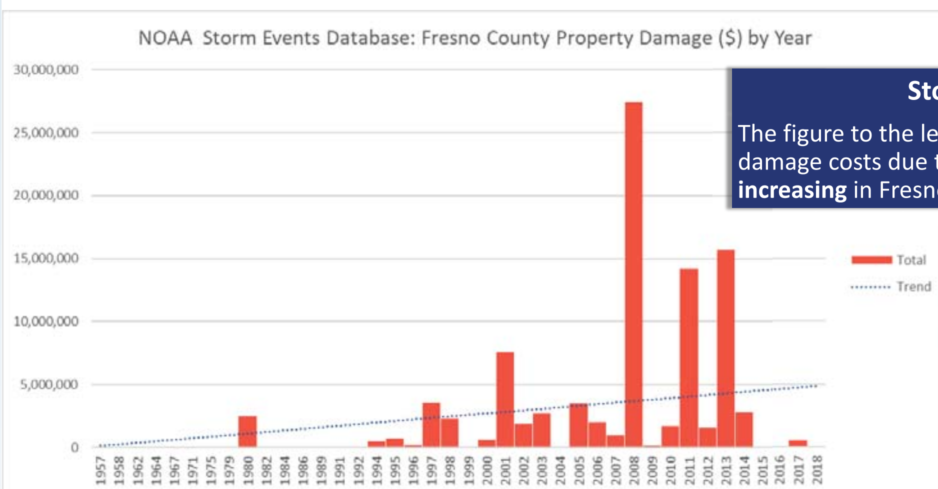
Heat health events are expected to increase over the coming century.

A heat health event is any event that results in a **negative public health impact**, such as an emergency room visit.

See the map to the right for the **projected increases in annual heat health events** by mid-century.



Source: California Heat Assessment Tool



Storm Events

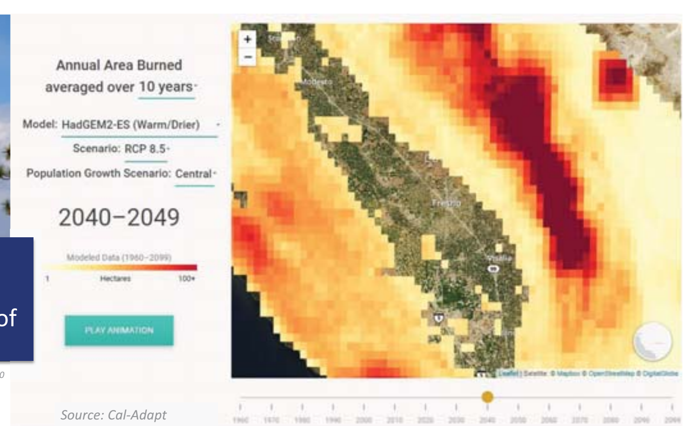
The figure to the left shows how property damage costs due to **storm events** are already **increasing** in Fresno County.

Washout on SR-41, photo courtesy of Caltrans

Area Burned

Average annual area burned is **expected to increase by 205%** in Fresno County by the end of the century.

Rim Fire as seen from SR-41, photo by Andrew Adams, Creative Commons License 2.0



Source: Cal-Adapt

Fresno Council of Governments

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VRPA TECHNOLOGIES, INC.

Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

El **Consejo de Gobiernos de Fresno** esta preparando una **Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno (TNVA),** financiada por la ley del Senado 1. La TNVA identificará las áreas de la región donde la red de transporte multimodal es vulnerable a los peligros por el cambio de clima e identificar estrategias para remediar los posibles impactos. Estas respuestas estarán diseñadas para proveer beneficios adicionales a la amplia comunidad por medio de mejoras a la salud pública, el medio ambiente, equitativas, y económicas.

Los principales peligros climáticos que serán evaluados como parte del TNVA son el **aumento de temperatura y calentamiento extremoso, inundaciones debido a eventos de precipitación extremosos, y riesgo de incendios forestales.** En general, los cambios que se proyectan son:

- **Las temperaturas altas y bajas se esperan que aumenten** por todo el Condado de Fresno, y habrá más olas de calor y días de calentamiento extremo.
- Las proyecciones de precipitación son inseguras y **la precipitación será aún más inestable**. Pero en general se espera que ambos eventos de sequias y tormentas sean más frecuentes y severos.
- **El incendio forestal esta incrementando** al secarse la tierra y la vegetación por el aumento de la temperatura.

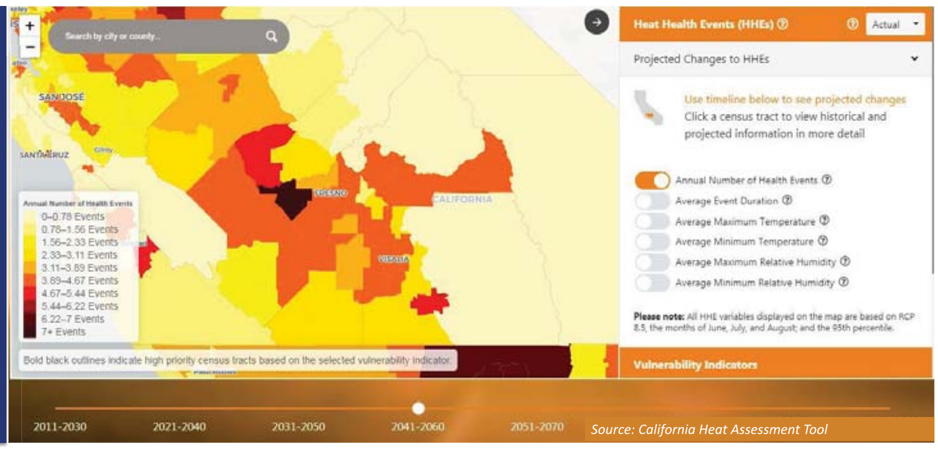
Clovis, CA, photo by David Prasad, Creative Commons License 2.0

Eventos de Salud por Calentamiento

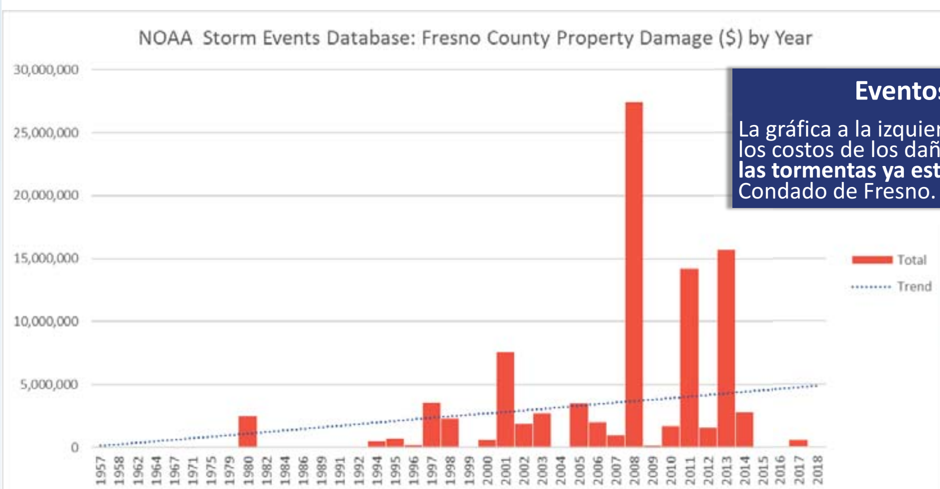
Los eventos de salud por calentamiento se espera que aumenten en el próximo siglo.

Un evento de salud por calentamiento es cualquier evento que resulta en un **impacto de salud pública negativa**, como la visita a la sala de emergencias.

Vea el mapa a la derecha para ver el **aumentos proyectados en los eventos de salud anuales a causa del calentamiento** de aquí a medio siglo.



Source: California Heat Assessment Tool



Eventos de Tormentas

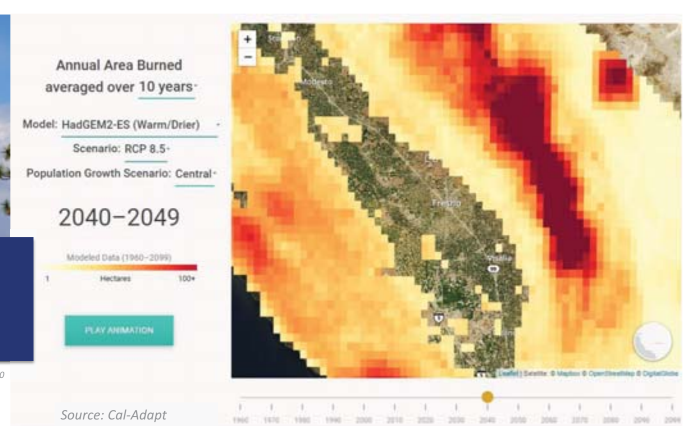
La gráfica a la izquierda nos enseña como es que los costos de los daños de propiedades debido a **las tormentas ya están aumentando en el** Condado de Fresno.

Washout on SR-41, photo courtesy of Caltrans

Área Quemada

El Promedio anual de área quemada se espera que **aumente por un 205 %** en el Condado de Fresno para fines del siglo.

Rim Fire as seen from SR-41, photo by Andrew Adams, Creative Commons License 2.0



Source: Cal-Adapt

Fresno Council of Governments

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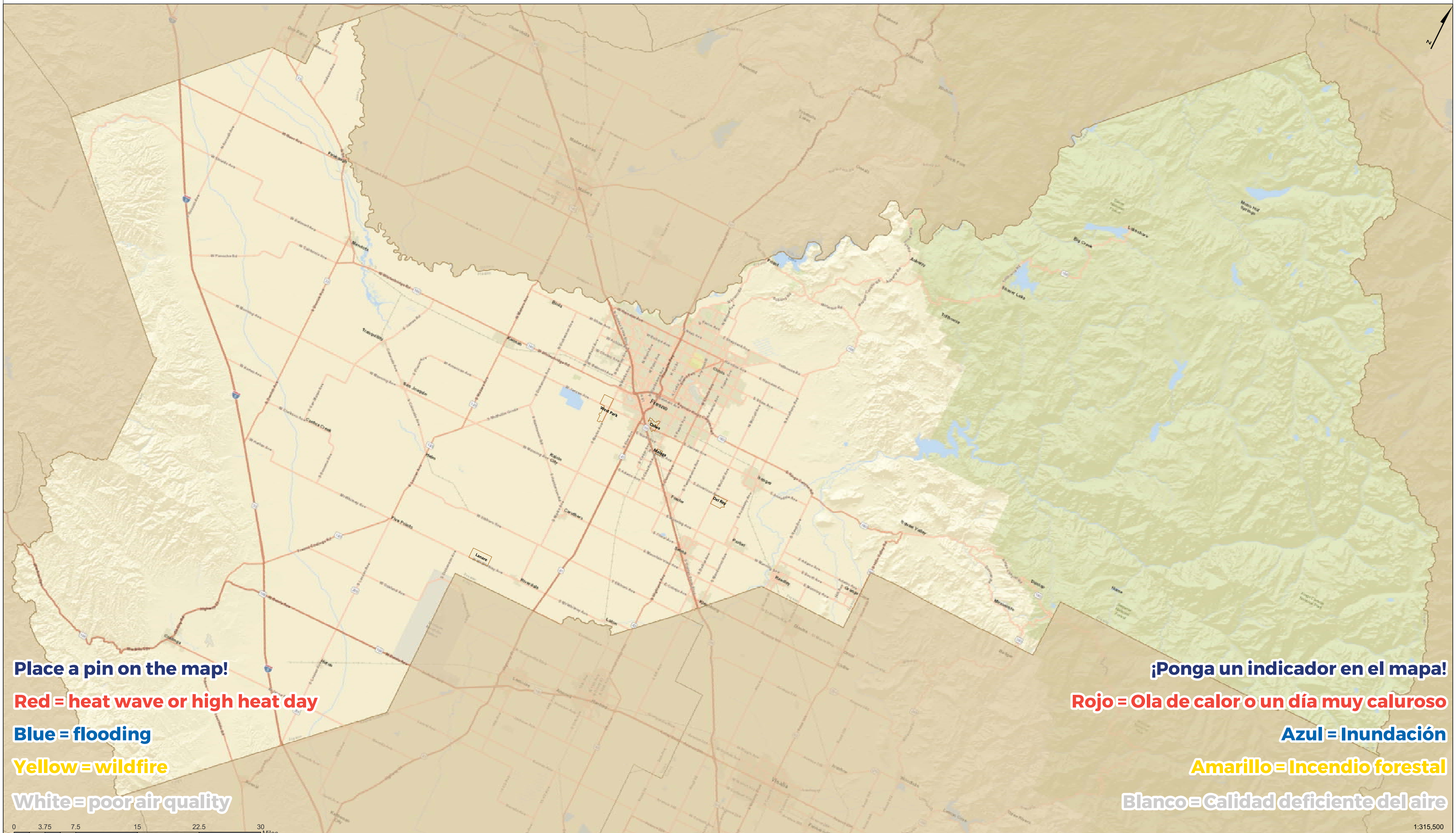
Has a weather event or other condition ever affected your ability to travel or required you to evacuate? Where?

¿Ha afectado algún evento climático u otra condición su habilidad de viajar o que haya tenido que evacuar? ¿En dónde?

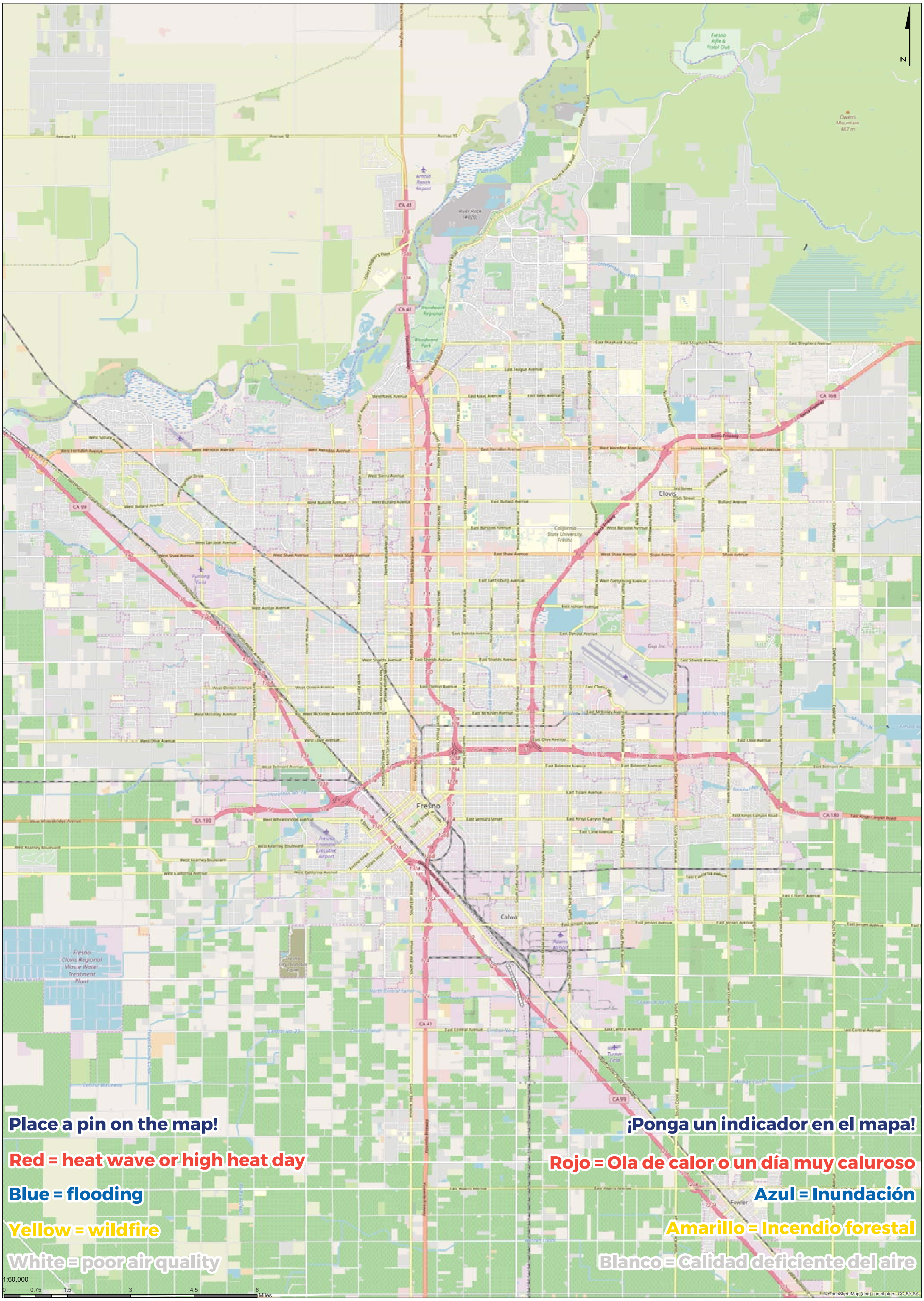


Fresno County Regional Transportation Network Vulnerability Assessment

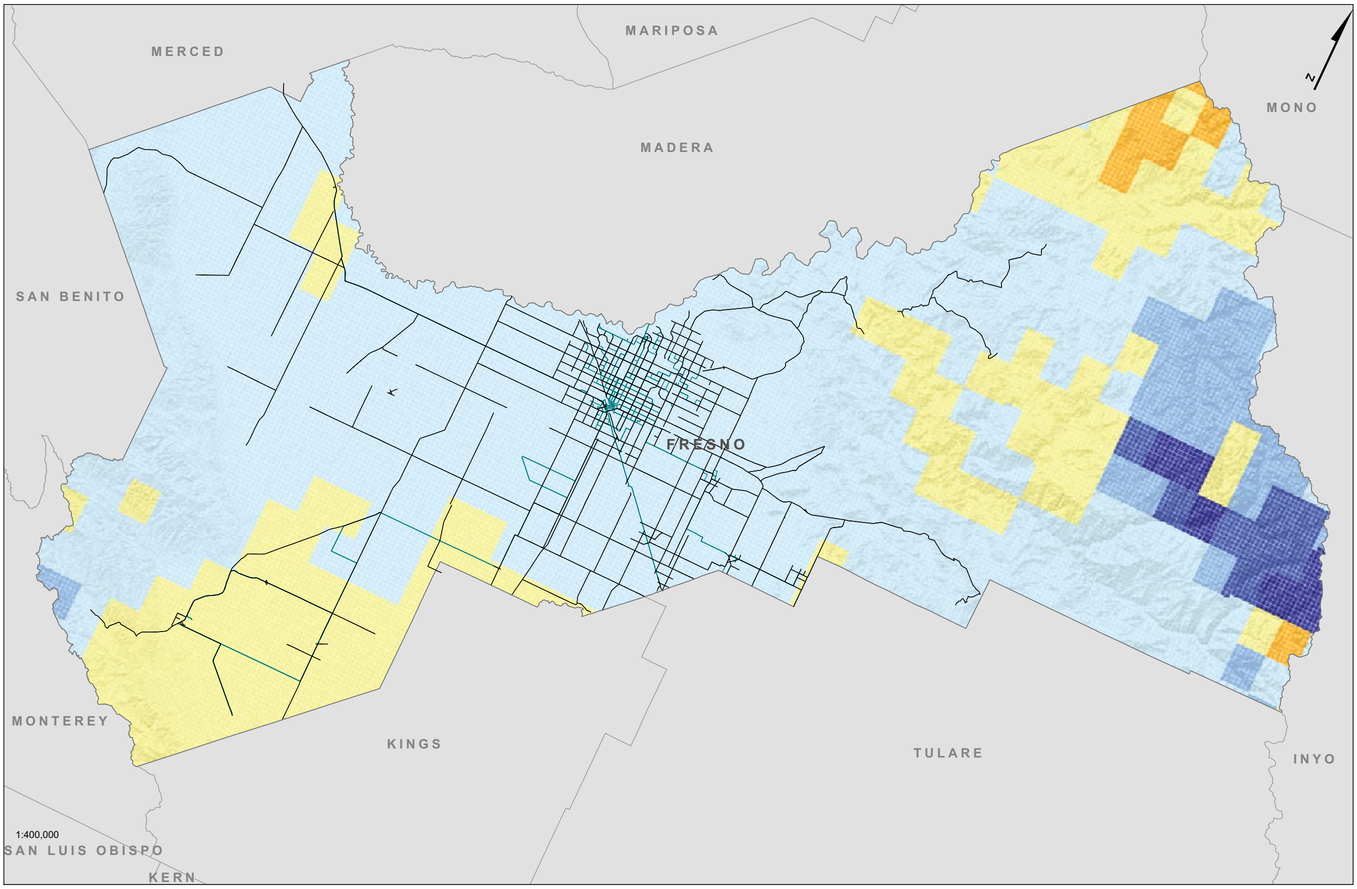
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Fresno Council of Governments

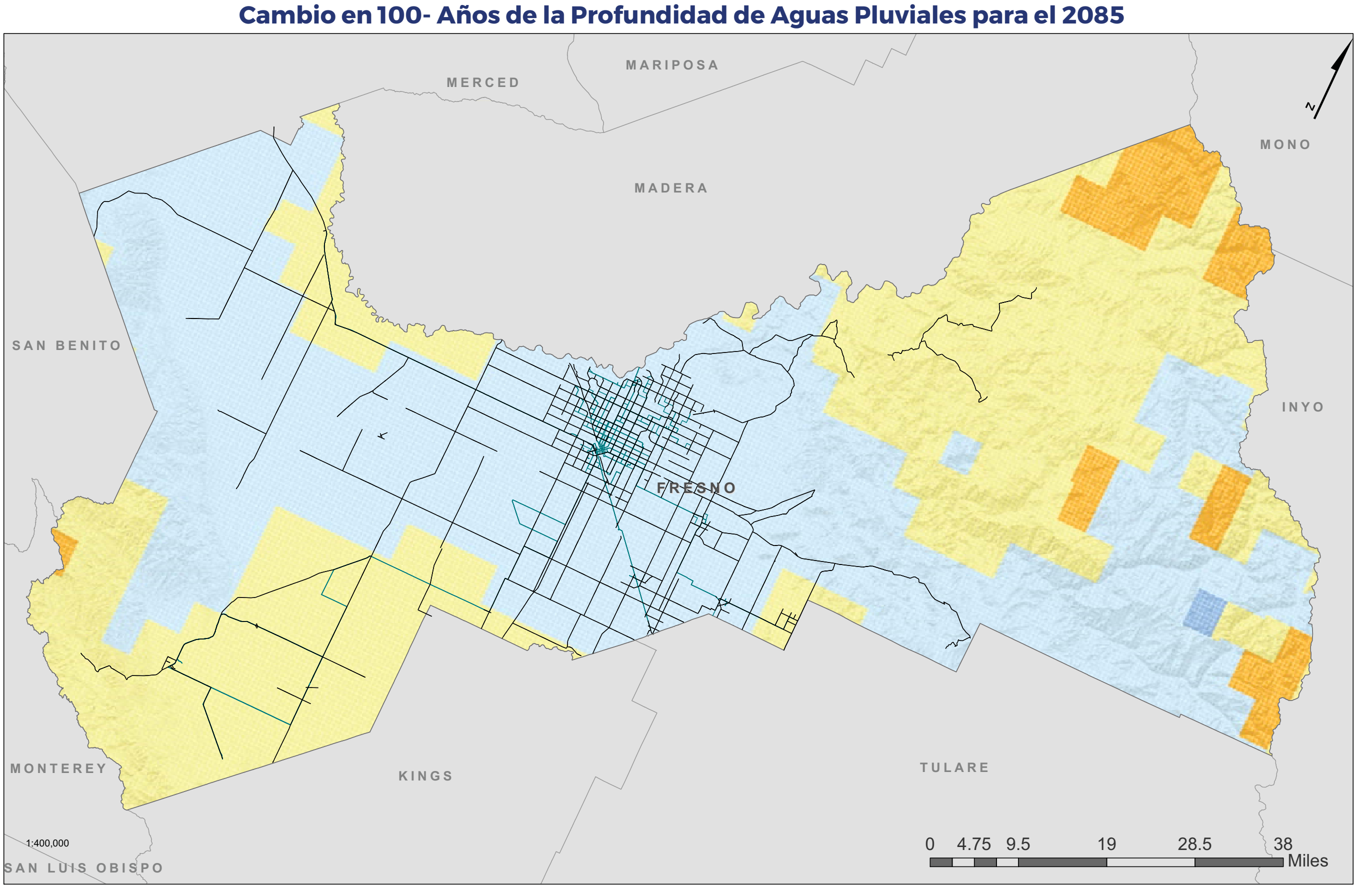
Has a weather event or other condition ever affected your ability to travel or required you to evacuate? Where?
¿Ha afectado algún evento climático u otra condición su habilidad de viajar o que haya tenido que evacuar? ¿En dónde?



Change in 100-Year Storm Depth by 2055
Cambio en 100- Años de la Profundidad de Aguas Pluviales para el 2055



Change in 100-Year Storm Depth by 2085
Cambio en 100- Años de la Profundidad de Aguas Pluviales para el 2085



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Transit Lines (Líneas de Transito)

2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

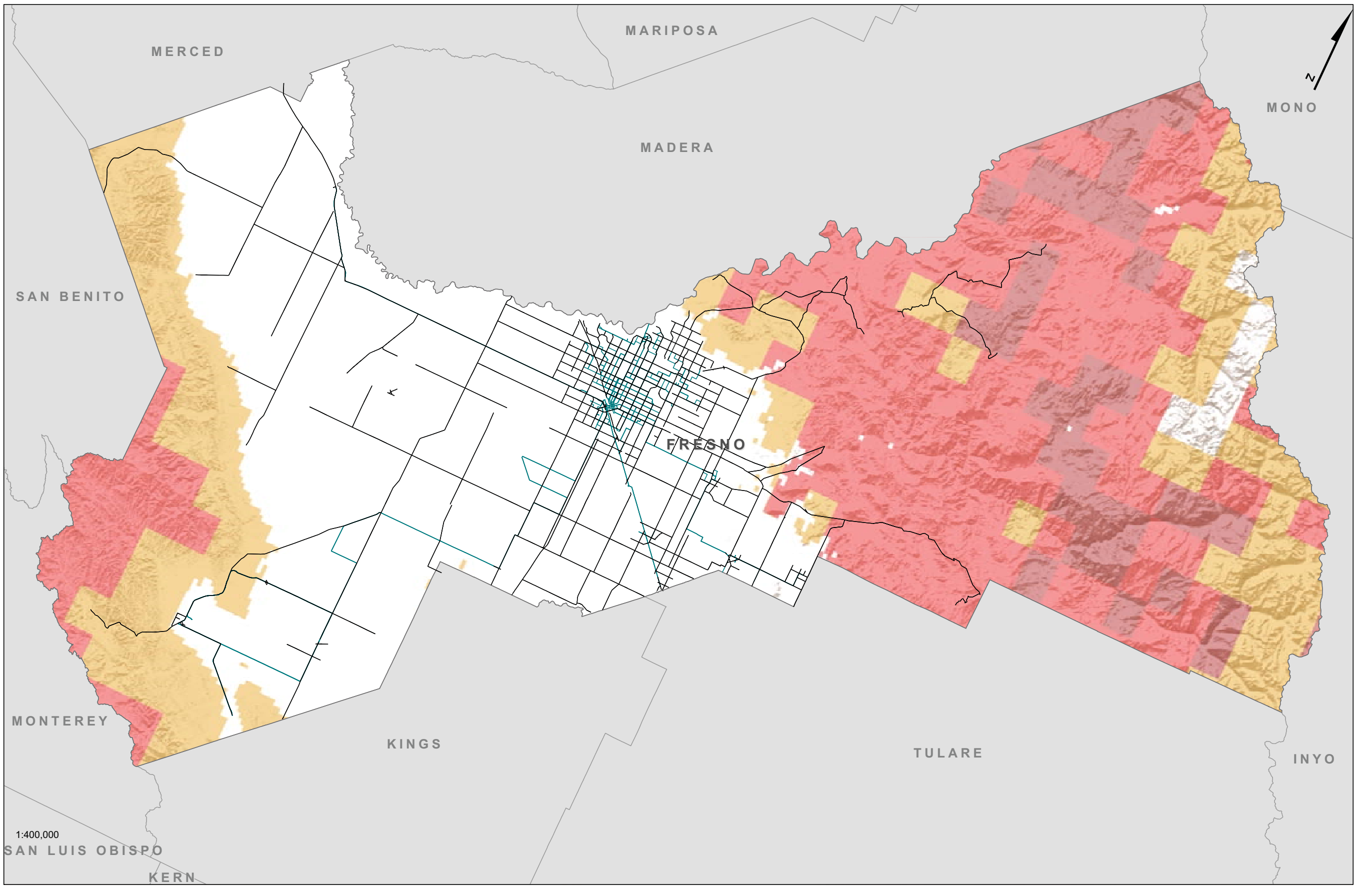
Inches Change in 100-Year Storm Depth - Historical to 2085 (Cambio en Pulgadas de 100- Años de la Profundidad de Aguas Pluviales - Historico hasta el 2085)

<-5 | -5 - 0 | 0 - 4 | 4 - 8 | 8 - 12 | >12

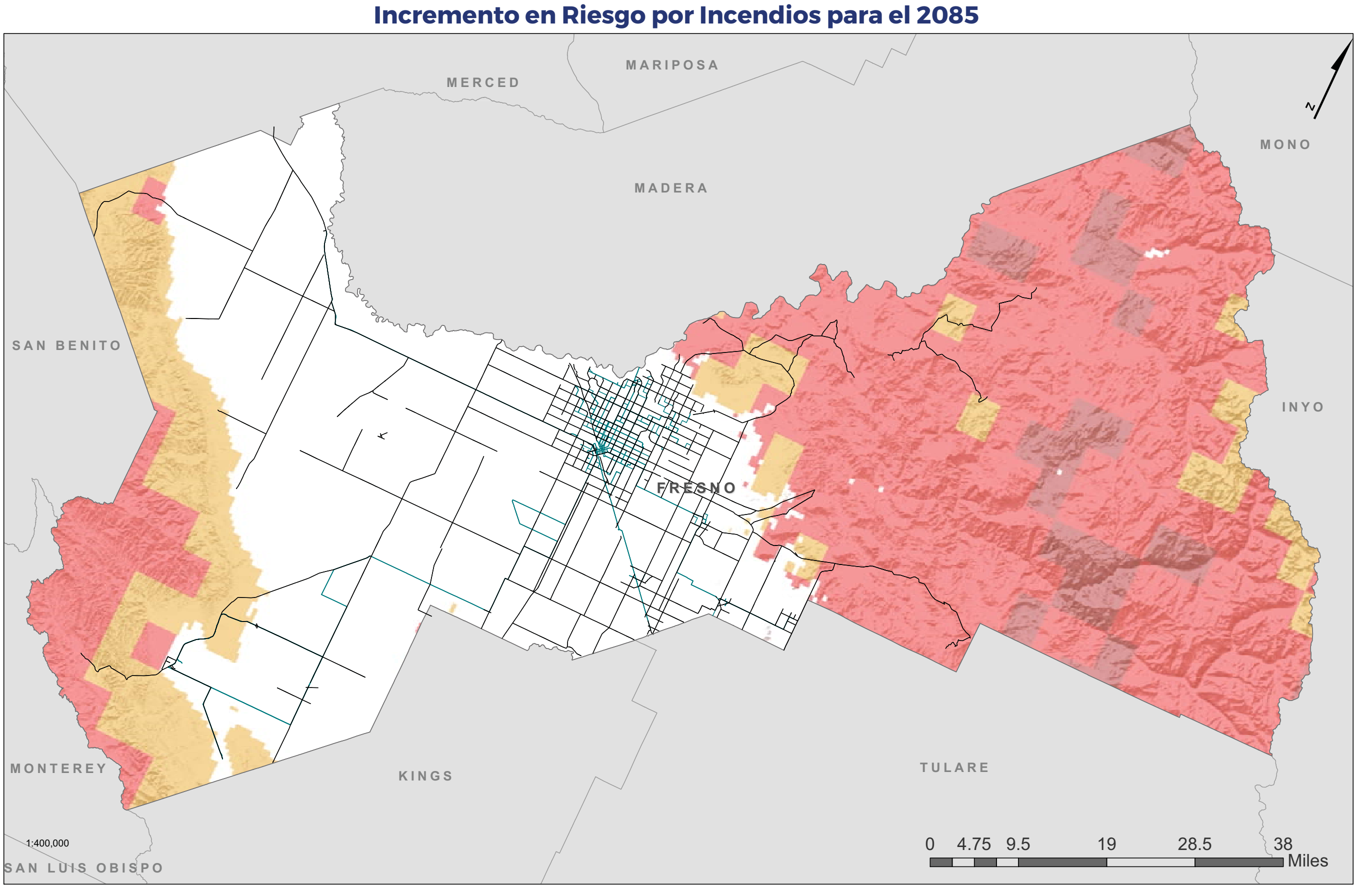
Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Source: CanESM2 Global Climate Model, downscaled by the Scripps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario. Results should be used with caution.

Increase in Wildfire Risk by 2055
Incremento en Riesgo por Incendios para el 2055



Increase in Wildfire Risk by 2085
Incremento en Riesgo por Incendios para el 2085



Transit Lines (Líneas de Transito)

2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

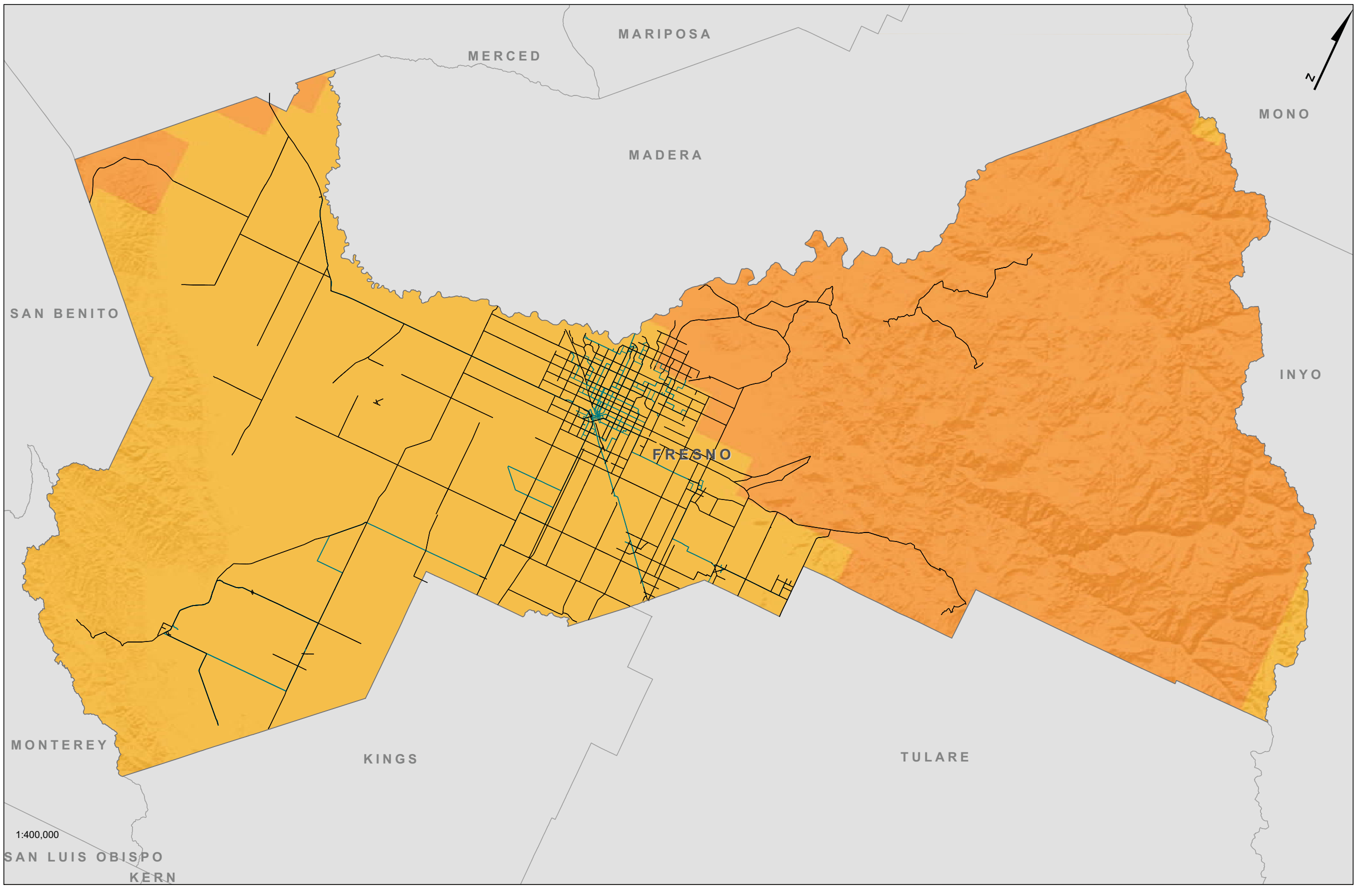
Level of Wildfire Concern RCP 8.5 (Nivel de Preocupación de Incendios RCP 8.5)

- Very High (Muy Alto)
- High (Alto)
- Moderate (Moderado)

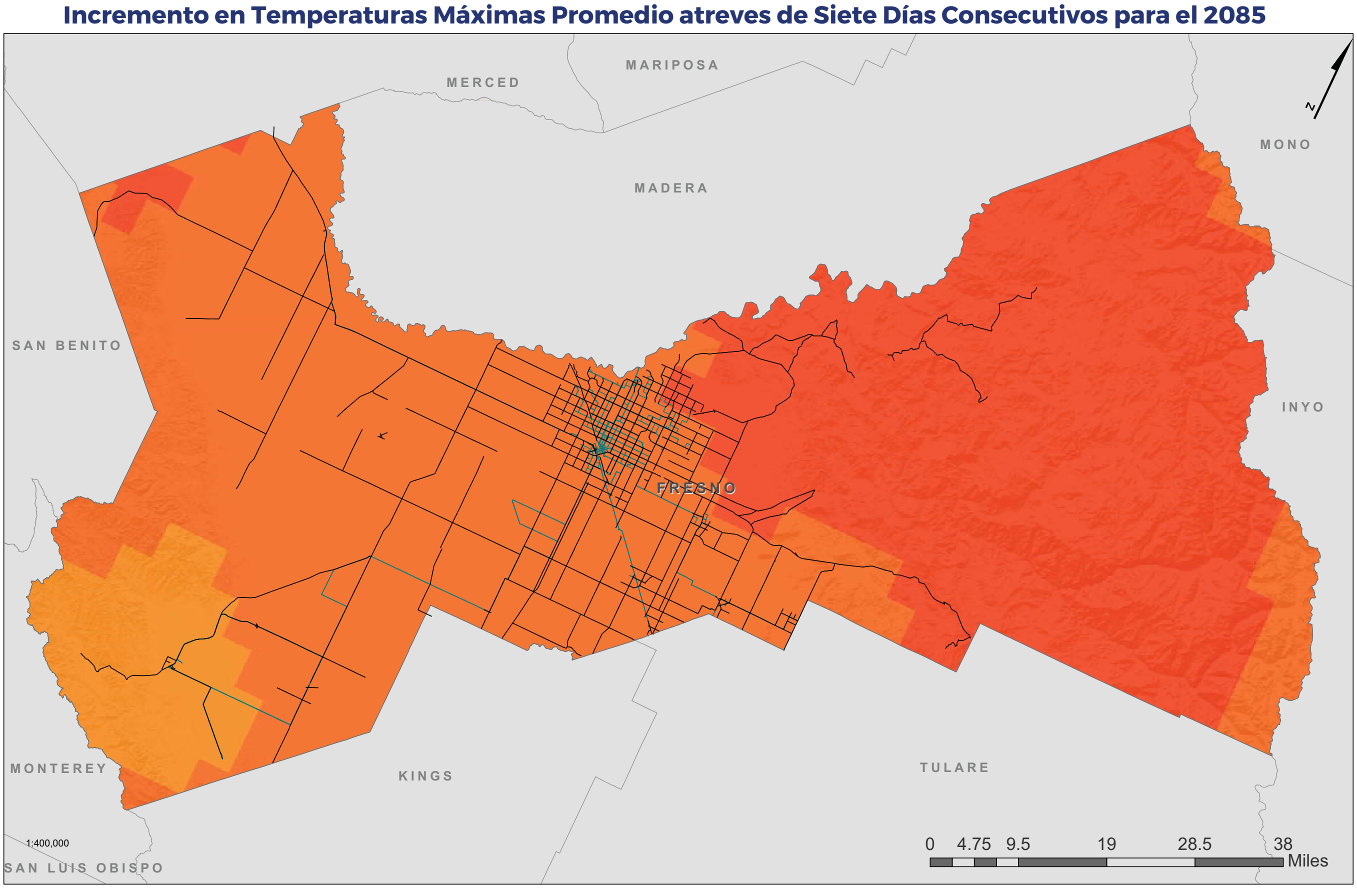
Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Source: Amalgamation of three fire models: 1) MC2-EPA Climate Impacts Risk Assessment, USFS, 2) MC2-Applied Climate Science Lab at the University of Idaho, 3) University of California Merced model.

Increase in Average Maximum Temperature over Seven Consecutive Days by 2055
Incremento en Temperaturas Máximas Promedio atreves de Siete Días Consecutivos para el 2055



Increase in Average Maximum Temperature over Seven Consecutive Days by 2085
Incremento en Temperaturas Máximas Promedio atreves de Siete Días Consecutivos para el 2085



Fresno Council of Governments

Transit Lines (Líneas de Transito)

2018 Roadway Network - Highways and Arterials (Red de Vías del 2018- Autopistas y Avenidas Principales)

Change in 7-Day Average Maximum Temperature (°F) (Cambio en Promedio de Temperatura (F°) Máxima de 7- Días)

-2.0° - -0.1°
0.0° - 1.9°
2.0° - 3.9°
4.0° - 5.9°
6.0° - 7.9°
8.0° - 9.9°
10.0° - 11.9°
12.0° - 13.9°

Fresno County Regional Transportation Network Vulnerability Assessment
Evaluación de Vulnerabilidad de la Red de Transporte Regional del Condado de Fresno

Source: CMCC-CMS Global Climate Model, downscaled by the Scrpps Institution of Oceanography using the Localized Constructed Analogs technique. RCP 8.5 emissions scenario.

Adaptation Strategies Summary Memorandum

Fresno Council of Governments

Fresno County Regional Transportation Network Vulnerability Assessment

Adaptation Strategies Summary Memorandum

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January 24, 2020

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Introduction

The Fresno Council of Governments (Fresno COG) conducted a Transportation Network Vulnerability Assessment (TNVA) for Fresno County to understand the potential impacts of climate change on the region's transportation infrastructure. The results of this TNVA are summarized in a Technical Memorandum that covers the assessment methodology and results. As part of the TNVA development process, the project team directly engaged with the community and Fresno COG stakeholders to understand the public's perspective on the threats of climate change. Findings and details on the community engagement process are summarized in a Public Outreach Synopsis.

The findings of the TNVA are also intended to help Fresno County jurisdictions with responding to Senate Bill 379, which requires that all cities and counties address climate adaptation and resiliency strategies in the next revision of the Safety Element of their General Plans. See the Senate Bill 379 section below for policy guidance.

The overarching objectives of the Fresno County Regional TNVA development process are to:

- Convene regional partners from multiple jurisdictions.
- Identify climate change impacts to multi-modal transportation infrastructure in the project area.
- Identify specific transportation infrastructure vulnerable to climate change impacts.
- Develop adaptation strategies and specific actions to remedy identified climate change-related vulnerabilities.

This memorandum addresses the final objective of the TNVA by summarizing adaptation strategies that can be implemented around the county to prepare for climate change impacts. This list of strategies is intended to act as a toolkit or menu of various response options, which Fresno COG and their stakeholders can pull from as needed. It is not intended to provide prescriptive recommendations for the county and its infrastructure. There are a wide range of responses for Fresno County to consider and they are based around changes to planning, policy, design, operations, and maintenance. Some strategies are more focused on natural or green infrastructure as opposed to engineered responses. There is no one response that is considered superior for addressing climate change-related vulnerabilities. The responses are context-dependent and should be considered and weighed individually depending upon the stressor of concern, project location, project budget and timeline, and other considerations. See the General Principles and Strategies section below for more information on how to generally evaluate and implement adaptation strategies.

The different adaptation options are summarized at a high-level by each climate stressor. The climate stressors assessed for the Fresno County Regional TNVA are:

- Temperature Rise
- Precipitation and Flooding
- Wildfire
- Landslides

Each section summarizes the main impacts to the transportation network that stem from these climate stressors and the variety of responses that mitigate those impacts. Each response includes descriptions of the strategy, the transportation network components it applies to, the co-benefits associated with the response, and resources to consult for more information.

To provide some examples of how these adaptation strategies can be incorporated into typical transportation projects, the final section of this memorandum highlights several Fresno County projects from the Regional Transportation Plan (RTP). These examples were chosen to demonstrate how climate change can be considered in transportation planning and identify some project types where adaptation strategies can be incorporated.

Senate Bill 379

Overview

California SB 379 requires that all cities and counties address climate adaptation and resiliency strategies in the next revision of the Safety Element of their General Plans by January 1, 2022. If cities and counties had a hazard mitigation plan when the bill was signed in October 2015, they can meet the requirements of the bill by instead updating their local hazard mitigation plan beginning January 1, 2017. SB 379 requires that the update include three core elements:

- **Vulnerability assessment** – Jurisdictions are expected to conduct and document a vulnerability assessment using data from sources including Cal-Adapt, California Adaptation Planning Guide, and relevant local, state and federal agencies, and considering historical materials and existing and planned development.
- **Set of adaptation and resilience goals, policies, and objectives –** These goals, policies, and objectives should be informed by the vulnerability assessment.
- **Set of feasible implementation measures** – The implementation measures should be designed to carry out the set of adaptation and resilience goals, policies, and objectives.

Additional information on the bill and the three primary requirements can be gleaned from reading the SB 379 bill text (California Legislature, 2015) and the Alliance of Regional Collaboratives for Climate Adaptation (ARCCA) guidance (ARCCA, 2016).

Fresno Transportation Network Vulnerability Assessment & SB 379

The Fresno Transportation Network Vulnerability Assessment (TNVA) can be utilized to help jurisdictions fulfill SB 379 requirements. The Vulnerability Assessment Summary Memo, completed earlier in the project, has information, maps, and data that can be used to help meet the first core obligation of SB 379. This document, the Adaptation Strategies Summary Memo, is a compendium of strategies that can be used to help meet the second core obligation of the policy. Jurisdictions can draw on the portions of these TNVA analyses that are most applicable to their local settings.

As the TNVA focuses primarily on transportation, climate impacts and adaptations pertaining to other sectors would also need to be considered. Jurisdictions also need to develop their own implementation measures. The implementation measures convey the “who does what” details of how the adaptation strategies are applied.

The Fresno County Multi-Hazard Mitigation Plan is another excellent resource for understanding the county’s climate-related hazards, strategies for mitigating these hazards, and how these mitigation strategies are implemented. While the plan focuses more on current rather than future climate conditions, it does include discussions about the impacts associated with climate change.

Strategies & Language for Addressing SB 379

We conducted research to understand how cities and counties across the state have addressed SB 379 to-date, by summarizing strategies for fulfilling the requirements and language used in the local hazard mitigation plans or general plans. In reviewing updates to these plans, it appears that many counties and cities are opting to incorporate by reference updates to their local hazard mitigation plans into their general plans to fulfill the requirements of SB 379. Also, given that general plan updates are not required to be completed until January 1, 2022, most of the updates identified in the research have been to hazard mitigation plans. Several examples are included below:

- **City of Los Angeles, Local Hazard Mitigation Plan (2018)** – Los Angeles has opted to update their local hazard mitigation plan to fulfill the requirements of SB 379, which is explicitly addressed in the update. Additionally, LA has integrated by reference the “Sustainable City Plan” into their local hazard mitigation plan. LA adopted a specific chapter on climate change, titled “Climate Change and Sea Level Rise,” which provides an overview of what climate change is and also discusses in more detail how climate change will impact the identified hazards of concern. Climate resilience and adaptation strategies are then incorporated into the mitigation strategies for each identified hazard of concern, rather than as standalone mitigation alternatives (City of Los Angeles Emergency Management Department, Tetra Tech, 2018).
- **Humboldt County Operational Area Hazard Mitigation Plan (2019)** – Humboldt County updated the Action Plan Implementation Section of the hazard mitigation plan to address SB 379. The plan has a chapter dedicated to climate change, including overviews of vulnerability assessments conducted in relation to hazards identified in the report (dam failure, drought, earthquake, flood, landslide, sever weather, tsunami, wildfire, and sea level rise). Climate change impacts are discussed in other sections of the report as well. Much like Los Angeles—the reports were prepared by the same consulting firm—the plan’s mitigation strategies incorporate climate change into strategies for identified hazards rather than having a standalone section (Humboldt County Office of Emergency Services, Tetra Tech, 2019).
- **Inyo County Multi-Jurisdictional Hazard Mitigation Plan – City of Bishop (2017)** – Inyo County formally has incorporated by reference the multi-jurisdictional hazard mitigation plan into the Public Safety Element of the county’s general plan (Inyo County Planning, 2018). Inyo County’s approach to addressing climate change was to not develop a separate section on climate hazards, but to discuss the projected effects climate change has had/will have on each type of hazard. The plan states, “Climate change is not profiled as a distinct hazard, but rather a phenomenon that could exacerbate hazards. Climate change will be considered as a factor for relevant identified hazards” (Inyo County, City of Bishop, 2017)
- **San Diego County Multi-Jurisdictional Hazard Mitigation Plan (2018) & the City of San Diego General Plan, Public Facilities, Services, and Safety Element (2018)** – The City of San Diego’s General Plan references working with the County of San Diego to make updates to the hazard mitigation plan to address climate adaptation and resiliency in fulfillment of SB 379. The County’s hazard mitigation plan approached climate change as an impact that exacerbates other hazards, stating, “Climate change was not included as a hazard. However, the impact of climate change on the identified hazards was included in the evaluation of hazards and their impacts.” As a result, strategies to address climate change are incorporated into goals to address identified hazards, not as a standalone section (City of San Diego, 2018).

General Principles and Strategies

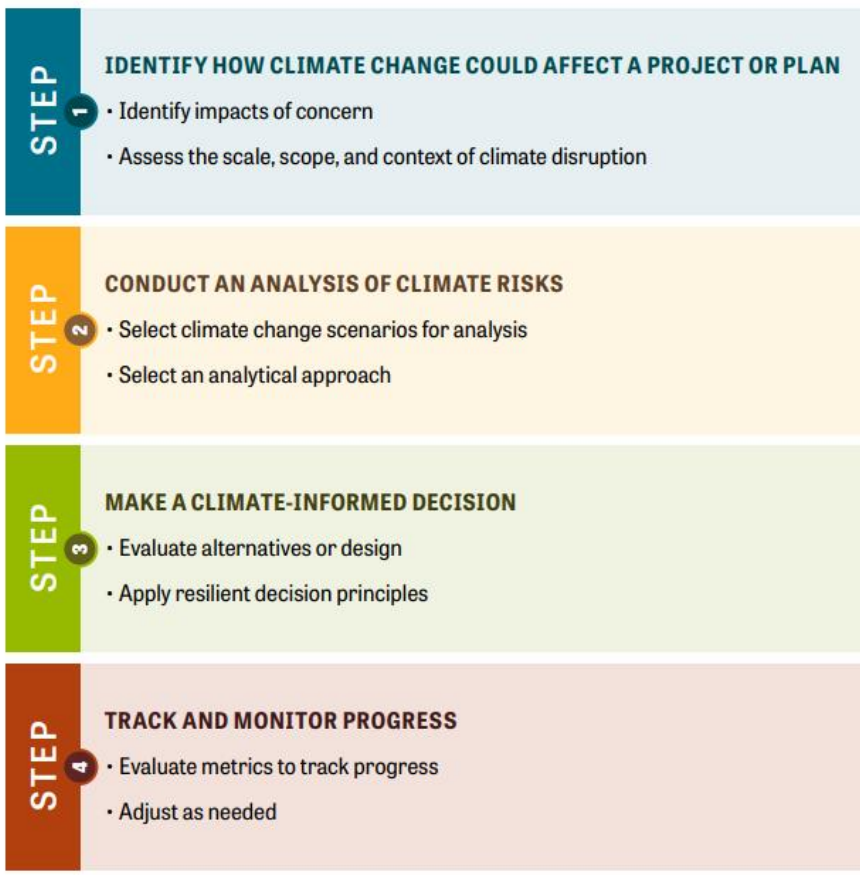
The term adaptation refers to an action taken to address a risk related to climate change. Transportation infrastructure has always interacted with the natural environment and its potential hazards, including flooding, high temperature, wildfire, and landslides. Infrastructure managers, operators, planners, and designers already have an arsenal of strategies for addressing these hazards. Thus, an adaptation is often simply an application of one of these traditional strategies. But the principles behind adaptations and adaptation decision making are different. Most current practice in Fresno County, the State of

California, and the U.S. assumes that the properties of the climate and its associated hazards will remain constant over time. As research and experience show that this assumption is unwarranted, different principles and methods are needed to address the risks associated with climate change and enable the transportation system to fulfill its objectives related to mobility, economic activity, public health, social equity, and the environment.

Processes and Resources

There are numerous resources and guidance documents on adaptation strategy approaches and evaluations, and this document will highlight a few of these rather than exhaustively catalogue them. The California Governor's Office of Planning and Research (OPR) guidebook entitled *Planning and Investing for a Resilient California* aims to "inform planning and investment processes to address the two primary elements of resilience – planning for future conditions and doing planning itself differently" (Governor's Office of Planning and Research, 2018). Figure 1 shows the OPR guidebook's high-level process for adaptation planning.

Figure 1: OPR's Process for State Agencies to Integrate Climate Change into Decisions



The Federal Highway Administration (FHWA) Adaptation Decision-Making Assessment Process (ADAP) is facility-level framework that helps transportation practitioners analyze climate hazards and evaluate adaptation options (see Figure 2) (FHWA, 2019). ADAP addresses some of the key challenges associated with climate change and transportation systems:

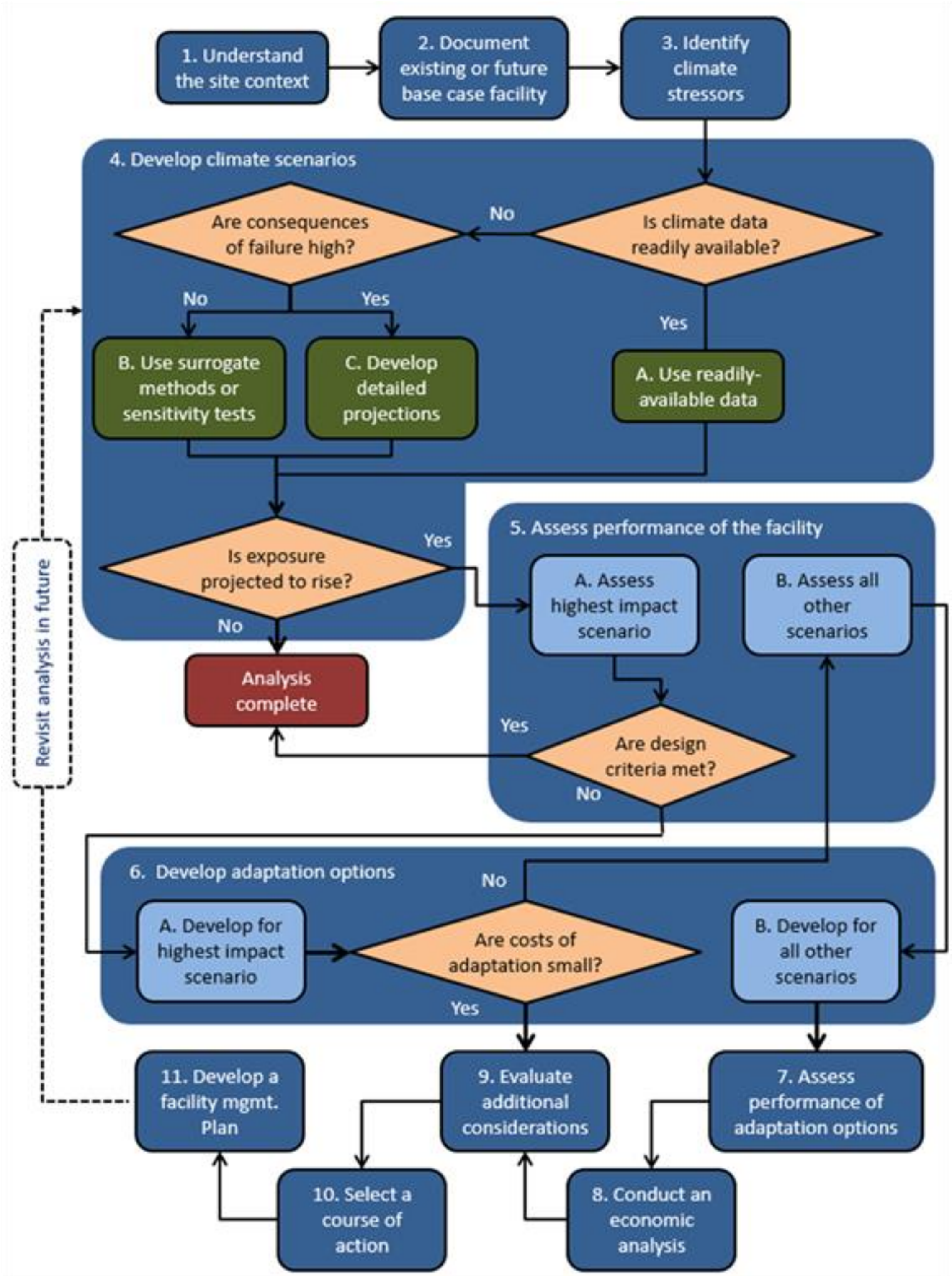
- The status quo assumption that historical climate conditions will remain the same in the future. This is often referred to as stationarity.
- The status quo assumption that we have certainty about climate conditions and other inputs into the design process. However, there is imperfect information about climate hazards and other factors attributing to risk. There is much uncertainty about the climate, whether it be historical, current, or future.
- The lack of accounting for the full consequences of infrastructure failure. The traditional planning and design process does not consider the costs of failure, including both damage and disruption, and how these affect the wider system and its users.

The ADAP process is a risk-based approach that addresses these challenges through several features:

- It uses climate scenario analysis to understand how an asset would perform under different future conditions. This helps address uncertainty and incorporate the best available information about future conditions.
- It assesses benefits and costs of different action alternatives across the lifecycle of the facility, accounting for how climate conditions could change over time. It includes measures of cost effectiveness (e.g., Net Present Value), which are helpful for decision making and making a case for support and funding for an alternative.
- It includes a consideration of socioeconomic benefits and costs in addition to damage repair and lost revenue estimates. ADAP includes ways to incorporate monetizable socioeconomic values (i.e., cost that can be estimated in dollar terms) and non-monetizable socioeconomic values.

The FHWA website describes the ADAP process and rationale behind in detail. ADAP was developed as part of FHWA's Transportation Engineering Approaches to Climate Resiliency (TEACR) project, and the TEACR website provides example applications of the ADAP framework that practitioners can reference (FHWA, 2019).

Figure 2: FHWA's Adaptation Decision-Making Assessment Process



At the local level, the Vulnerability Assessment memo for this study (the Fresno COG Transportation Network Vulnerability Assessment) references other tools and resources that can be used for adaptation planning. These include the Fresno County Multi-Hazard Mitigation Plan.

Policy and Funding

Aside from SB 379, there are other policies and programs that are relevant for adaptation planning in the Fresno region.

California Executive Order (EO) B-30-15, signed in 2015, requires that state agencies (and, therefore, the infrastructure they fund) "take climate change into account in their planning and investment decisions" (Office of Governor Edmund G. Brown Jr., 2015). It requires them to use "full life-cycle cost accounting to evaluate and compare infrastructure investments and alternatives." Assembly Bill 2800, approved in 2016, codifies EO B-30-15. It requires state agencies to account for "current and future impacts of climate change when planning, designing, building, operating, maintaining and investing in state infrastructure (California Legislature, 2016)."

The implication of these policies is that local agencies that understand their climate-related risks and seek to make their systems more resilient will be better positioned to obtain state funding for these projects and activities. They may also be better positioned for federal funding. The Federal Emergency Management Agency (FEMA) will soon increase its pre-disaster funding, which aims to protect infrastructure and communities from hazards before they occur. Its new pre-disaster program is called Building Resilient Infrastructure and Communities (BRIC). BRIC authorizes a "National Public Infrastructure Pre-Disaster Mitigation fund, which will be funded through the Disaster Relief Fund as a six-percent set aside from estimated disaster grant expenditures" (FEMA, 2019). This six-percent set aside will likely represent a larger, more reliable source of funding (Holdeman, 2019). In addition to public programs, private lenders, insurers and credit rating agencies have demonstrated more concern about climate-related risks embedded in financial instruments and insurance policies.

Figure 3: Yolo Bypass: Central Feature of the Sacramento River Flood Control Project

Source: California Department of Water Resources

While this document does not provide background on potential funding sources for each adaptation strategy presented, there are some helpful general resources for identifying funding sources. The [State Adaptation Planning Clearinghouse has a page on funding opportunities] organized by sector. The [U.S. Climate Resilience Toolkit also lists potential funding sources]. Funding sources can vary considerably by strategy type. Furthermore, many investments with a resilience element need not seek funding solely from resilience-specific sources. Demonstrating that a potential investment can make an asset or system more resilient can help it obtain funding from traditional transportation funding sources.

Co-Benefits

Co-benefits are other key considerations of adaptation planning. These are the additional benefits that may stem from a single adaptation strategy, which positively influence the surrounding community and social equity, natural resources, greenhouse gas mitigation, and/or the local economy. Natural infrastructure solutions can provide a variety of different co-benefits.

For example, project landscaping can be designed so that it is an adaptation strategy that reduces risks from temperature rise, flooding, and wildfire, and it also provides co-benefits by reducing greenhouse gas emissions, providing habitat and green space, and even recreational activities.

The benefits that are generated by an adaptation strategy depend on the factors such as the local geography, environment, and community. What is most beneficial depends upon location. For example, planting shade trees to reduce Urban Heat Island (UHI) would be more beneficial along a roadway in a low-income neighborhood then along a highway with no pedestrian access.

Where applicable, the adaptation strategies summarized in this memo will outline relevant co-benefits associated with that response.

Understanding Consequences of Design Criteria Exceedance

Transportation assets are often engineered to withstand certain design events or similar standards. For instance, a critical roadway might be designed to remain in service during a 50- or 100-year storm (i.e., a storm that has a 2% or 1% chance of occurring each year). A design event is selected based on the risk tolerance for the facility. An agency with a relatively low risk tolerance for an asset would typically use a relatively low probability (and therefore higher magnitude) design event. But design event can occur at some point over its service life due to statistical chance, uncertainties in the underlying nature of the climate event, uncertainties in the infrastructure design, maintenance practices, changing land use patterns, changing climate factors (i.e., non-stationarity) and other factors.

Practitioners can make the system more resilient by understanding the consequences of exceeding an asset's design event. This includes information about what magnitudes of hazards could substantially affect an asset (e.g., flood elevation, discharge rate, temperature threshold). It also includes information about how the asset itself could be affected, including damage and disruption costs associated with those magnitudes (West Riverside Council of Governments, 2019). Consequence information can be used during the design process and later in an asset's lifecycle to improve performance from an operations and maintenance perspective.

A simple way to examine consequences is to require that designers assess and document the consequences a check event, which refers to an event whose magnitude exceeds the design event.[1] For example, an asset with a design storm recurrence interval of 100 years could have a check storm recurrence interval of 500 years. For higher risk facilities, a more comprehensive analysis may be

1 For example, see https://flh.fhwa.dot.gov/resources/design/pddm/Chapter_07.pdf

warranted, particularly given the expected changes in climate conditions.

Other Principles

Decision making timing is another important factor in climate adaptation. Adaptation can require increased capital spending depending on the facility and applicable strategies. In these cases, there can be opportunities for agencies to incorporate adaptation into their other projects and planning activities. For instance, whereas modifying a bridge to withstand higher magnitude floods might be a costly effort in and of itself, if the asset is to be replaced or repaired anyway, it could be a cost-effective opportunity to adapt it to those higher floods. Furthermore, because climate change is a relatively long term trend, there is a temptation to delay response and take a reactive approach. This may be sufficient in some cases, but in others it might be cost effective to be more proactive. By assessing the lifecycle costs and benefits of adaptation and no action options (see "Processes and Resources" above), practitioners can better understand how best to time their adaptation-related activities.

Community engagement is another crucial component to adaptation planning. With knowledge of the challenges facing the communities they represent, agencies can better cater adaptation responses. This is particularly important in disadvantaged communities, where members may not have access to resources necessary to respond to extreme events or changing climate conditions. The resources can include funding to address damaged property or infrastructure or equipment such as vehicles that can be used for evacuation or for avoiding extreme weather conditions. There is also a need for stakeholder and public education regarding climate change risks and adaptation options. Increased awareness can enhance the capacity of communities to respond to hazards. This could include knowledge of evacuation best practices or who to contact when extreme events do occur.

Temperature Rise

Climate change-related temperature rise and the UHI effect can result in impacts to 1) health and community and 2) the operations of transportation assets. This section discusses these two categories of impacts and the possible responses Fresno COG and members can adopt to respond to and mitigate these impacts.

Health and Community Impacts

Increased temperatures can impact human health and put additional stress on communities, resulting in 1) heat stress, 2) reduced access to transit, and 3) increased localized air pollution.

The body can regulate its temperature on a hot day, but more stress is put on the body if there are multiple high heat days in a row and/or if temperatures do not cool off at night. These events can lead to risk of heat-related illnesses, especially if those affected cannot escape the heat and rest in a cool area. Vulnerability to heat impacts varies geographically and with certain population characteristics. Key vulnerability factors include age, socio-economic status, pre-existing health, pregnancy, occupation, as well as geographic variables such as local surface temperature, tree cover, and distance from the coast.

High heat days can also have secondary health and community impacts, including the degradation of localized air quality. Customer energy demand rises during warm months due to the need for air conditioning. Increased energy demand and consumption will also lead to higher emissions of greenhouse gases and unhealthy air pollutants.

Responses

Shaded Bus Stops

Brief Description: Providing shade at bus stops can address the health and transit accessibility implications of climate change-related high heat days by keeping riders cooler while waiting for transit services. Many survey results noted that bus stops lack shelters around Fresno County, which can cause a disproportionate burden on low-income, transit-dependent, and rural transit riders who may be required to travel further to access a bus stop. Shade protection can be provided by building shade canopies or by planting trees near transit stops, which relates to the section on vegetation cover below. More advanced options to provide shade and cooling for riders at transit stops include installing misters, water fountains, and benches. Additionally, bus shelters can be installed with green roofs, solar panels, or even enclosed shelters with air conditioning.

Figure 4: Shaded Bus Stop

Source: City of Santa Monica

Relevant Transportation System Components: Transit stops & passengers

Co-Benefits: Increased urban shade/decreased UHI, benefit to public health and safety

Resources:

- See the resources listed under the Vegetation Cover strategy for natural shading resources.
- The Caltrans' Complete Streets Elements Toolbox provides information on roadway elements that can be adopted to provide multi-modal mobility and access, including transit stops.
- National Association of City Transit Officials (NACTO) Transit Street Design Guide discusses bus station and stop elements.
- Transit Cooperative Research Program (TCRP) provides Guidelines for the Location and Design of Bus Stops, including guidance on shading.
- Potential funding sources include the FTA Buses and Bus Facilities Program; FTA Formula Grants for Rural Areas; and the California State Transit Assistance Program and State of Good Repair Program.

Figure 5: Tree Shaded Transit Stop, Escondido, CA

Vegetation Cover (Urban Forestry)

Brief description: Increasing vegetation cover by planting more trees, also known as urban forestry, can be used as a strategy to combat the temperature rise and the UHI. Increased tree cover increases the amount of shade and can help to reduce exposure to high heat and as a result reduce the risk of health and community impacts for transit riders and the general public. Trees should be planted in strategic areas, such as along roadways and sidewalks. Vegetation cover can also be deployed in a targeted fashion to provide shade at rural bus stops where riders may need to travel further to access the stop and also in areas of the county with dense transit-dependent populations. This strategy was a recommendation from the FCOG TNVA community survey.

Relevant Transportation System Components: Transit stops, roadways & passengers

Co-Benefits: Improved air quality, greenhouse gas mitigation

Resources:

- Sacramento Metropolitan Utility District's (SMUD) initiative "Shading Sacramento" can be a model for urban forestry in Fresno.
- Tree Fresno could be a potential partner for a Fresno-based initiative.
- Calscape's California Native Plant Gardening Guide provides information on what types of plants thrive where.
- Climate Change Response Framework provides resources on different tree species and their vulnerability to climate change.
- The U.S. Forest Service has resources about how tree species distribution will change due to climate change.

- The Caltrans' Complete Streets Elements Toolbox provides information on roadway elements that can be adopted to provide multi-modal mobility and access, including transit stops.
- Potential funding resources include the CAL FIRE Urban and Community Forestry Grant Programs; National Urban and Community Forestry Advisory Council grants; and the Vibrant Cities Lab Urban Forestry Toolkit Funding section.

Cooling Centers

Figure 6: Fresno Cooling Centers

Source: Fox 26 News

Brief Description: Establishing cooling centers is a strategy to address human health hazards associated with high-heat conditions and the UHI effect (West Riverside Council of Governments, 2019). Cooling centers are air-conditioned public locations where individuals can keep cool during high-heat and extreme heat days. Fresno County's local jurisdictions already offer cooling centers on high-heat days and local transit agencies provide free transit to those cooling centers. The county may consider conducting a small study to better understand who utilizes cooling centers, when, and how people access the center. This study could be particularly helpful to meet the needs of socially vulnerable populations, such as low-income and minority residents who may have limited access to air conditioning and to transportation to get to cooling centers. This information is currently unavailable and the results of this study could inform strategies local jurisdictions take to enhance the effectiveness of cooling centers. Depending on the results from the study, enhancements could include offering expanded hours, more locations, increased messaging and advertising about cooling centers and free transit opportunities, and on-demand transit to cooling centers.

Relevance to Transportation System: Passengers

Co-Benefits:

- Increased access to cooling centers and other community resources such as free transit to cooling centers.
- Targeted access improvements for low income and minority.

Resources:

- The Cal Office of Emergency Services (OES) has a cooling center checklist in their Contingency Plan for Excessive Heat Emergencies.
- The U.S. Centers for Disease Control and Prevention's report titled "The Use of Cooling Centers to Prevent Heat-Related Illness,"

Figure 7: Poor Air Quality in Fresno

Source: Fresno Bee

offers additional guidance on how and when to hold cooling centers.

Mitigating Air Quality Impacts

Brief Description: Air quality worsens in high-heat environments (Fann, et al., 2016). Given temperature projections, it is important to improve air quality as it is expected to worsen over time. Low-income populations are particularly at risk of exposure to poor air quality and the subsequent health risks (American Lung Association, 2018). One way to mitigate air quality impacts is to adopt transportation technologies and practices that limit pollution and emissions, such as early adoption of battery electric buses in place of diesel emission vehicles (transit bus fleets must be zero emission by 2040). Transportation agencies and local jurisdictions can also strive to reduce energy consumption through adopting more sustainable practices. Taking small steps to increase energy efficiency can have a large impact over time. Building energy auditing and weatherization are simple and cost-effective ways to understand building energy use and take actions to reduce consumption. An energy audit is an assessment of how much energy a building uses. Weatherization is the act of making minor building upgrades to mechanical systems, health and safety systems, the building shell, and electrical baseload, to increase the building's efficiency. Upgrades may include replacing hot water systems with newer devices, insulating hot water pipes, changing lighting to LEDs, and installing new/additional insulation. Installing renewable energy systems like solar arrays are another way to reduce fossil fuel consumption. Transportation agencies can also use roadside landscaping to improve surrounding air quality, while reducing greenhouse gas emissions.

Relevance to Transportation System: Passengers

Co-Benefits: Long-term community health benefits, particularly for low-income populations and environmental quality

Resources:

- The Fourth National Climate Assessment chapter on Climate and Health discusses the relationship between air quality and high heat in detail.
- The California Air Resources Board offers resources on sustainable transportation strategies, which can help mitigate air quality issues, including case studies that reflect best practices.
- The Office of Energy Efficiency and Renewable Energy provides useful information on energy auditing and weatherization.
- The Environmental Protection Agency has conducted research specifically on how roadside vegetation strategies can be employed to improve surrounding air quality.

Multilingual Notification During Poor Air Quality Events

Brief Description: When the Air Quality Index (AQI) indicates poor air quality, it is important that all residents be notified. By distributing air quality alerts and notifications in multiple languages, and via multiple communication methods, including social media, television, radio, and newspapers, local jurisdictions can help to reduce exposure to poor air quality to reduce the risk of health implications.

Relevance to Transportation System: Passengers

Co-Benefits: Improved equity and inclusivity of community health benefits

Resources: The Federal Communications Commission published a report on recommendations for multilingual emergency alerting.

Pavements

Higher average temperatures and higher extreme maximum temperatures can impact the level of service and useful life of pavement, due to warping, cracking, rutting and shoving. Caltrans and the California State Transportation Agency consider minimum and maximum air temperatures in a region when choosing a binder for a pavement mix (Caltrans, 2019). The binder is essentially the "glue" that holds the aggregate together in pavement, ensuring that the bonds continue to hold when the pavement expands and contracts with temperature. When temperatures reach outside of these specifications, they can cause thermal cracking and pavement distortion (Qiang Li, 2011).

A flexible pavement transfers load (the weight from vehicles on the road surface) from grain to grain of the aggregate material down to the earth below, whereas a rigid pavement is made of concrete slabs that distribute the load over a wide area. Both can be distorted and damaged under higher temperatures, though the types of impacts vary between the two pavement types. Flexible pavements have an increased potential for rutting and shoving under higher average temperatures and the asphalt binder can harden with age (Sadasivam, 2019). Rigid pavements have an increased potential of curling and moisture related warping under higher average temperatures. Under extreme temperatures and high heat events, flexible pavements can experience asphalt rutting and shoving, and rigid pavement slabs can expand, causing slab buckling (Qiang Li, 2011).

Responses

Pavement Design

Brief Description: Adopting adapted pavement engineering design alternatives can mitigate the impacts the high temperatures can have on traditional pavement, and in turn maintain level of service and the useful life of the asset into the future. Engineered mitigation focuses on improving the adaptive capacity of pavements through enhancing structural resilience, improving the durability and quality of pavement materials and construction, and reducing the likelihood of the onset and progression of various forms of pavement distresses (West Riverside Council of Governments, 2019). There are several pavement engineering design strategies, including:

Figure 8: Impacts of Higher Temperature on Pavement

Source: Caltrans District 8 Climate Change Vulnerability Assessment, 2019

- Review and revise pavement design policies, as necessary, to incorporate future climate forecasts instead of historical climate records, tighten-up design criteria, and increase the design reliability to incorporate climate uncertainties in decision-making.
- Select more durable materials to withstand the adverse effects of future temperature and moisture trends.

- Encourage or enforce best practices to improve materials and construction quality.

Relevant Transportation System Component: Pavement/Roads

Co-Benefits: Context-dependent

Resources:

- AASHTO maintains a Mechanistic-Empirical Pavement Design Guide.
- FHWA LTPPBind Online is an FHWA tool that helps agencies investigate asphalt binder performance grade.

Asset Management

Brief Description: Incorporating climate projections into pavement asset management can mitigate heat-related impacts to pavement, and help to maintain level of service. Transportation agencies can utilize pavement deterioration models to identify when treatments are needed and how quickly pavement will degrade (Sadasivam, 2019). Deterioration models can be developed using predicted climate data as well as mechanistic-empirical design models currently implemented in CalME and AASHTOW are Pavement M-E for flexible and rigid pavements, respectively.

Figure 9 provides an example of deterioration model results and pavement condition impacts over time (FHWA, 2016). Incorporating climate data into these models is a helpful way to understand pavement performance over its lifespan and when rehabilitation is needed. By operationalizing this data in maintenance practices Fresno County transportation agencies can improve pavement level of service countywide.

Most local jurisdictions in Fresno County use a regional pavement management system called StreetSaver to document pavement quality and condition over time. StreetSaver also has a prediction model, which projects maintenance requirements and costs up to 30 years out. Tools like StreetSaver can help track data related to location, pavement damages and distress, and lifespan that can be used to maintain and monitor pavements into the future. The tool can also be used for asset management of other non-pavement assets like signs and roadside infrastructure. Users may also explore how to integrate climate data into the StreetSaver pavement system to evaluate how maintenance requirements, pavement lifespan, and costs will change as temperatures rise.

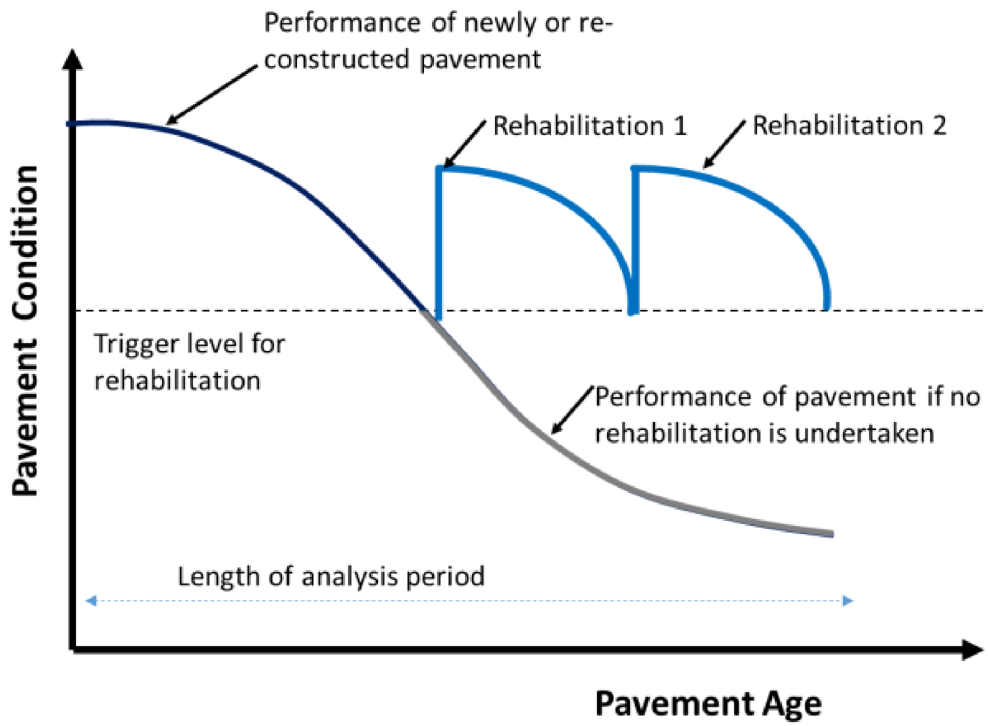
Relevant Transportation System Component: Pavement/roads

Co-Benefits: Context-dependent

Resources:

- AASHTO Mechanistic-Empirical Pavement Design Guide
- CalME, A Mechanistic-Empirical Program to Analyze and Design Flexible Pavement Rehabilitation
- StreetSaver, a tool used to document pavement performance and lifespan

Figure 9: Changing Pavement Conditions with and without Rehabilitation



Source: FHWA Temperature and Precipitation Impacts to Pavements on Expansive Soils: Proposed State Highway 170 in North Texas (FHWA, 2016)

Bus Operations

Battery Electric Buses (BEBs) are also vulnerable to heat-related impacts. BEBs are being deployed across California, due to the state's mandate to transition to 100-percent zero-emission bus fleets by 2040 to meet greenhouse gas reduction goals. Heat impacts to BEBs are not well-documented yet, but potential risks include increased energy usage, increased associated costs, decreased vehicle range, and reliability concerns for the battery. Research from the National Renewable Energy Laboratory indicates that the desired operating temperature to maximize efficiency for a BEB ranges between 59 and 95°F, meaning that as temperatures rise, BEB batteries may be operating at lower efficiencies (National Renewable Energy Laboratory, 2011). Substations, signal rooms, and electrical boxes are also at increased risk of failure outside of the temperature range for which they were designed.

Responses

Power Redundancy

Brief Description: Given that BEBs may contend with efficiency and performance challenges in high-heat conditions, transit agencies can consider having on-site power generation, on-site power storage, and or multiple power sources connected to the BEB charging facility (National Academies of Sciences, Engineering and Medicine, 2018). Additionally, high-heat days pose risks to the efficacy of the energy grid in general, which BEBs need to charge. To mitigate this risk, transit agencies can consider supporting local or regional efforts to develop micro-grids for energy resilience and to be able to reliably charge BEB fleets. Fresno County Rural Transit Agency (FCRTA) received a grant for an electrical grid analysis study for rural Fresno County to assess whether the current grid system is sustainable and can support EV charging infrastructure countywide. This plan, which is expected to be completed in January 2022, will provide local cities with valuable information, such as areas in greatest need of electrical grid improvements and the associated costs, areas with greatest capacity, and best locations for EV charging infrastructure.

Relevant Transportation System Component: Battery-electric buses/transit service

Co-Benefits: Resilient energy grid

Figure 10: Fresno County Rural Transit Agency Electric Bus

High Heat Event Response Planning

Brief Description: Given that battery efficiency is affected by temperature, there are limited design changes that can be made to reduce this risk.[2] Bus operators should develop a response plan for high heat events, which leverage power redundancy strategies noted above. This plan will be dependent upon the needs of the operator and community, but it may consider:

- Maintaining and charging "back-up" BEBs in advance of high-heat projections,
- Maintaining and deploying alternative fuel source fleets, such as hybrid and diesel buses during high-heat events,
- Charging buses more frequently, and
- Altering bus routes/directing service to higher ridership routes and routes that service the most transit-dependent populations so as not to disproportionately impact low-income and rural populations.

Individual driver performance (e.g. how fast they drive, how they start and stop the vehicle) also affects battery range and operator training is another way to preserve battery life during high heat.

[2] Heat affects battery performance, but not as drastically as cold temperatures. See this CityLab article for some examples of transit agencies struggling with BEBs in cold weather.

Relevant Transportation System Component: Battery-electric buses/transit service

Resources: TCRP Synthesis 130, Battery Electric Buses—State of the Practice

Precipitation and Flooding

Flood Impacts

Flooding can have severe impacts to the transportation network and its users. Flooding refers to a longer-term event where a low-lying area may inundate for days or weeks at a time due to ongoing rainfall, snowmelt, and/or rising water bodies. Flash floods refer to rapid flooding of an area due to extreme rainfall over a short period. Both can lead to roadway inundation, pavement damage/reduced pavement life, erosion of roadbeds and earthworks, washouts and sinkholes, overloaded and clogged drainage infrastructure, among other impacts. Each of these impacts leads to travel delays and their associated costs, along with response and repair time/costs. Flood-related impacts often have a disproportionate impact on low-income and minority populations due to a lack of sufficient infrastructure or flood mitigation improvements in these communities, and further may lack the resources to sufficiently respond to damages from a flood event such as flood insurance. These inequalities can help to inform how Fresno County prioritizes improvements to reduce the burden of flood impacts on these communities through engineered, natural, and land use responses.

Engineered Responses

Adjust Precipitation/Discharge Projections Used in Design

Brief Description: Transportation infrastructure is designed based on assumptions of the hydrology of the natural environments interacting with it. These assumptions tend to be based on historical observations of precipitation, runoff, and discharge (e.g., flow) rates. Existing practice often involves designing to discharge rates that are developed using historical discharge rates. Historical discharge rates can be observed directly or estimated using historical precipitation observations across a watershed that drains into an asset’s location. If precipitation patterns change, if historical estimates contain errors, then assets can be under-designed; that is, they fail to meet their normal design standards (West Riverside Council of Governments, 2019).

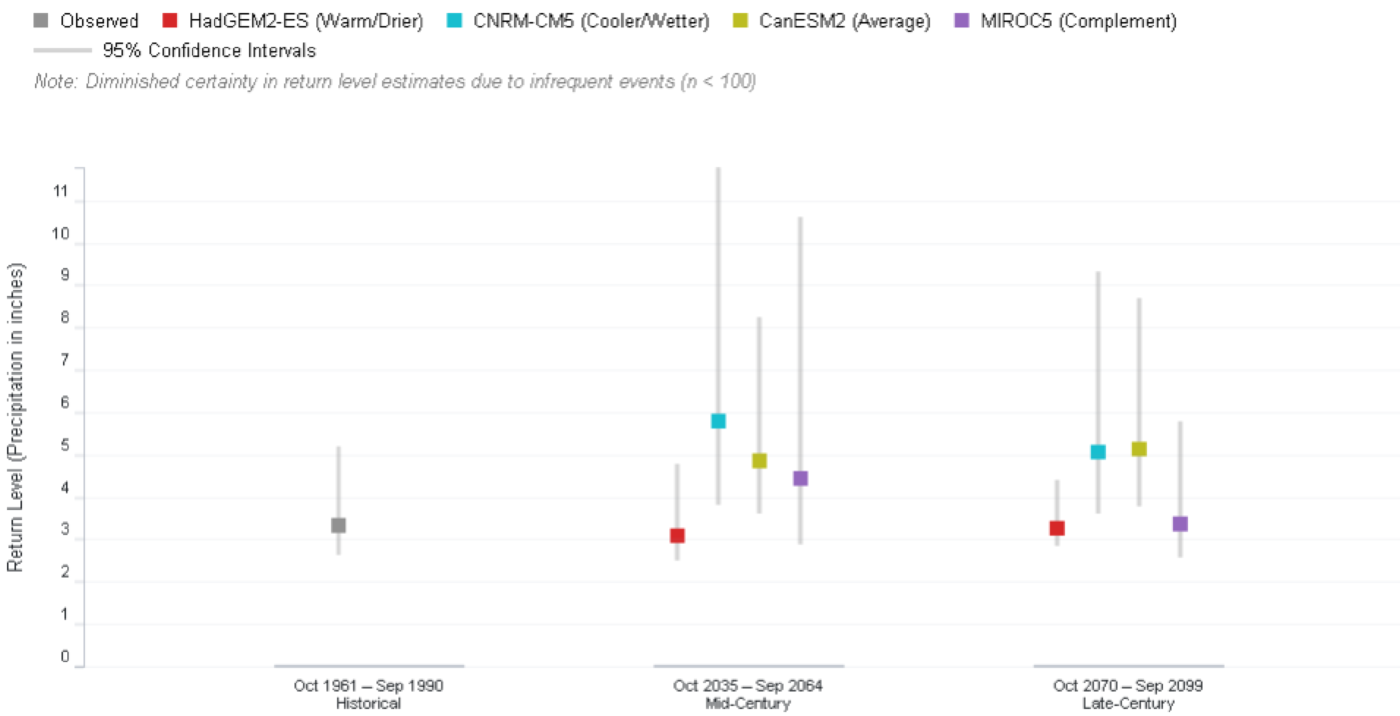
Thus, one adaptation strategy is to adjust precipitation and discharge inputs into design. The FHWA Hydraulic Engineering Circular No. 17, 2nd Edition (HEC-17), entitled *Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience*, suggests methods for doing this (FHWA, 2016). Chapter 7 discusses different levels of discharge analysis. The levels, which range from less to more analytically intensive, are:

- **Level 1:** Use historical discharges and analyze future changes qualitatively
- **Level 2:** Use historical discharges with confidence limits and analyze future changes qualitatively
- **Level 3:** Use historical discharges with confidence limits and quantitative future precipitation projections
- **Level 4:** Use projected discharges with confidence limits
- **Level 5:** Use projected discharges with confidence limits and expanded evaluations, such as custom site-specific projections in land use and climate

To help illustrate some of these values conceptually, Figure 11 shows historical and future projected precipitation depths for the 50-year event over a 24-hour duration in Fresno County (California Energy

Commission, 2019). The leftmost section shows historical precipitation (the gray square) with confidence intervals (gray bars), and the two right sections show future precipitation values (colored squares) and their confidence intervals (gray bars) for two different timeframes under several different climate models. Per the discussion in the "Processes and Resources" section earlier in this document, it is strongly recommended that multiple climate scenarios be assessed when incorporating future projections into design.

Figure 11: Historical and Future Projected 50-Year Precipitation Depths for Fresno, CA



- Source: Cal-Adapt. Data: LOCA Downscaled CMIP5 Projections (Scripps Institution of Oceanography), Gridded Observed Meteorological Data (University of Colorado, Boulder).

Relevant Transportation System Components: Bridges, culverts, drainage infrastructure

Co-Benefits: Context dependent

Resources:

- FHWA HEC-17
- NOAA Atlas 14 is a commonly used historical source for estimates of gridded precipitation rates organized by duration and frequency.
- LOCA (Locally Constructed Analogues) for future daily downscaled climate projections generated by the Scripps Institution of Oceanography that can be processed into extreme precipitation and discharge projections.
- Cal-Adapt Extreme Precipitation provides downloadable projected extreme precipitation values and confidence intervals for different locations across California.

Enhance Drainage Capacity

Brief Description: Enhancing drainage capacity of new or existing infrastructure is an option for addressing anticipated increases in flood risk.[3] This could entail upsizing culverts, retention basins, gutters, or other drainage-related infrastructure. It could also involve properly maintaining existing infrastructure so that it remains free of debris and able to accommodate water according to its design (see Figure 12). Which drainage infrastructure is prioritized for updates can be informed by past flood event impacts and population demographics, since low-income communities are more likely to lack adequate stormwater infrastructure and other relevant drainage infrastructure.

Relevant Transportation System Components: Culverts, channels, gutters, retention basins, inlets, pipes, pumps, other drainage infrastructure

Co-Benefits: Stormwater management

Resources:

- Caltrans Highway Design Manual, Chapters 800-890 Highway Drainage Design
- FHWA Hydraulic Design of Highway Culverts (HDS) 5: Hydraulic Design of Highway Culverts
- FHWA Hydraulic Engineering Circular (HEC) 22: Urban Drainage Design Manual
- FHWA Maintenance of Drainage Features for Safety

Figure 12: Caltrans District 10 Clogged Culvert

Source: https://twitter.com/i/web/status/844630478585942016

[3] See "Adjust Precipitation/Discharge Projections Used in Design" for more information on how to assess potential increases in flood risk associated with climate change.

Increase Scour Prevention

Brief Description: Scour is the "erosion of streambed or bank material due to flowing water" (US DOT FHWA, 2012). If it occurs at the base of a structure, such as bridge abutments or piers, it can compromise the structure's integrity. When increased flows are anticipated over a structure's useful life[4], one response option is to increase the scour protection measures at the facility. The Key Resources listed below describe common countermeasures for bridge scour, such as river training structures, armoring, foundation/pier strengthening, and monitoring.

Relevant Transportation System Components: Bridges, culverts, other structures interacting with flowing water

Co-Benefits: Context dependent

Resources:

- FHWA Hydraulic Engineering Circular (HEC) 18: Evaluating Scour at Bridges
- FHWA HEC-23: Bridge Scour and Stream Instability Countermeasures Experience, Selection and Design Guidance

Figure 13: Bridge Abutment Scour

Source: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12003.pdf

[4] See "Adjust Precipitation/Discharge Projections Used in Design" for more information on how to assess potential increases in flood risk associated with climate change.

Elevate Infrastructure

Brief Description: Elevating planned or existing infrastructure is another adaptation option for areas with expected increases in flood risks.[5] This strategy can apply to a variety of infrastructure types including roadways, bridges, transit stops, maintenance facilities, and other structures.

Relevant Transportation System Components: Roadways, bridges, transit stops, other structures

Co-Benefits: Context dependent

Resources: Caltrans Highway Design Manual, Chapters 800-890 Highway Drainage Design

Channelization

Brief Description: One of the more intensive strategies for addressing riverine flooding is channelization. Expanding an existing channel or digging a new channel creates an additional passage for water flow, increasing the carrying capacity of a river or other water body. Channels can also refer to open ditches dedicated to drainage. Channels can be lined with different materials, such as concrete, rock riprap, or vegetation (TxDOT, 2019).

Relevant Transportation System Components: Roadways or other infrastructure adjacent to rivers, drainage channels

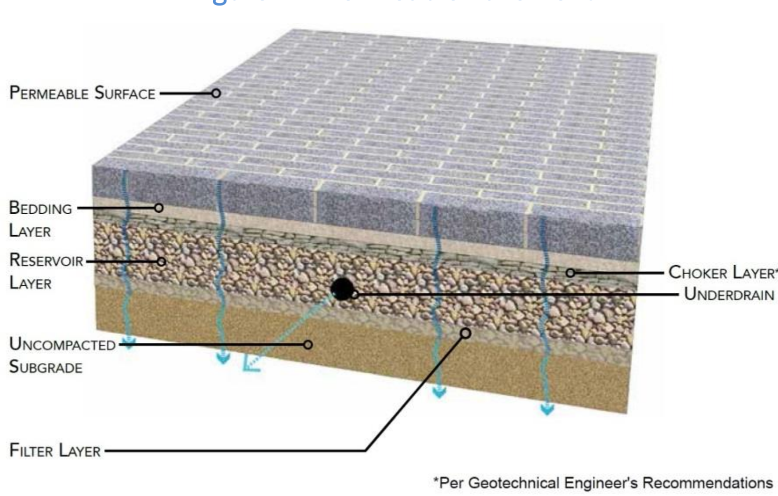
Co-Benefits: Natural environment through habitat enhancement (particularly for vegetation lined channels), stormwater management

Resources: Caltrans Highway Design Manual, Chapters 800-890 Highway Drainage Design

Install Permeable Pavement

Brief Description: This strategy refers to pavements composed of materials that are relatively pervious to water. By capturing stormwater that would otherwise flow across road surfaces, permeable pavements can reduce peak flows, lessen the strain on drainage systems, and recharge groundwater, where it can be filtered naturally by the soil (US DOT FHWA, 2015). Most permeable pavements are have higher initial costs than traditional pavements and are used to manage stormwater in "low-traffic, low-speed applications, such as shoulders or parking lots." Permeable pavement need to be regularly maintained so that sediment does not accumulate and prevent the infiltration of water.

Figure 14: Permeable Pavement



Source: San Diego County, 2019

Relevant Transportation System Components: Pavement (particularly low-volume, low-speed areas)

[5] See "Adjust Precipitation/Discharge Prc … e information on how to assess potential inc

Co-Benefits: Natural environment, stormwater management

Resources:

- Caltrans Pervious Pavement Design Guidance
- FHWA Toward Sustainable Pavement Systems: A Reference Document (Chapter 6)

Natural Responses

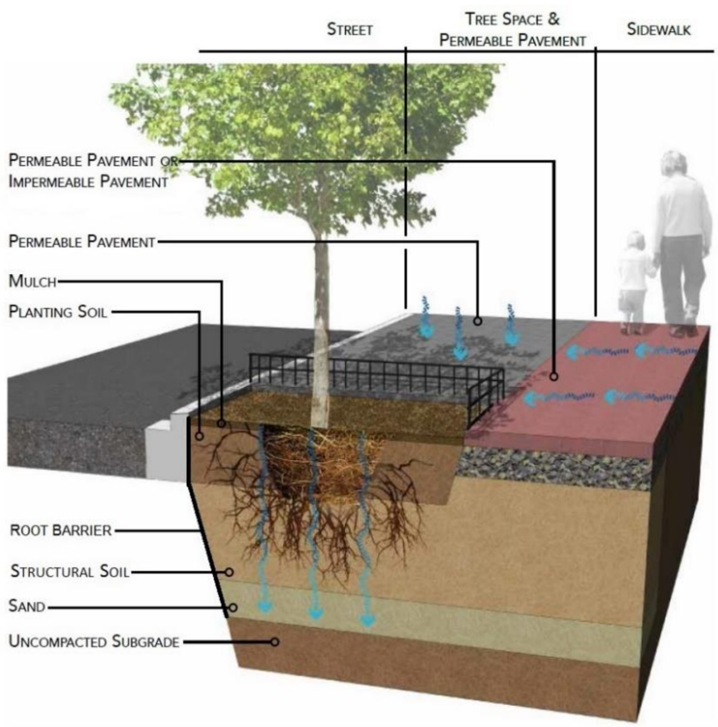
Install Tree Wells

Brief Description: Tree wells or basins can help capture stormwater and provide a dedicated space for tree growth in urban or suburban streetscapes. Features of tree wells can include permeable pavement, mulch, uncompacted planting soil, structural soil (mix of stone and soil), sand, structural cells (lattice structure supporting sidewalk and providing space for uncompacted soil), and uncompacted subgrade.

Relevant Transportation System Components: Urban/suburban streets and sidewalks

Co-Benefits: Preservation of natural environment and creation of green space, greenhouse gas mitigation, stormwater management, heat/air quality mitigation (See Extreme Temperature section earlier in this document), community/placemaking.

Figure 15: Tree Well Components



Source: https://www.sandiegocounty.gov/content/dam/sdc/dpw/WATERSHED_PROTECTION_PROGRAM/watershedpdf/Dev_Sup/County_BMPDM.pdf

Resources:

- County of San Diego BMP Design Manual
- Tree Fresno Tree Selection Guide
- The US EPA has a webpage dedicated to information on rain gardens.

Install Bioretention Areas and Bioswales

Brief Description: Bioretention areas, also called rain gardens or bioinfiltration areas, are depressions in the earth that consist of plants, organic matter, and often an engineered substrate, which is used to capture and filter stormwater and sediment captured from nearby impervious surfaces. These areas help slow runoff and foster groundwater infiltration. Bioretention features can also include tree wells (see Figure 15 above), planter boxes, curb extensions, or bioswales (Water Environment Research Foundation, n.d.). Vegetated swales are "long, shallow vegetated depressions, with a slight longitudinal slope. As water flows through the swale, it is slowed by the interaction with plants and soil, allowing sediments and pollutants to settle out. Water soaks into the soil and is taken up by plants, and may infiltrate further into the ground if the soil is well drained" (EPA, 2009). Plants chosen for bioretention areas and bioswales should be native or regional. In California, many native species are accustomed to receiving heavy rainfall, followed by long periods of drought, and therefore are convenient for use in a rain garden or bioswale (Metzger, n.d.). However, choosing plants is site-specific and depends upon conditions like soil type, sunshine, and root structure. Consulting local landscapers and gardeners is important to choose the right mix of plant species. The University of California Agriculture and Natural Resources (UCANR) connects academics and members of California communities to study and address agricultural and natural resource issues. UCANR's Fresno County Cooperative Extension could provide useful advice and consultation on this topic.

Relevant Transportation System Components: Urban/suburban streets and sidewalks

Co-Benefits: Natural environment, stormwater management

Resources:

- FHWA Hydraulic Engineering Circular (HEC) 22: Urban Drainage Design Manual
- National Association of City Transportation Officials Urban Street Stormwater Guide
- County of San Diego BMP Design Manual
- This Ecological Landscape Alliance article provides some useful information on how to choose plants for a bioretention/bioswale
- UCANR's Fresno County Cooperative Extension

Figure 16: Bioswale

Source: https://nacto.org/wp-content/themes/sink_nacto/views/design-guides/retrofit/urban-street-design-guide/images/bioswales/carousel//unknown_unknown_3.jpg

Bank Vegetation/Seeding

Brief Description: Planting native species along riverbanks can protect against erosion and decrease the magnitude of floods. These plants can prevent erosion, trap sediment, and slow flood waters.

Relevant Transportation System Components: Rivers/streams adjacent to or crossing roadways, bridges, culverts

Co-Benefits: Natural environment, greenhouse gas mitigation

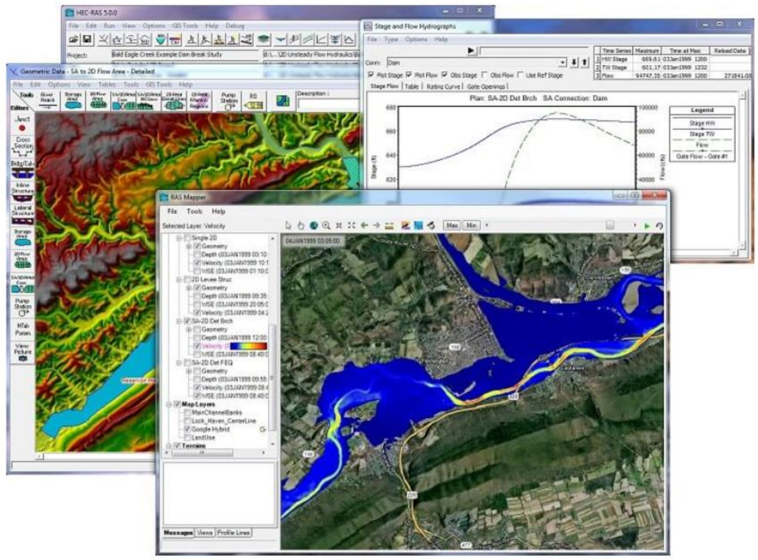
Resources:

- [Caltrans Erosion Control Toolbox: Specifying Seed and Plant Species]
- [California Riparian Habitat Restoration Handbook]

Land Use Responses

Designate Future Floodplains

Figure 17: HEC-RAS Software for Floodplain Modeling



Source: https://www.hec.usace.army.mil/software/hec-ras/

Brief Description: Floodplains are a crucial information source used in locating and managing transportation infrastructure and other development. However, except for some coastal floodplains, virtually all floodplains in the U.S. are based on historical climate information rather than future climate projections. These include the FEMA Floodplain Insurance Rate Maps (FIRMs). Therefore, one adaptation strategy is to develop future floodplains based on modeled projections. This strategy is very similar to the "Adjust Precipitation/Discharge Projections Used in Design" strategy in that it also uses forecasted future precipitation and discharge projections as an input for decision making.

Relevant Transportation System Components: All

Co-Benefits: Context dependent

Resources:

- United States Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) documentation on floodplain modeling.
- FEMA Guidelines and Standards for Flood Risk Analysis and Mapping note that FEMA FIRM floodplains are based on observed data regarding the historical climate rather than projected future climate conditions.

Minimize and Avoid Development in Flood Hazard Areas

Brief Description: Agencies and jurisdictions can restrict or avoid the location of development in floodplains. Development can refer to transportation facilities specifically or to other public ally- or privately-owned structures and improved property. The California Adaptation Planning Guide mentions several relevant practices that agencies can consider (CalEMA, CA NRA, 2012):

- Use floodplains (from FEMA or other sources) for determining general plan policies and zoning patterns,

- Participate in the Community Rating Service system, which reduces rates for flood insurance purchasers,
- For flood-prone Severe Repetitive Loss communities, pursue flood mitigation assistance grants designed to reduce flood exposure,
- Restrict allowable densities in hazardous areas,
- Cluster development or set it back from flood hazard areas,
- Transfer allowable density from hazardous sites to safer areas,
- Modify proposed parcel boundaries and street locations to avoid hazardous areas,
- Require multiple ingress and egress points for emergency access and evacuation.

Relevant Transportation System Components: All

Co-Benefits: Natural environment, public safety

Resources:

- California Adaptation Planning Guide, Identifying Adaptation Strategies
- State of California Hazard Mitigation Plan

Land Acquisition /Exchange

Brief Description: Jurisdictions can offer to acquire flood-prone property from owners in exchange for comparable land elsewhere or cash. This can be a potentially cost-effective option when properties or the infrastructure that serves them incur or are expected to incur substantial, repetitive flood-related costs. Heavy coordination and sufficient funding are important aspects of this strategy. There are several FEMA programs that can help fund flood-prone land acquisition.

Figure 18: Home Relocation

Source: https://www.fema.gov/media-library-data/20130726-1446-20490-0539/FEMA511-complete.pdf

Relevant Transportation System Components: All

Co-Benefits: Natural environment, stormwater management, greenhouse gas mitigation

Resources:

- FEMA, Reducing Damage from Localized Flooding
- Environmental Law Institute, Prioritizing Future Floodplain Acquisitions: Maximizing Opportunities for Habitat Restoration, Community Benefits, and Resilience

Wetland Conservation/Restoration Areas

Brief Description: Conserving or restoring natural wetland areas can serve as a flood mitigation strategy for transportation infrastructure. Natural riverine floodplains, which can include ecosystems such as freshwater marshes, swamps, bogs, and fens, can absorb floodwater and prevent erosion (Kumar, 2017).

Relevant Transportation System Components: All

Co-Benefits: Natural environment, stormwater management, and greenhouse gas mitigation.

Resources:

- EPA Wetlands Protection and Restoration
- California Riparian Habitat Restoration Handbook

Wildfire

Direct Infrastructure Damage

Wildfires are a risk to the operations of existing transportation infrastructure and key facilities. In many instances, infrastructure was not designed to withstand direct wildfire impacts such as burning and high heat, or secondary impacts of wildfires like subsequent debris flows. Studies indicate that low-income and minority communities are not necessarily at greater risk of wildfires based on where they live, but if impacted by a wildfire typically experience a greater burden and have a more difficult time recovering than wealthier communities (Davies, Haugo, Robertson, & Levin, 2018).

Responses

Maintain Defensible Space & Protect Critical Assets

Brief Description: Defensible space is a strategy for transportation planners to reduce the risk of structural damage to transportation assets in the event of a wildfire, particularly for critical assets such as arterial roads and evacuation routes. This strategy helps to reduce the risk of fire hazard and enables firefighters to defend the asset (University of California Cooperative Extension, 2009). Providing defensible space is a strategy that can be widely applied and is an especially important strategy for critical structures and evacuation routes and major roadways. Maintaining defensible space is a year-round process, which requires resources and coordination and time and monetary resources.

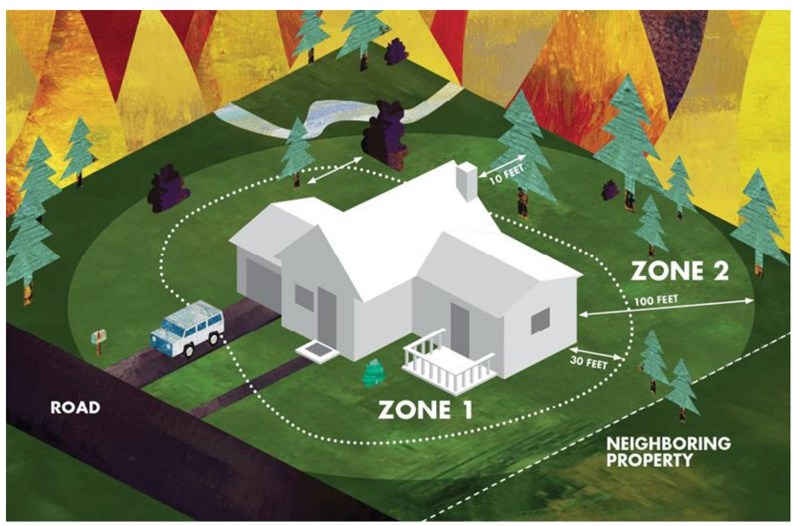
Relevant Transportation System Components: Facilities, Roadways, Transit Assets such as bus shelters

Co-Benefits: Reduce fire risk and risk of property damage in the county more broadly

Resources:

- California Public Resources Code 4291 establishes requirements for maintaining defensible space for property owners.
- Cal Fire offers guidance on how to protect properties and assets, which can be useful to inform maintenance activities.

Figure 19: Defensible Space Zones



Source: CalFire

Remove Post-Wildfire Debris

Brief Description: Post-wildfire debris removal is a longer-term recovery strategy to reduce the severity of post-fire flooding events, which can be exacerbated by post-wildfire debris flows (West Riverside Council of Governments, 2019). To defend transportation assets, transportation agencies can remove potentially dangerous debris following a wildfire event when reduced vegetation can increase the velocity of flooding events and debris flows. This strategy is often implemented outside the transportation right-of-way; however, transportation managers can be involved in implementation to help prevent damage to transportation assets, disruptions to transportation service, and barriers to evacuation routes (USGS, n.d.).

Key actions for post-wildfire debris removal include:

Figure 20: Post-Wildfire Debris Removal Northern California

Source: Society of American Military Engineers

- Employing best-available monitoring and data collection to identify areas susceptible to future debris flows.
- Employing best-available data to predict future debris flows.
- Establishing and continuing to maintain barriers, such as riprap, in areas determined to be susceptible to future debris flows.
- Reforesting immediately following a wildfire event.
- Regularly monitoring areas burned by wildfire years after the event.
- Coordinating with property owners and other stakeholders.

Relevant Transportation System Components: Roadways, ancillary transportation assets such as bus shelters and guardrails

Co-Benefits: Context-dependent

Resources: Cal Recycle and the California Environmental Protection Agency have guidance on how to properly transport and dispose of debris.

Size Culverts, Bridges, and Drainage Infrastructure to Account for Wildfire Exposure

Brief Description: Post-wildfire debris flows can cause damage to culverts, bridges, and drainage infrastructure, since debris flows can overwhelm the design capacity of these assets. By sizing infrastructure to account for and accommodate "bulked" flows— mass movement of primarily rocks, debris and soils—jurisdictions can minimize damage. To design assets based on bulked flows, jurisdictions can apply a bulking factor to peak (clear water) flow rates to determine the total or bulked peak flow, offering a safety factor in the sizing of culverts. Engineered mitigation strategies for increases in stormwater volume and peak flows due to debris include (West Riverside Council of Governments, 2019):

- Design of new culverts using appropriate bulking factor.
- Retrofit of existing culvert capacity through enhanced inlet design.

- Increasing existing culvert capacity through replacement or addition of a culvert barrel(s).
- Construction of sediment/debris capture mechanism at, or upstream of, the culvert entrance (inlet riser pipe, desilting/debris basin).

Relevant Transportation System Components: Culverts, bridges, drainage infrastructure

Co-Benefits: Context-dependent

Resources:

- Caltrans District 5 Draft Climate Change Vulnerability Assessment
- United States Army Corps of Engineers' Method (Tatum Method) for determining bulked flows for use in appropriate sizing detention basins, debris basins, and culverts.
- Los Angeles County Department of Public Works (LADPW) Flood Control District Method for determining single storm event debris production and bulking factor rates.
- The FHWA Hydraulic Engineering Circular No. 9, "Debris-Control Structures," shows types of debris control structures and provides a guide for selecting the type of structure suitable for various debris classifications.

Choose Appropriate Materials for Wildfire Prone Areas (for Drainage, Signage, etc.)

Brief Description: In wildfire prone areas, jurisdictions can use fire-resistant materials, such as concrete pipes and steel, to build and replace drainage infrastructure in order to reduce damage and loss of service of these assets. Additionally, jurisdictions can consider replacing existing plastic culvert pipe inlet structures (plastic flared end sections) with concrete headwalls in these areas. Other assets that can be protected by replacing them with wildfire/heat resistant materials include ITS signage and cables and any wooden sign posts, fencing, earthworks supports, walls, etc. (West Riverside Council of Governments, 2019).

Figure 21: Metal Pipe and Concrete Headwall Post-Fire

Source: Caltrans District 8 Climate Change Vulnerability Assessment Summary Report, 2019

Relevant Transportation System Components: Culverts, ancillary transportation assets such as signs and guardrails

Co-Benefits: Stormwater management

Resources: FEMA's Wildfire Hazard Mitigation Handbook for Public Facilities

Evacuation

Wildfires can trigger the need for evacuations and can inhibit the ability of populations to evacuate high-risk areas by damaging or disrupting the level of service of transportation and infrastructure. This is particularly true for the eastern parts of Fresno County, which are forested and mountainous regions. Two types of strategies are available to Fresno County to prepare for evacuations: 1) emergency and communication responses, and 2) operations and design responses.

Emergency and Communication Responses

Maintain and Update Community Emergency Response and Communication Plan

Brief Description: An up-to-date and collaboratively produced community emergency response and communication plan can help to facilitate effective emergency response and evacuation in the event of a wildfire. This plan should be coordinated across other agencies and stakeholders, and it may also be a part of a city or county emergency operations plan that covers all sectors.

Examples of best practices include (West Riverside Council of Governments, 2019):

- Clear communication plan for coordination between agencies across jurisdictions, with adjacent municipalities or counties, and overarching organizations, such as Cal OES, Caltrans, and Cal Fire. It should cover communication with emergency services personnel and other sectors involved with emergency management, in addition to within the transportation sector.
- Command structures and transfer of command protocols for hazard events.
- Multiple and redundant modes of communication, including plans for when communications and power grids are offline.

Additional best practices can be found in the resources listed below.

Relevant Transportation System Components: Roadways

Co-Benefits: Collaboration and relationship-building amongst key management agencies in the county

Resources:

- Fresno County Master Emergency Services Plan
- State of California Emergency Plan
- Standardized Emergency Management System
- National Response Framework
- National Incident Management System
- FHWA's primer on Concept of Operations (CONOPS) for emergency response outlines important emergency planning and operations considerations specifically for transportation managers.

Figure 22: Evacuation Stakeholders

Source: FHWA Using Highways for No-Notice Evacuations, Ch. 5

Identify Key Evacuation Corridors and Bottlenecks

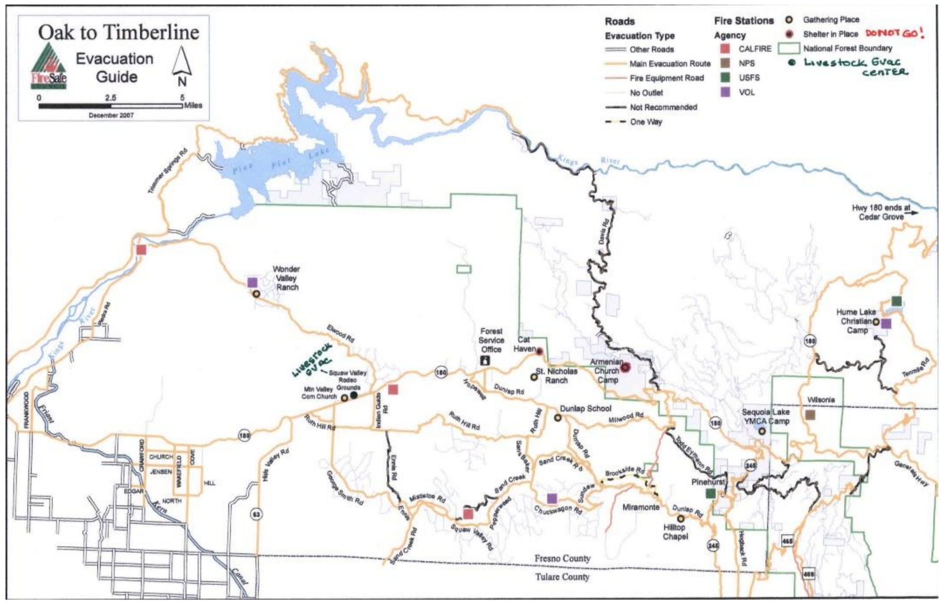
Brief Description: To develop and effective evacuation plan, jurisdictions must have a strong understanding of how the transportation network might be used in the event of a hazard. Decision-makers need to understand several aspects of the transportation network, including (West Riverside Council of Governments, 2019):

- The capacity of roadways and other infrastructure.
- The locations of high hazard risk areas, such as fire- or flood-prone areas and where people could be evacuated to if those hazards were to occur.
- The patterns of travelers by time of day and mode and the typical origin-destination numbers.
- The potential origin-destination numbers patterns during hazard events at different times of day on different modes. Decision-makers can grasp and understanding of these patterns by using knowledge of typical numbers and patterns, high hazard risk areas, and where people would need to be evacuated to.
- The characteristics and locations of potential evacuees, such as languages spoken and potential mobility restrictions.
- The portions of the network that would be susceptible to disruption from hazards (e.g., roadway blockage or bridge failure).
- The redundancy of the transportation network (i.e., availability of alternative routes).

- The expected roadway volumes and timing based on both typical and hazard origin-destination patterns, including the volumes and timings when vulnerable assets are disrupted.
- The locations of chokepoints, such as intersections/interchanges, road narrowing, etc.

After developing an understanding of how the transportation network might be used during an evacuation event, by utilizing traffic demand models and microsimulation models, an evacuation plan can be developed. This plan can include actions for addressing potential vulnerabilities, such as capacity constraints, populations with special mobility needs, and asset failure points.

Figure 23: Oak to Timberline Evacuation Guide



Source: Fresno County Sheriff

Relevant Transportation System Components: Roadways, Bridges

Co-Benefits: Public safety, improved working knowledge of the transportation system to inform planning and maintenance

Resources: Cal OES, Evacuation & Transportation Planning Guidance

Transit Services to Help Facilitate Evacuation

Brief Description: Transit services are essential for the mobility of county residents in the event of an evacuation, particularly for vulnerable populations to reduce the risk to human life (Transportation Research Board, 2008). Using transit vehicles for evacuee transport is an especially important consideration, as buses will be able to transport more evacuees at one time than personal vehicles. In addition, some evacuees may not have access to a car at all, or cannot drive themselves, and will need assistance. Deploying paratransit services is especially important. Operating transit services to support evacuation efforts requires upfront planning, such as making transit vehicles available and making sure transit staff is available to operate buses and manage operations.

Figure 24: PRIDE Private Transit Service Responding to Wildfire Evacuees in Placer County

Source: PRIDE Industries

In the case of the Tubbs Fire, the Santa Rosa CityBus service was critical in evacuating hospitals and senior care facilities such as the Kaiser Permanente Santa Rosa Medical Center and Fountaingrove Assisted Living Facility. Santa Rosa CityBus employees were prepared for such an event because of annual drills and trainings and each bus operator had directions on their ID cards telling them where to go in case of an emergency. Overall "CityBus helped evacuate nearly 400 people within the first 12 hours of the crisis" and their support did not stop there, as buses helped the Sonoma County Emergency Operations Center move evacuees over the next couple weeks following the fire (California Transit Association, 2019).

Relevant Transportation System Components: Passengers

Co-Benefits: Benefits include short and long-term public health outcomes by removing people from high-risk environments

Resources:

- TCRP Special Report 294, The Role of Transit in Emergency Evacuation
- Caltrans, Rural Transit Emergency Planning Guide
- TCRP Report 160, Paratransit Emergency Preparedness and Operations Handbook

Community Engagement and Public Education

Brief Description: A foundational element of evacuation planning in response to wildfires is ensuring that the public has the opportunity to inform and is aware of the plans and strategies in place to respond to these emergencies. The public needs to be aware of what the evacuation routes are and what services, like transit, are available to them. Additionally, the public are aware of the nuances and concerns in their own community, such as where vulnerable populations live and further which languages need to be used in communicating emergency messages. These pieces of information and others can help to inform a more effective and efficient emergency response and evacuation process. Fresno COG has already conducted extensive public outreach through the Fresno County TNVA, which is a first step in getting individuals involved in developing adaptation strategies.

Relevant Transportation System Components: Passengers

Co-Benefits: Public trust

Resources:

- Fresno County Regional Transportation Network Vulnerability Assessment, Public Outreach Synopsis
- ICLEI Resource Guide, Outreach and Communications

Figure 25: Fresno COG TNVA Public Outreach Pop-Up Event

Operations and Design Responses

Implement Transportation Design Strategies for Evacuation Events

Brief Description: Roadway design can have major implications for how well it functions in the event of an emergency. For example, shoulders can function as additional lanes for emergency vehicles. Dynamic shoulders can also be opened to additional vehicles in case of an evacuation. Median breaks and crossovers can also be used by emergency vehicles and can be necessary to redirect traffic during an emergency. Both dynamic shoulders and median breaks/crossovers can be used when facilitating "contraflow" lanes, which is a lane that is used to direct traffic in the opposite direction of the way it would normally go. Opening contraflow lanes is useful in the event of an evacuation because it can relieve congestion and allow more people to exit dangerous areas over a given timeframe. Evacuations can be streamlined by implementing these other potential transportation design strategies (West Riverside Council of Governments, 2019):

- Broadening roadways that are key evacuation routes,
- Maintaining defensible space along key evacuation routes to minimize fire hazards and act as a fire break (see the section on direct infrastructure damage),
- Establishing and creating emergency pull-off or refuge areas for emergency vehicles or evacuees,
- Installing and using heat-resistant intelligent transportation systems (ITS) to communicate information to passengers during an evacuation,
- Installing mile markers to assist emergency responders and evacuees during an evacuation to identify locations when people are without cell service and to serve as a marker for the side of the road when it is dark or smoky,
- Monitoring traffic and debris with closed circuit television (CCTV) or similar systems to also respond and provide redundancy in case of system disruption,
- Using adaptive signal control (ASC) systems to adjust traffic lights and other signals to high volumes during hazard events, and provide redundancy in case of system disruption.
- Establishing Traffic Management Centers (TMCs) and develop contingency plans for loss of power and communications.

Relevant Transportation System Components: Roadways, roadway corridors/right-of-way.

Co-Benefits: Enhanced public safety and streamlined evacuations.

Resources:

- The Federal Highway Administration (FHWA) released a guidance document on Evacuation Transportation Management in 2006, which provides information on advanced evacuation planning, identifying resources, roles, and responsibilities, and step by step guidance on facilitating evacuation from start to finish.
- FHWA's Designing for Transportation Management and Operations: A Primer includes a section on "Design Considerations for Specific Types of Operation Strategies," which covers how transportation project design can influence operations strategies.

Implement Transportation Operations Strategies for Evacuation Events

Brief Description**:** There are many operational responses that can help facilitate an efficient and successful evacuation. Some of these strategies rely on the design changes and equipment that discussed in the section above. For example, contraflow lanes may not be possible unless there are median breaks which allow vehicles to cross to the other side of a roadway. Using dynamic shoulders for emergency vehicles or evacuee traffic may not be feasible if the shoulder was not designed for these vehicle loads. Other operational strategies include (West Riverside Council of Governments, 2019):

Figure 26: Florida Emergency Response Vehicle Using Shoulder

Source: FDOT

- Adjusting signals to direct and manage traffic during evacuation events,
- Stocking and utilizing deployable signs and barriers to direct traffic,
- Operating transit services to transport evacuees, as discussed in the section above,
- Designating lanes (such as shoulder lanes) for emergency vehicles,
- Coordinating and managing timed evacuation from areas with heavy volumes and high potential for congestion and bottlenecks,
- Planning for closure of road lanes or ramps leading into hazard areas,
- Coordinating additional on-call maintenance support for debris clearing during events,
- Establishing and operating temporary traffic control points staffed by emergency management personnel.

Relevant Transportation System Components: Roadways, roadway corridors/right-of-way.

Co-Benefits: Enhanced public safety and streamlined evacuations.

Resources:

- FHWA's Evacuation Primer includes information on planning considerations to resolve issues ahead of time, and improve evacuation scenarios.
- FHWA's Evacuation Transportation Management report on operational concepts of evacuation.

Implement General Plan Safety Elements Through Zoning and Subdivision Practices That Provide Adequate and Redundant Evacuation Routes in Wildfire Hazard Areas

Brief Description: Jurisdictions can leverage land use planning and zoning practices to reduce risk and to improve resilience in high-hazard areas, which can be folded into the safety element of their general plan to meet the SB 379 requirements. Land use planning can minimize risk in several ways such as (West Riverside Council of Governments, 2019):

- Prohibiting development in high-risk areas through zoning and overlay controls.
- Limiting the types of development in high to moderate risk areas for open space or recreation, reducing the potential impacts of natural hazard events.
- Applying appropriate development controls in moderate and lower risk areas such as setbacks and lot sizes, as well as maximum densities and site coverage (Bajracharya, Childs, & Hastings, 2011).
- Transferring allowable density to areas that are less at risk of wildfires (CalEMA, CA NRA, 2012).
- Encouraging development in areas with multiple access routes, or ensuring that new, wildfire-prone development includes at least two access routes.

Relevant Transportation System Components: Roadways, Right-of-way, Bridges

Co-Benefits: Improved accessibility to employment and essential services

Resources:

- California Adaptation Planning Guide: Identifying Adaptation Strategies (2012) provides insights into possible land use strategies that can be used to address multiple climate hazards.
- The California Hazard Mitigation Plan has examples of different hazard mitigation strategies.

In-Place Shelters for Areas Without Redundant Evacuation Routes

Brief Description: If populations live in areas that are not easily accessible by multiple evacuation routes, Fresno County can reduce the risk to life during a wildfire by providing shelter-in-place facilities in these regions. Shelter in-place is defined as, "The use of a structure to temporarily separate individuals from a hazard or a threat (FEMA, 2019)." As a result, a shelter in-place strategy can be requiring residents to stay in their homes or to have residents in an isolated community meet at a proximate centralized location to seek shelter.

Relevant Transportation System Components: Roadways/Bridges/Evacuation Routes

Co-Benefits: Reduced congestion on evacuation routes, reduced costs of wildfire events

Resources: FEMA's Planning Considerations: Evacuation and Shelter-in-Place (2019) provides an overview on the topic and examples to learn from.

Figure 27: Shelter In-Place Sign

Landslides

There are around 20 different types of landslides that commonly occur in California, ranging in type because of various soil conditions, triggers, size, and speed. While some landslides may cause more severe impacts, each type can cause direct impacts to transportation infrastructure. Several landslide response and preparation strategies are explained in more detail below.

Direct Infrastructure Damage

There are many different types of landslides, but they generally fall into five common classifications: earth flows, debris flows, debris slides, rock slides, and rock falls (CGS, 2019). Deep-seated landslides, which were assessed as part of the Fresno County Transportation Network Vulnerability Assessment, fall into the earth flow and rock slide categories. Each of these five, general landslide types are included in California landslide inventory mapping, which is done to identify locations of past slides and potential future failures (CGS, 2019).

- **Earth flow:** Made up of fine-grained soils cohesively flow down a moderately steep slope. Slow moving, normally only a couple millimeters or centimeters per day.
- **Debris flow:** Made up of coarse-grained soils that are non-cohesive. These are large and move quickly; they can cause devastating impacts.
- **Debris slide:** Made up of coarse-grained soil on very steep slopes. These slides have a greater mass than debris flows and can move at meters per week or faster.
- **Rock slide:** Made up of moving bedrock that occurs on relatively steep slopes. These slides can vary greatly in size and can be caused by many triggers.
- **Rock fall:** Made up of boulders and rock masses detached from a steep slope. These occur on slopes made of hard and fractured rock and are extremely dangerous.

Each of these types of slides can cause direct transportation infrastructure damage by cracking pavement and compromising roadbeds, destroying roadway signage and guardrails, interrupting utility networks, destroying embankments and earthworks, clogging corridors and drainage with debris, causing road closures, and generating associated public safety and travel concerns. While landslides of a larger scale can cause major and unavoidable impacts, there are strategies that can be applied more broadly to monitor landslide activity, mitigate risks, and prepare responses. Additionally, Fresno County can again consider equity in this decision-making process by prioritizing the deployment of hazard mitigation strategies in underserved communities, which may experience a greater burden in the event a landslide occurs.

Responses

Implement Zoning and Subdivision Practices that Restrict Development in Landslide Hazard Areas

Brief Description: The most straightforward solution to risks and impacts posed by landslides is to avoid hazard areas entirely. By adopting local codes and ordinances to protect steep slopes, there are inherent protections granted to the public, natural resources, and infrastructure. Fresno County zoning ordinances specify that private property in dangerous areas, such as “areas too steep to build upon” can be designated as an Open Conservation Land Use District, but otherwise do not cite specific zoning requirements related to steep slopes (Fresno County, 2018). Other counties and cities have adopted ordinances to restrict development on steep slopes, which Fresno County may consider to protect property. Allegheny County in Pennsylvania, for example, limits development on slopes between 25 and 40 percent, does not allow any development on slopes between 15 and 40 percent located within conservation areas, and prohibits all development on slopes exceeding 40 percent (US EPA, 2014).

Relevant Transportation System Components: Drainage infrastructure, roadways, bridges, facilities, earthworks.

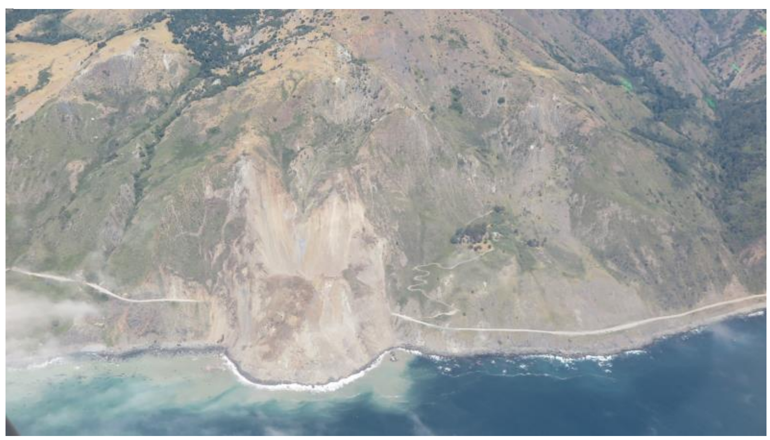
Co-Benefits: Benefit to public safety by limiting exposure to slide risk areas, preservation of natural areas, cost savings from reduced maintenance, recovery, and response needs.

Resources: The California Adaptation Planning Guide: Identifying Adaptation Strategies report identifies the following adaptation strategy to avoid risks from flooding and landslides: "WM 5: Implement general plan safety elements through zoning and subdivision practices that restrict development in floodplains and landslide hazard areas (CalEMA, CA NRA, 2012)."

Slope Stability Monitoring

Brief Description: Monitoring slope stability, especially in active or historically active slide zones, is a relatively easy way to understand and prepare for potential slide risk. Early warnings of instability can allow for timely evacuation and response, and can be lifesaving if vulnerable areas are blocked off ahead of time. This was the case in Big Sur, California, when multiple landslides wreaked havoc on the State Highway System in 2017. Caltrans detected the first signs of slope instability before the massive Mud Creek slide buried a third of a mile of the Pacific Coast Highway and preemptively stopped traffic on the roadway (AASHTO, 2018) (USGS, 2017). Now that the highway is re-opened, Caltrans continues to monitor the area by using a variety of techniques that provide real-time movement analysis.[6] USGS is also helping Caltrans to monitor the slide by taking aerial photos and creating Digital Elevation Models (DEMs) of the slide area (USGS, 2017)

Figure 28: Mud Creek Slide, Big Sur, CA



Source: Caltrans District 5

Relevant Transportation System Components: Drainage infrastructure, roadways, bridges, facilities, earthworks.

Co-Benefits: Benefit to public safety by preemptively identifying slide risk.

[6] Information provided by Caltrans District 5.

Resources:

- The *Draft Caltrans District 5 Vulnerability Assessment Summary Report* will provide useful information on the 2017 Central Coast landslides and how the district responded. The report will also provide information on the monitoring equipment used in the Mud Creek Slide area.
- The *Geomorphology* journal article "Assessment of ground-based monitoring techniques applied to landslide investigations" provides a detailed look at monitoring landslides and their triggers, and the results summarize the performance of different monitoring techniques.

Asset Design Changes in At-Risk Areas

Brief Description: Altering transportation asset design can help mitigate risks from landslides by addressing landslide triggers, such as heavy precipitation, prolonged rainfall, rapid runoff, and wildfire. Design strategies can also be applied to avoid landslide impacts altogether and to increase the resilience of infrastructure in landslide risk areas. Some general design strategies used to prevent or prepare for landslide impacts include (Johnson, 2019):

- **Enhanced drainage:** Provide sufficient drainage for surface and subsurface runoff. Heavy precipitation can lead to erosion, washouts, and slope instability. This is applicable for all five landslide types.
- **Debris flow catchment:** Mitigate likelihood of debris flow by maintaining slope stability. Install debris flow catchment infrastructure like debris flow catchment fences across drainage channels.
- **Reduce driving/resistance force:** These are two ways to reduce overall slide risk by manipulating the slope itself. Reduce driving force by moving material from the top of a slide mass to reduce the weight. Increase resistance force by adding fill to the base of a slope to increase the weight at the bottom of a potential slide area. Adjusting the weights in this way can reduce risk of a slide by relieving potential energy at the top of a slope.
- **Subsurface drainage:** Provide subsurface drainage to help reduce driving force and increase the strength of material in a slide zone.
- **Avoiding at-risk areas**: Avoid slide areas where possible. Where it is unavoidable, consider design changes to keep as much construction outside of the slide zone as possible. For example, Caltrans re-built the Pfeiffer Canyon Bridge to a single span bridge after a landslide damaged one of its central columns (AASHTO, 2018).

Relevant Transportation System Components: Drainage infrastructure, roadways, bridges, facilities, earthworks

Co-Benefits: Benefit to public safety by reducing slide risk

Resources:

- The California Geological Survey (CGS) provides helpful background information on types of landslides, landslide mapping/inventory, and recently reporting landslides.
- The American Association of State Highway and Transportation Officials (AASHTO) Resiliency Case Studies: State DOT Lessons Learned report provides two landslide examples and Department of Transportation (DOT) responses: a rockfall in Colorado and multiple coastal landslides in the Central Coast of California.

Natural Infrastructure Solutions

Brief Description: In addition to design changes, there are natural infrastructure or "green" solutions that can be applied to increase slope stability, decrease runoff, and reduce landslide risk overall. These strategies include:

- **Vegetation and seeding:** Seed slopes to provide additional stabilization and reduce surface runoff (Native Plant Solutions, 2016). Plant roots will help keep surface soils in place, but do not necessarily protect against deeper slides (EPA, 2014).
- **Runoff management:** Place vegetation at the top of a slope to absorb runoff and reduce the velocity of water flow (EPA, 2014). Berms and trenches can also be used to direct runoff, absorb surface water, and reduce erosion (Lynn Highland, 2008).
- **Bioengineering and biotechnical stabilization:** Bioengineering is the use of vegetation to stabilize slopes. When combined with structural components such as textiles, stones, terraces, and berms it is called biotechnical stabilization. Both techniques are used to reduce erosion and driving force (EPA, 2014).

Relevant Transportation System Components: Drainage infrastructure, roadways, bridges, facilities, earthworks

Co-Benefits: Greenhouse gas reductions, enhanced air and water quality, creation of green, blue, and open space

Resources:

- See the Caltrans Construction Manual, Chapter 4, Section 21 on "Erosion Control" for standards and recommendations related to landscaping, materials use, and construction practices.
- The Environmental Protection Agency (EPA) report Addressing Green Infrastructure Design Challenges in the Pittsburg Region provides useful background information on natural infrastructure solutions to steep slopes and associated challenges.
- The USGS Landslide Handbook – A Guide to Understanding Landslides provides background information on the different types of landslides, how to evaluate landslide risk, and different mitigation strategies, including natural and engineered strategies.

Maintain and Update a Clean-Up/Debris Management Plan

Brief Description: Having a plan in place in case of a slide is another way to ensure that transportation infrastructure can be restored and re-opened to traffic as soon as possible. In another Caltrans example, the agency applied this tactic following the Montecito debris flows. Given that there was some early warning that there would be a debris flow due to heavy storms in the Thomas Fire burn scar, the agency began organizing resources before disaster struck. Caltrans closed highways and lined up contractors in preparation for the event, to accelerate debris removal from state highways (Hendrix, 2018).

Relevant Transportation System Components: Drainage infrastructure, roadways, bridges, facilities, earthworks.

Co-Benefits: Benefit to public safety by clearing debris, more efficient use of resources.

Resources:

- The Caltrans Landslide Management Plan: Landslide Management Activities and Best Management Practices, released in 2013, provides best management activities for landslide prevention, response, and repair/clean-up.
- The EPA report, Planning for Natural Disaster Debris, heavily focuses on pre-disaster efforts to plan for natural disaster related debris management.

Regional Project Examples

The adaptation strategies summarized above can be applied in a variety of situations and projects. A project does not specifically need to be designed as a response to climate change to incorporate these responses. Adaptation strategies and general principles can be woven into planned and ongoing projects whenever there is a relevant climate change related hazard or risk that will affect that area.

A selection of project types and project examples were chosen from the 2018 Fresno COG RTP to demonstrate how climate change could be considered in project planning and adaptation strategies can be layered into project execution. There are five project types provided in the 2018 RTP:

- Bike and Pedestrian
- Transit
- Streets and Roads
    - Capacity Increasing
    - Maintenance
    - Operations

There are thousands of projects in the RTP, distributed among these five project types. One example from each project type is highlighted here to provide site-specific demonstrations of how: 1) climate stressors can be evaluated in project planning, 2) potential adaptation strategies are relevant to those projects, and 3) co-benefits stem from those responses and provide broader value for the Fresno region. These are not intended to be adaptation strategy recommendations for these sites, but rather sets of strategies that could be considered and evaluated using the principles outlined in this memo.

Bike and Pedestrian

Lake Joallan Class I Shared Use Path

Project ID: FRE501587

Agency: City of Firebaugh

Estimated completion date: 2035

Project description: In Firebaugh, along the San Joaquin River and Lake Joallan between the River Ln Trail Head and the end of the Birch Drive shared use path, construct Class I shared use path and trail amenities.

Main climate stressors of concern: Temperature rise is a concern and relevant climate stressor across Fresno County. Some areas may suffer more severe impacts from the UHI effect, which will likely be a greater concern from the Fresno-Clovis metropolitan area. The greatest change in temperature rise is expected in the eastern portion of the county, in the Sierra Nevada, as this geography historically experienced lower average and maximum temperatures. Given that temperature rise is a universal concern, it can be considered in all Fresno County transportation projects. It is especially relevant when considering impacts to bicyclists and pedestrians, who will exert themselves in the heat. Community survey results identified that walking and biking is uncomfortable in the summer months and more shade is needed along sidewalks/roadways.

Flooding is another concern for this trail construction project, as it will follow the San Joaquin River and the trail may flood periodically.

See the Fresno County Regional TNVA Final Technical Memorandum for more information on future projections and exposed transportation assets in Fresno County.

Potential adaptation strategies:

There are several adaptation strategies worth considering for trail construction projects, including:

Temperature responses:

- Shaded protection from structures and vegetation to ensure bicyclist and pedestrian comfort/health and safety during high heat events
- Air quality impact mitigation for bicyclist and pedestrian comfort/health and safety
- Multilingual notifications during poor air quality events for bicyclist and pedestrian health and safety

Co-benefits include improved bicyclist and pedestrian experience, reduced instances of heat health events, and reduced instances of poor air quality-related health events.

Flooding responses:

- Tree wells, bioswales, and rain gardens to mitigate flash flooding and re-direct surface runoff
- Increase gutter/drainage capacity based on future projections to accommodate heavy precipitation
- Elevate path and amenities to avoid potential seasonal flooding
- Use permeable pavements to accelerate percolation of rainfall into the soil

Co-benefits include improved bicyclist and pedestrian experience, flood control improvements on a larger scale, greenhouse gas reductions, green, blue, and open space from landscaping.

Figure 29: San Joaquin River Trailhead

Source: Photo by niicedave, licensed under CC BY-SA 2.0

Transit

Associated Transit Improvements

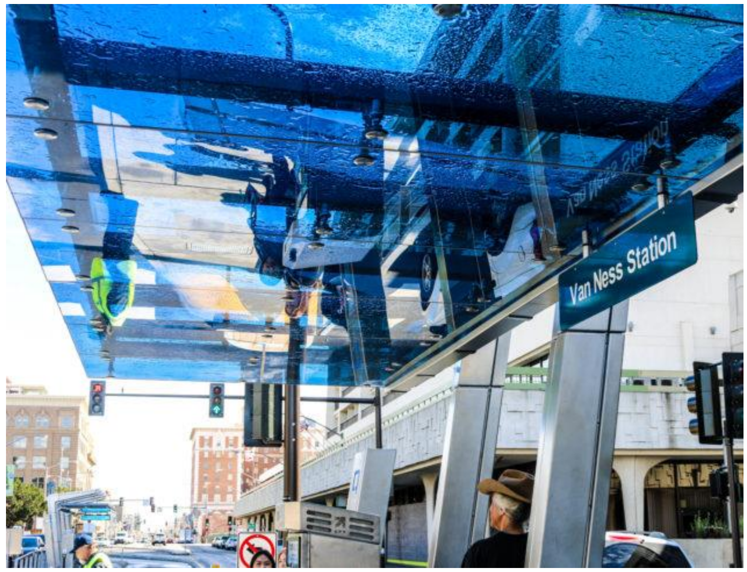
Project ID: FRE501099

Agency: Fresno Area Express

Estimated completion date: Unknown

Project description: Passenger amenity improvements (bus stops/stations) throughout FAX route system, including concrete improvements, shelters, lighting, signage, etc.

Figure 30: FAX Van Ness Station



Source: https://theknowfresno.org/03/02/2018/whats-fix-fax/

Main climate stressors of concern: As noted above, temperature rise is a concern and relevant climate stressor across Fresno County. Heat impacts are relevant to transit projects as riders, especially those dependent upon public transportation, because they will be disproportionately affected by heat impacts if they need to walk to/wait at transit stops in the heat.

Flooding is a concern for rural transit stops, because many stops do not have stormwater systems or adequate drainage to convey surface runoff. This was an issue that came up in survey and interview results with members of the community. Standing water at transit stops can make them hard to access during winter months.

See the Fresno County Regional TNVA Final Technical Memorandum for more information on future projections and exposed transportation assets in Fresno County.

Potential adaptation strategies:

There are several adaptation strategies worth considering for transit stop upgrades, including:

Temperature responses:

- Shaded protection from structures and vegetation to ensure rider comfort during high heat
- Benches and other bus stop amenities to ensure rider comfort during high heat

Co-benefits include: improved rider experience, reduced instances of heat health events, equitable distribution of resources – if transit stop improvements are focused in low-income, disadvantaged, or heat vulnerable communities in Fresno County.

Flooding responses:

- Tree wells, bioswales, and rain gardens to mitigate flash flooding and re-direct surface runoff
- Increase gutter/drainage capacity based on future projections to accommodate heavy precipitation

Co-benefits include flood control improvements on a larger scale, greenhouse gas reductions, green, blue, and open space from landscaping.

Streets and Roads – Capacity Increasing

Belmont-Cornelia to Marks: 2 LU to 5 LU

Project ID: FRE500634

Agency: City of Fresno

Estimated completion date: 2035

Project description: 2 LU to 5 LU with bike lanes, gutter, curbs and sidewalks.

Figure 31: Belmont Avenue from Cornelia to Marks

Main climate stressors of concern: Temperature rise is a concern and relevant climate stressor across Fresno County. Heat can not only impact the health and safety of the public, but the long-term viability of certain materials such as pavements. A capacity increasing project such as this one can incorporate strategies that mitigate heat impacts to the public and to pavements.

Flooding is a concern especially in locations without existing drainage. As this capacity increasing project will also add gutters, there is an opportunity to incorporate strategies that reduce flood impacts to the roadway, bike lanes, sidewalks, and the users of those transportation options.

See the Fresno County Regional TNVA Final Technical Memorandum for more information on future projections and exposed transportation assets in Fresno County.

Potential adaptation strategies:

There are several adaptation strategies worth considering for capacity increasing projects, including:

Temperature responses:

- Plant shade trees along street and sidewalk to ensure bicyclist and pedestrian comfort/health and safety during high heat events

Co-benefits include improved bicyclist and pedestrian experience and reduced instances of heat health events.

Flooding responses:

- Install tree wells, bioswales, and rain gardens to mitigate flash flooding and re-direct surface runoff

- Increase gutter/drainage capacity based on future projections to accommodate heavy precipitation

Co-benefits include flood control improvements on a larger scale, greenhouse gas reductions, green, blue, and open space from landscaping.

Streets and Roads – Maintenance

Replace Bridge No. 42C0264-Jose Basin Road Over Bald Mill Creek

Project ID: FRE130082

Agency: Fresno County

Estimated completion date: 2035

Project description: Bridge no. 42C0264, Jose Basin Rd, over Bald Mill Creek, 2.3 mi northeast of Auberry Rd. Replace existing one lane bridge with two lane bridge.

Figure 32: Jose Basin Road Bridge over Bald Mill Creek

Main climate stressors of concern: The Jose Basin Road Bridge crossing lies in a rural part of the county in Auberry, California. The roadway crosses through forests in the Sierra Nevada, making it inherently exposed to wildfire risk. Wildfires can damage roadways and supporting infrastructure, while also cutting off corridors needed for evacuation.

The Bald Mill Creek crossing also inherently creates a flood risk in the event of heavy precipitation and runoff. Flooding can impact the bridge approaches and debris can damage/erode bridge substructure.

See the Fresno County Regional TNVA Final Technical Memorandum for more information on future projections and exposed transportation assets in Fresno County.

Adaptation strategies:

There are several adaptation strategies worth considering for bridge replacement projects, including:

Flooding responses:

- Adjust discharge/flow estimates used for assessing water levels and scour
- Account for post-wildfire debris in design of bridge substructure

- Understand consequences of design storm exceedance
- Use risk-based design based on expected future precipitation conditions and consequences

Co-benefits include flood control improvements on a larger scale, improved stormwater management, enhanced public safety during heavy precipitation and flood events.

Wildfire responses:

- Consider the bridge's use in evacuation planning
- Implement transportation design strategies that will facilitate smoother evacuation
- Consider operational responses at the site that will facilitate smoother evacuation

Co-benefits include enhanced public safety during wildfires and evacuations.

Streets and Roads – Operations

Drainage

Project ID: FRE501841

Agency: Caltrans

Estimated completion date: 2023

Project description: Replace and reline culverts.

Main climate stressors of concern: Precipitation and flooding is the primary stressor of concern for culverts and drainage infrastructure. Increased frequency and severity of heavy precipitation events may lead to events that exceed the design capacity for existing culverts.

See the Fresno County Regional TNVA Final Technical Memorandum for more information on future projections and exposed transportation assets in Fresno County.

Adaptation strategies:

- Adjust precipitation and discharge projections used in culvert design
- Enhance drainage capacity of culverts

Co-benefits include flood control improvements on a larger scale and improved stormwater management.

Next Steps

Fresno COG and its stakeholders can use this toolkit of adaptation strategies to identify implementable and beneficial responses to climate change impacts across the region. These strategies can be applied to planned or current projects, or may even stand alone as their own projects in future rounds of the RTP. And more broadly, Fresno County jurisdictions can incorporate the findings of this memorandum and the Fresno County Region TNVA into the Safety Elements of their General Plans to satisfy the requirements of SB 379. The information summarized in this memorandum and other Fresno County Region TNVA deliverables will be compiled into a final report for use by Fresno COG, its stakeholders, and the public.

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