Potential Climate Change Impacts and the BLM Rio Puerco Field Office's Transportation System: A Technical Report

Prepared for the Bureau of Land Management's Rio Puerco Field Office, New Mexico

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13. ABSTRACT (Maximum 200 words) This report provides information about potential climate change impacts in central New Mexico and their possible implications for the Bureau of Land Management (BLM) Rio Puerco Field Office (RPFO) transportation network. The report considers existing global and regional climate change projections and analyzes the results of locally downscaled climate change projections corresponding to different RPFO ecoregions; identifies BLM's options for adapting the transportation system to climate change impacts, as well as how RPFO can incorporate climate change adaptation and resilience into its TTMP; and considers opportunities for greenhouse gas (GHG) emission reduction, or climate change mitigation, at Rio Puerco.			
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List of Abbreviations

Abbreviation	Term
BLM	Bureau of Land Management
CCSP	Central New Mexico Climate Change Scenario Planning Project
FLMA	Federal Land Management Agency
FWS	U.S. Fish and Wildlife Service
CMIP	Coupled Model Intercomparison Project
GCM	Global Circulation Model
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
MRCOG	Mid-Region Council of Governments
NCA	National Conservation Area
NPS	National Park Service
RPFO	Rio Puerco Field Office
TTMP	Travel and Transportation Management Plan
Volpe Center	John A. Volpe National Transportation Systems Center

Executive Summary

The Bureau of Land Management (BLM) owns approximately 800,000 public surface acres of land and manages 3 million acres of subsurface mineral acres in the Rio Puerco Field Office (RPFO) in central New Mexico. The RPFO transportation network supports recreation, local community access, resource extraction, and agency management activities in the region.

The RPFO is currently developing its Travel and Transportation Management Plan (TTMP), which will help the BLM identify and manage its transportation network. This report provides information about potential climate change impacts in central New Mexico and their possible implications for the RPFO transportation network, which the BLM may use to inform its TTMP process. This report has been prepared as part of the Central New Mexico Climate Change Scenario Planning Project (CCSP), which is a collaborative effort between the Federal Highway Administration (FHWA), BLM, National Park Service (NPS), U.S. Fish and Wildlife Service (FWS), the John A. Volpe National Transportation Systems Center (Volpe Center), Mid-Region Council of Governments (MRCOG), and other Federal and local partners to research and identify potential climate change impacts to the region and incorporate them into regional land use and transportation planning processes.

The CCSP's analysis shows that climate change is projected to affect both natural ecosystems and transportation infrastructure in the region. As a significant landowner and transportation manager in the region, the BLM should be aware of these potential impacts and how they may affect the BLM's infrastructure and operations. This report describes these potential impacts, suggests ways in which BLM can incorporate climate change adaptation into its transportation planning process, and analyzes opportunities for climate change mitigation.

Potential Climate Change Impacts for the RPFO

Recent literature on projected climate changes in central New Mexico and the Southwest generally come to similar conclusions with regard to the direction and possible range of magnitude of potential changes to climate conditions. However, there is substantial uncertainty in the climate projections, which are expressed in ranges of potential change. This report considers existing global and regional climate change projections and analyzes the results of locally downscaled climate change projections corresponding to different RPFO ecoregions.

This report presents these projections for the period 2025 to 2055. This period is centered on 2040 with 15 years of projections on either side to smooth the data and avoid noise from year-to-year variations. Focusing on the year 2040 allows the CCSP's analysis to be compatible with the planning timeframes for the RPFO TTMP and the central New Mexico region's Metropolitan Transportation Plan time horizons.

In general, the primary climate change trends affecting the region in 2040 are projected to be:

- Increasing average and extreme temperatures, especially during the summer and fall months;
- Increasing water scarcity and drought due to a variety of causes;
- Increasing likelihood of flash floods due to heavy precipitation events;
- Increasing likelihood of more intense and frequent wildfires; and

- Implications from hotter and drier conditions, such as impacts to natural resources.

Implications for the RPFO Transportation System

These projected climate impacts increase the potential risk of damage to RPFO's transportation system. Because the vast majority of the Rio Puerco's road system is made up of unpaved roads, the most relevant threats to its transportation infrastructure listed above are erosion due to flooding, blockage or damage to culverts and drainage structures, and post-wildfire damage. RPFO paved roads also may face higher maintenance costs due to higher temperatures.

Although many of the projected climate change impacts will affect transportation infrastructure throughout the RPFO, there are certain areas that will be particularly vulnerable to certain types of climate change impacts. For example:

- Seventy-eight percent of all RPFO roads in existing flood hazard areas are in four TMAs: El Malpais, Petaca Pinta, San Juan Basin Badlands, and Zuni. Ninety-eight percent of RPFO roads in flood hazard areas are located in the Arizona/New Mexico Mountains Ecoregion. These areas will continue to be the most vulnerable to flooding in the future as the climate changes.
- Extremely high temperatures and heat waves are more likely at lower elevations. These areas generally correspond to the Arizona/New Mexico Plateau and the Southwest Tablelands Ecoregions. Paved roads in these areas will be more vulnerable to degradation from extreme heat in the future.
- Although wildfire risks vary across the RPFO, the ecoregions that generally have the highest wildfire risk are the Arizona/New Mexico Mountains and Southern Rockies ecoregions. These areas are most likely to experience road damage due to wildfires in the future.

Adaptation and Mitigation Options for the RPFO

Later sections of this report discuss BLM's options for adapting the transportation system to climate change impacts, as well as how RPFO can incorporate climate change adaptation and resilience into its TTMP. Adaptation strategies fall under the general categories of protection, accommodation, retreat, maintenance, and disaster recovery. These strategies can be assessed based on each transportation asset's importance, vulnerability, and adaptive potential.

Lastly, the report considers opportunities for greenhouse gas (GHG) emission reduction, or climate change mitigation, at Rio Puerco, as well as some case studies RPFO could use as examples. It also suggests ways in which the field office could collaborate with regional partners to reduce emissions.

Chapter 1: Introduction

A changing climate will affect natural ecosystems as well as transportation systems and other infrastructure in central New Mexico for the foreseeable future. As a significant landholder in the region, the Bureau of Land Management (BLM) should be aware of climate change impacts in the region and how they may affect the BLM's infrastructure and operations. By understanding and anticipating potential climate change impacts as part of its transportation planning process, the BLM can prepare for a number of management options to adapt its transportation infrastructure and decrease its vulnerability. This technical report is compiled to support the BLM's Rio Puerco Field Office (RPFO) Travel and Transportation Management Plan (TTMP), which is currently under development.

Report Context

This report is a product of the Central New Mexico Climate Change Scenario Planning Project (CCSP), a collaborative research and planning effort in the Albuquerque metropolitan region to incorporate considerations of climate change mitigation, adaptation, and resilience into regional land use and transportation planning processes. The CCSP is funded by the Federal Highway Administration (FHWA), Bureau of Land Management (BLM), U.S. Fish and Wildlife Service, and National Park Service. The CCSP is managed by the U.S. Department of Transportation's Volpe National Transportation Systems Center (Volpe Center) with oversight from FHWA. The project was a partnership between FHWA, the Volpe Center, the Mid-Region Council of Governments (MRCOG), and Federal land management agencies in the Albuquerque region.

One key task of the CCSP was to develop a series of climate futures to demonstrate a range of possible changes to temperature and precipitation trends in central New Mexico by the year 2040, which could be incorporated into interagency planning efforts. As part of the CCSP, MRCOG coordinated with local and federal partners to develop land use and transportation development scenarios in the region and used the climate futures to evaluate the resilience of these scenarios as part of its 2040 Metropolitan Transportation Plan.

Relationship to the RPFO TTMP

The purpose of this report is to provide information about the potential impacts of climate change in central New Mexico that can inform the development of the RPFO TTMP. The BLM owns approximately 800,000 public surface acres of land and manages 3 million acres of subsurface mineral acres in the region.[1] The BLM's RPFO transportation network supports travel for recreation, local communities, resource extraction, and BLM management activities. Figure 1 shows BLM land in the Rio Puerco, the area's ecoregions, the RPFO's roads network, and the RPFO's designated Travel Management Areas (TMAs).[2] The RPFO's transportation system affects natural ecosystems and is vulnerable to damage from

[1] BLM, 2012a. Rio Puerco Resource Management Draft Plan and Environmental Impact Statement: http://www.blm.gov/nm/st/en/fo/Rio_Puerco_Field_Office/rpfo_planning/rpfo_draft_rmp.html.

[2] The BLM may designate TMAs within a Field Office to identify areas with unique travel, resource, or other planning characteristics as part of a Field Office's Resource Management Plan. BLM, 2011a. Travel and Transportation Manual.

natural events, such as flooding, erosion, or wildfires.

This report presents the CCSP's findings that are most relevant for the RPFO TTMP, given the purpose of the TTMP and the nature of the BLM's transportation system. It also provides a framework for considering actions to mitigate the effects of climate change and adapt the RPFO's transportation system to changing climate conditions and to increase its resilience, which BLM staff may consider as they develop TTMP recommendations.

This report presents these projections for the period 2025 to 2055. This period is centered on 2040 with 15 years of projections on either side to smooth the data and avoid noise from year-to-year variations. Focusing on the year 2040 allows the CCSP's analysis to be compatible with the planning timeframes for the RPFO TTMP and the central New Mexico region's Metropolitan Transportation Plan time horizons.

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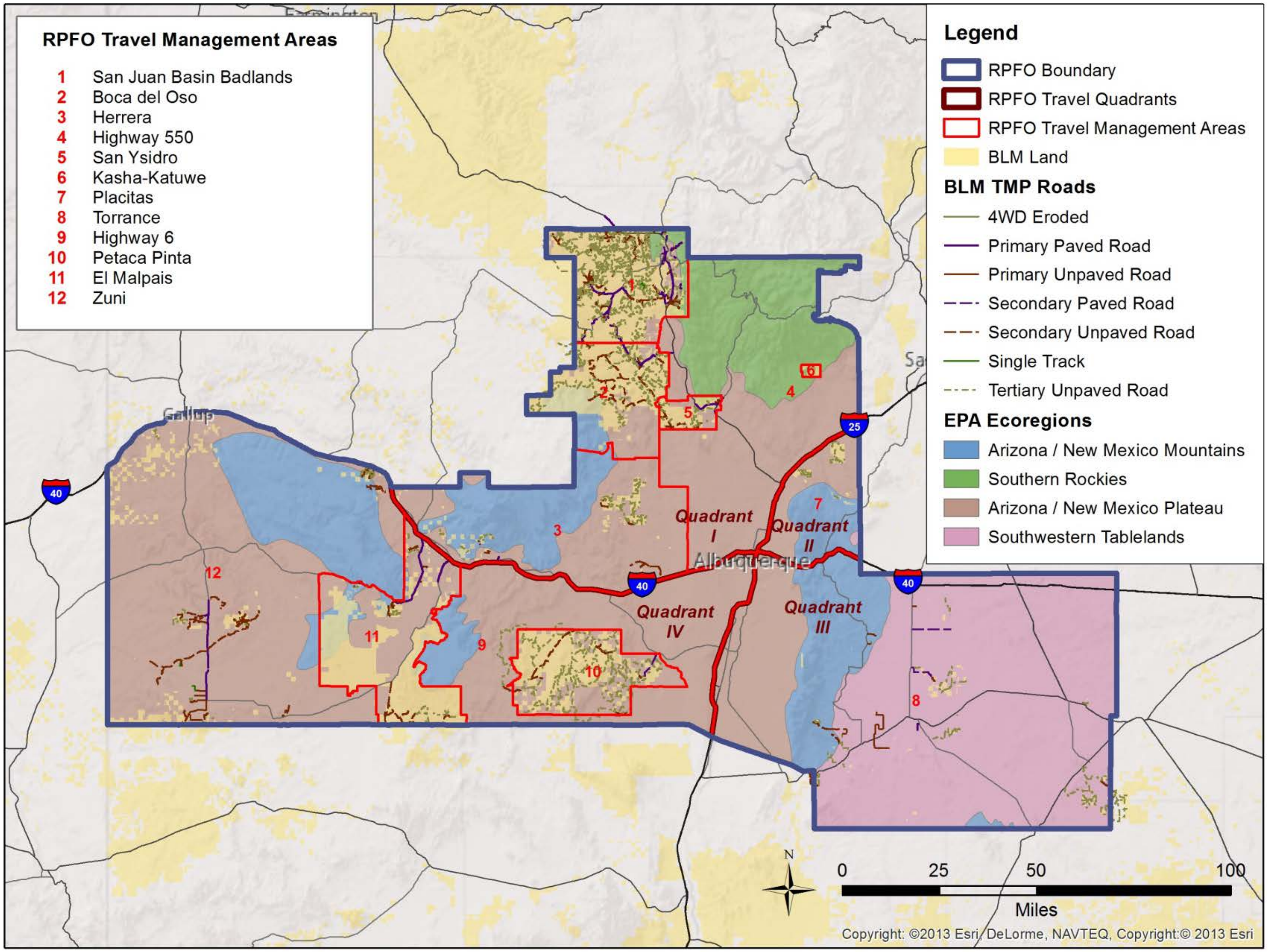
http://www.blm.gov/style/medialib/blm/wo/Information_Resources_Management/policy/blm_manual.Par.38105.File.dat/1626.pdf.

Figure 1: RPFO Site Map



Climate Change and Transportation Infrastructure

Climate change planning as it relates to transportation infrastructure falls within two categories: adaptation and mitigation. Climate change adaptation strategies focus on preparing for projected climate change impacts, whereas climate change mitigation strategies aim to reduce the causes of climate change. Climate change adaptation and mitigation are interrelated and, ideally, Federal land management agencies should considered them holistically and, where possible, identify strategies that advance both categories.

Adaptation strategies focus on adapting infrastructure design, maintenance, or operations to prepare for potential climate change impacts, such as increased flooding, erosion, landslides, and wildfires, and to increase the resilience of the transportation system to potential disruptions. Adaptation strategies also provide an opportunity to revisit current management practices and to improve existing policies and practices, including those that increase vulnerability, to ensure a more sustainable future.[3]

Climate change mitigation strategies focus on reducing the causes of climate change by reducing or sequestering greenhouse gas emissions. In the case of transportation, common climate change mitigation strategies include multi-modal transportation planning to reduce reliance on private vehicles, the use of low-emissions vehicles, and reducing energy consumption from transportation-related facilities and operations.

Report Organization

Although the focus of this report is on how BLM can incorporate climate change adaptation into its transportation planning process in the RPFO, it also analyzes some opportunities for climate change mitigation. The report is organized into five chapters:

- **Chapter 1: Introduction**
- **Chapter 2: Potential Climate Change Impacts to Rio Puerco and Local Transportation Systems:** This chapter analyzes the state of current knowledge on the potential impacts on climate change for the Rio Puerco and the potential impacts these changes could have on the BLM's transportation systems.
- **Chapter 3: Adaptation and Resilience Framework for Rio Puerco Transportation Planning:** This chapter analyzes potential adaptation options for the BLM to increase the resilience of its transportation systems and minimize the impacts of the transportation system on the Rio Puerco's natural resources.
- **Chapter 4: Potential Greenhouse Gas Mitigation Strategies at Rio Puerco:** This chapter summarizes actions that the BLM could take to reduce transportation-related greenhouse gas (GHG) emissions at the Rio Puerco, highlighting related regional efforts that Rio Puerco can use

[3] White House Council on Environmental Quality, 2010. *Progress Report of the Interagency Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy.* http://www.whitehouse.gov/sites/default/files/microsites/ceq/Interagency-Climate-Change-Adaptation-Progress-Report.pdf.

as examples and potential regional partnerships.

- **Chapter 5: Conclusion**
- **Appendix A: Climate Futures Analysis by Ecoregion:** Appendix A provides the climate futures for grid cells throughout the Rio Puerco area that correspond to each of the BLM's ecoregions. This information is a supplement to the analysis in Chapter 2.

Chapter 2: Potential Climate Change Impacts to the Rio Puerco and Local Transportation Systems

Potential Changes to Climate in the RPFO

The RPFO is located in the Upper Rio Grande River basin in the American Southwest, the hottest and driest region in the United States. The Upper Rio Grande River basin is in the central part of the U.S. Southwest and has regional variation due to microclimates and elevation changes. In general, the primary climate change trends affecting the region are projected to be:

- Increasing average and extreme temperatures, especially during the summer and fall months;
- Increasing water scarcity and drought due to a variety of causes;
- Increasing likelihood of flash floods due to heavy precipitation events;
- Increasing likelihood of more intense and frequent wildfires; and
- Implications from hotter and drier conditions, such as impacts to natural resources.

These trends are discussed in more detail below.

Summary of Recent Research on Central New Mexico Climate Change Projections

Recent literature on projected climate changes in central New Mexico and the Southwest generally come to similar conclusions with regard to the direction and magnitude of potential changes to climate conditions.[4,5,6] However, there is substantial uncertainty in the climate projections, which are expressed in ranges of potential change. For this reason, it is important for the BLM to consider how climate change could affect the Rio Puerco under a range of different future temperature and precipitation conditions.

Global Climate Models and Sources of Uncertainty

Most projections of potential temperature and precipitation changes over the next century have been made by analyzing the outputs of global climate models (GCMs) run through a range of GHG emission scenarios. These models generally agree on the direction of future global change, but the projected size of those changes cannot be precisely predicted across models. This range of uncertainty is due to three primary sources: natural variability in weather conditions, uncertainty about future GHG emissions, and

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[4] Garfin, et al., 2014. Ch. 20: Southwest. *Climate Change Impacts in the United States: Third National Climate Assessment.* J.M. Melillo, Terese (T.C.) Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 462-486.

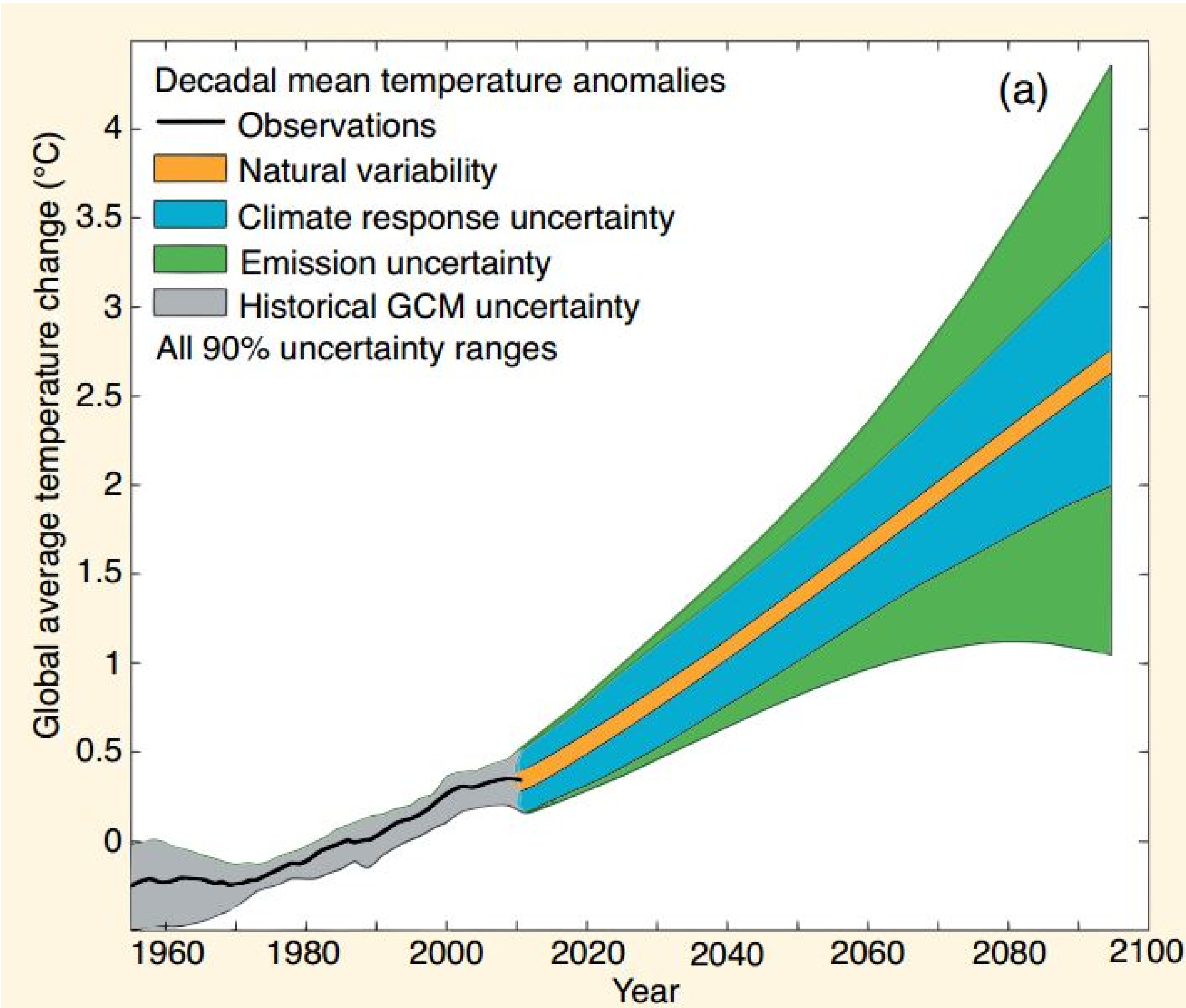
[5] Weiss, J., 2014. *Potential Changes in Future Regional Climate and Related Impacts – A Brief Report for the Central New Mexico Climate Change Scenario Planning Project.* Climate Assessment for the Southwest (CLIMAS). Prepared for the Central New Mexico Climate Change Scenario Project and available upon request.

[6] Llewelyn, et al., 2013. Appendix B: Literature Review of Observed and Projected Climate Changes. *West-Wide Climate Risk Assessment: Upper Rio Grande Impact Assessment*. U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Sandia National Laboratories. http://www.usbr.gov/WaterSMART/wcra/reports/urgia.html.

model uncertainty about how the region's climate will respond to changes in GHG emissions over time.[7]

Figure 2 illustrates the relative importance of these three sources of uncertainty over different timescales.

Figure 2: Schematic diagram showing the relative importance of different uncertainties and their evolution in time



Source: Intergovernmental Panel on Climate Change Fifth Assessment[8]

The IPCC developed several GHG emissions scenarios to model the potential range of climate change impacts depending on the magnitude of future GHG emissions. In 2001, the IPCC developed the Special Report on Emissions Scenarios (SRES) scenarios, which the project team used in much of the research cited below, which the project team in turn used to model potential climate change in the central New

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[7] Cubasch, et al., 2013. Introduction. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Stokcker, et al., Eds. Cambridge University Press, New York, NY.
[8] Cubasch, et al., 2013.

Mexico Region. The SRES scenarios include:

- A2: rapid economic growth with limited transition to low-GHG technologies (high GHG emissions)
- A1B: rapid economic growth with a balance of fossil intensive and non-fossil energy sources (medium GHG emissions)
- B1: transition to a low-GHG economy with introduction of clean and resource-efficient energy sources (low GHG emissions)

Projected Temperature Changes

The U.S. Global Change Research Program's Third National Climate Assessment for the U.S. Southwest discusses climate change projections for the six-state Southwest region (California, Nevada, Arizona, Colorado, Utah, and New Mexico). For the Southwest region, the Third National Climate Assessment projected that regional average temperatures will rise by 2.5°F to 5.5°F by 2041-2070 and by 5.5°F to 9.5°F by 2070-2099 if GHG emissions continue to grow (A2 emissions scenario). If global GHG emissions reduce substantially (B1 scenario), then the region would see a projected increase of 2.5°F to 4.5°F by 2041-2070 and 3.5°F to 5.5°F by 2070-2099. Summertime heatwaves are expected to be longer and hotter, and wintertime cold weather is expected to decrease.[9]

Climate Assessment for the Southwest (CLIMAS) prepared a report for the CCSP summarizing current research on potential climate change effects in the Southwest.[10] This report found that annual mean temperature for the six-state region could increase relative to the 1971-1999 reference period by 1.3°F to 3.8°F for 2021-2050, 1.8°F to 6.0°F for 2041-2070, and 2.7°F to 10.1°F. This shift in annual mean temperatures is expected to have impacts on extreme temperatures, as well, leading to fewer cold spells and warmer, longer, and more frequent heat waves.

The U.S. Bureau of Reclamation (BoR), U.S. Army Corps of Engineers (USACE), and Sandia National Laboratories' *Upper Rio Grande Impact Assessment (URGIA)* analyzes the potential hydrological impacts of climate change on the Upper Rio Grande River basin and includes a literature review of observed and projected climate changes in the Upper Rio Grande area of New Mexico.[11] This report provides more locally downscaled projections than the Third National Climate Assessment or CLIMAS, so the findings are more directly applicable to the Rio Puerco and do not include areas of the Southwest that have substantially different climates. According to the *URGIA* report, mean annual temperatures in the Upper Rio Grande River basin are projected to rise by 5.4°F to 9°F by 2100. Temperature increases are expected to be greater in the summer and fall months, cold spells will be shorter and less cold, and heat waves will be longer and more intense.

Projected Precipitation Changes

The Third National Climate Assessment for the U.S. Southwest states that projections of precipitation changes are less certain and vary more throughout the Southwest. In the southern part of the Southwest, reduced winter and spring precipitation is projected, but precipitation changes projected for the northern part of the southwest are smaller than natural variations. Because central New Mexico is in the center of this region, projections for precipitation changes are uncertain. However, the Third

[9] Garfin, et al., 2014.
[10] Weiss, 2014.
[11] Llewelyn, et al., 2013.

National Climate Assessment also states that droughts will be hotter and more intense. Precipitation in higher elevations will also fall less as snow and more as rain.[12]

CLIMAS reports similar conclusions, noting that the southern part of the Southwest may see drier conditions while the northern area may see little or no change relative to natural variation. According to CLIMAS, the region's total annual precipitation may change between -10 percent to +7 percent during 2021-2050, -17 percent to +7 percent during 2041-2070, and -20 percent to +10 percent during 2070-2099, relative to a 1971-1999 baseline.[13]

The *URGIA*[14] explains the reason for this uncertainty in precipitation projections: central New Mexico's location on the boundary between the subtropical dry zone and the temperate mid-latitude zone means that if this boundary moves north, then the region will receive less precipitation, while southward movement of this boundary would result in more precipitation for the Upper Rio Grande. The region's precipitation patterns will thus be influenced by how climate change affects the oceanic and atmospheric processes that influence the location of this boundary and the instance of ocean-driven anomalies such as El Niño, La Niña, and the North American Monsoon. The report states that overall, models project that precipitation in the Upper Rio Grande will remain unchanged or will decline slightly over the 21st century, with a maximum reduction of approximately 13 percent.

The *URGIA* also states that there is a potential for a greater frequency and intensity of extreme precipitation events, but GCMs currently do not model this well. According to recent studies (such as Kunkel, et al., 2013[15] and Kunkel, et al., 2014[16]), the size of the probable maximum precipitation event for most of the world may increase by 10 to 30 percent in 2017-2100, compared to a baseline period of 1971-2000. According to the *URGIA*, the increased storm intensity in the Southwestern U.S. is anticipated to occur mainly in July and August: "Climatologically, this would seem to indicate more intense, localized monsoon storm events (e.g., bigger flash floods) and not increased spring runoff flood events. The driving force in this increase in storm intensity is increased global atmospheric moisture content."[17] However, the magnitude of future extreme precipitation events is difficult to project with current GCMs.

CCSP Climate Futures

The CCSP project team built upon the previous studies of regional climate change projections to develop projections that would serve the additional needs of the CCSP by being more local in scale, focusing on the 25-year time horizon of local metropolitan planning, and providing more detailed scenarios of potential future climate conditions. The CCSP team developed "climate futures" for the planning horizon year of 2040; these futures represent multiple scientifically plausible alternative scenarios that provide a

[12] Garfin, et al., 2014.
[13] Weiss, 2014.
[14] Llewelyn, et al., 2013.
[15] Kunkel, et al., 2013. *Monitoring and Understanding Trends in Extreme Storms: State of Knowledge*. Bulletin of the American Meteorological Society, 94: 499-514. http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00262.1.
[16] Kunkel, et al., 2014. *Changes in weather and climate extremes: State of knowledge relevant to air and water quality in the United States*. Journal of the Air & Waste Management Association, 64(2): 184-197. http://www.tandfonline.com/doi/abs/10.1080/10962247.2013.851044#.VHJC1IvF-xV.
[17] Llewelyn, et al., 2013.

quantitative and local basis to plan for the range of potential changes in future climate in central New Mexico. The climate futures are not forecasts but rather are alternative model-based visions of how the climate can evolve in the study area. Developing and investigating the climate futures allows stakeholders in the CCSP Project, including the BLM, to test decisions or develop strategies in a context of uncertain environmental factors.

The methodology and findings of the Climate Futures are detailed below.

CCSP Climate Futures Methodology

The CCSP Climate Futures are based on the Intergovernmental Panel on Climate Change's (IPCC) Coupled Model Intercomparison Project (CMIP) 3 daily time step climate projections that have been spatially downscaled to 1/8th degree (approximately 7.5 mi^2) resolution by the Bureau of Reclamation.[18] The dataset contained a total of 112 model runs, consisting of nine different climate models and three emissions scenarios (A1B, A2, B1).

The Volpe Center calculated model outputs for the following time periods:

- *Baseline period:* 1950-1999
- *Future* period: 2025-2055. This period is centered on 2040, with 15 years of projections on either side to smooth the data and avoid noise from year-to-year variations.

The Volpe Center also performed a calibration of the models' forecasts based on agreement between historic meteorological data and the models' back casts.

To classify the 112 GCM runs into potential climate futures, the Volpe Center divided the model runs into four quadrants based on their changes in annual mean temperature and annual mean precipitation. In addition, Volpe created a fifth Central Tendency future, which was defined by the 25th and 75th percentile values of the average changes in temperature and precipitation. The five climate futures are:

- Warm, Wet
- Warm, Dry
- Central Tendency
- Hot, Wet
- Hot, Dry

The temperatures range widely along the temperature axis, but it is important to note that none of the possibilities is a decrease in annual temperature. All of the models agree about the direction of change, but not the magnitude. By contrast, the change in average annual precipitation is less certain and ranges from a small increase in precipitation to a small decrease in precipitation. This is consistent with the findings in the literature cited above, particularly the *URGIA*.[19]

In addition to annual mean temperature and precipitation, the Volpe Center calculated the following statistics from the 112 GCM runs:

- Monthly average temperatures

[18] For more detailed information on the development of the Climate Futures, see Volpe Center (in development), Central New Mexico Climate Change Scenario Planning Guidebook, Chapter 3.
[19] Llewelyn, et al., 2013.

- Extreme hot days (above 100°F)
- Heat waves (defined as the number of consecutive days above 100°F)
- Monthly precipitation change
- Extreme precipitation (maximum 24-hour precipitation amount)
- Drought indicator (consecutive days without precipitation)

The Volpe Center created Climate Futures for five locations within the RPFO, shown on Figure 3. The results of these Climate Futures, below, also show an amount of variation within the region.

Rio Puerco Climate Futures Analysis

The CCSP team ran the climate futures analysis for five locations, which correspond to the different Rio Puerco Field Office (RPFO) ecoregions, as shown in Figure 3. These ecoregions correspond to the Environmental Protection Agency's (EPA) Level III Ecoregions, which the BLM uses to inform its planning and environmental monitoring, assessment, and reporting. Over 85 percent of BLM-owned lands in the RPFO are in the Arizona / New Mexico Plateau ecoregion, with the rest being in the Arizona / New Mexico Mountains, the Southern Rockies, and the Southwestern Tablelands. For more discussion of these ecoregions, see the BLM's Rio Puerco Resource Management Draft Plan.[20]

This section presents the climate futures results for Grid Cell A, which is located in the El Malpais National Conservation Area (NCA) in the Arizona / New Mexico Plateau and Mountains ecoregions. This location is shown here because it is an area with substantial BLM lands. However, all five grid cell outputs are shown in Appendix A. The five grid cells analyzed in this report and their associated ecoregions are:

A. El Malpais NCA, Arizona / New Mexico Plateau and Mountains
B. Santa Fe National Forest, Southern Rockies
C. Cibola National Forest, Arizona / New Mexico Mountains
D. Desert area near Estancia, Southwestern Tablelands
E. Southwest Albuquerque, Arizona / New Mexico Plateau

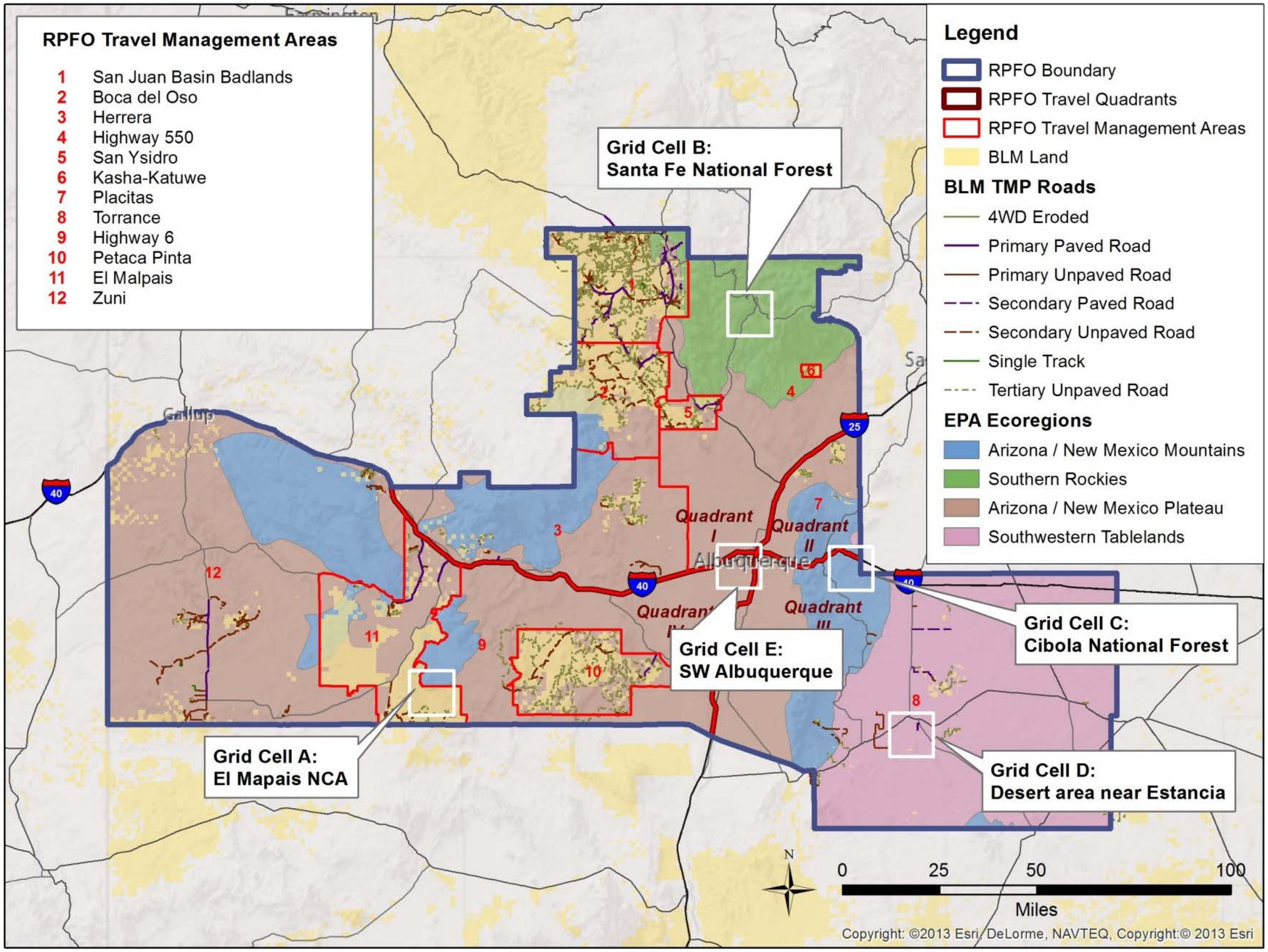
Each of the climate change outputs below are based on the following baseline and future periods for analysis:

- *Baseline period:* 1950-1999
- *Future* period: 2025-2055. This period is centered on 2040, with 15 years of projections on either side to smooth the data and avoid noise from year-to-year variations.

All statistics are calculated as averages of each of the years within the date range. For example, when outputs report a maximum daily temperature for the future period, the number calculated is the average of the projected daily maximum daily temperatures for each year within the 2025-2055 period. Averages, such as average mean temperature, are calculated as the average of the mean temperatures for each year of the period reported (either 1950-1999 or 2025-2055).

[20] BLM, 2012a.

Figure 3: Map showing grid cell locations throughout the RPFO for climate futures analysis

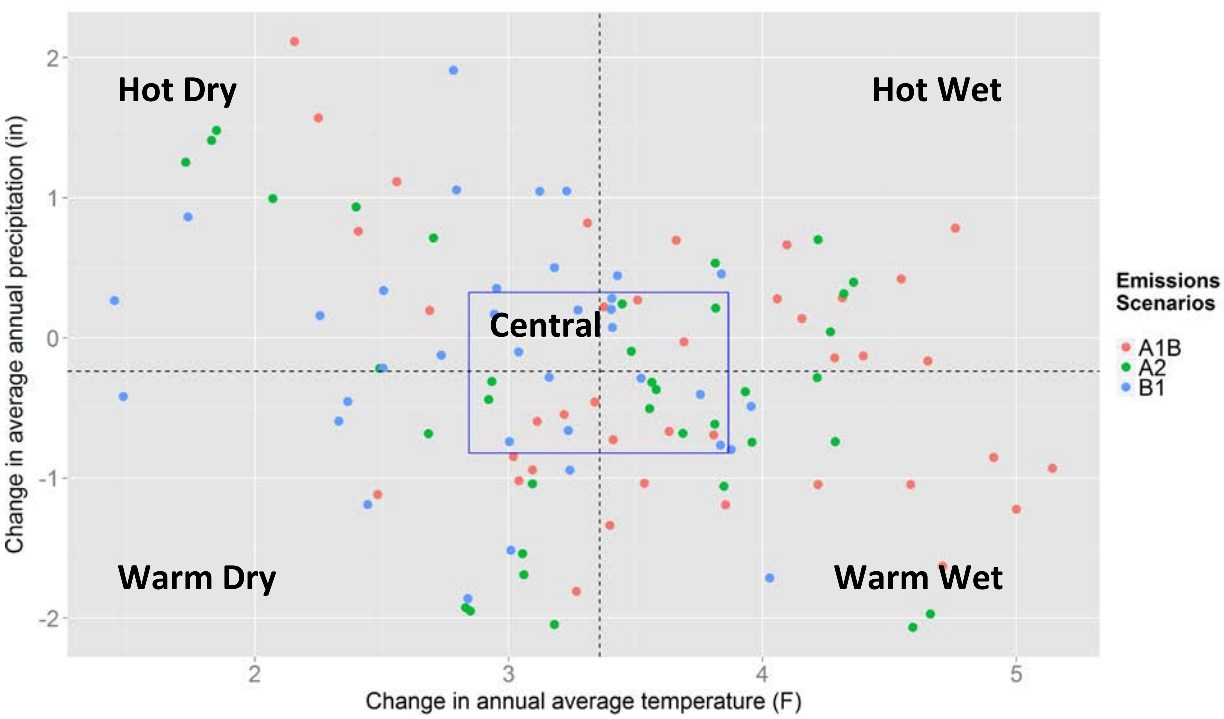


Grid Cell A: El Malpais National Conservation Area, Arizona / New Mexico Mountains and Plateau

Grid Cell A is located in the El Malpais National Conservation Area near Grants, NM. It straddles the boundary between two BLM ecoregions: Arizona / New Mexico Plateau and Arizona / New Mexico Mountains.

For temperature, all of the GCMs agree that it will be hotter, but they disagree on how much. The climate futures analysis shows that the range of projected annual mean temperature changes in the future period (2025-2055) is from +1.4°F to +5.1°F (Figure 4). (The 25th percentile value is +2.8°F, the median value is +3.4°F, and the 75th percentile value is +3.9°F.) For annual mean precipitation, the GCMs show a range of change from -2.1 inches per year to +2.1 inches per year in the future period. (The 25th percentile value is -0.8 inches per year, the median value is -0.2 inches per year, and the 75th percentile value is +0.3 inches.) The uncertainty about whether there will be more or less precipitation per year is consistent with the conclusions in the *URGIA*.[21] In Figure 4, the GCMs are colored based on their emissions scenarios. Generally, there is a higher proportion of GCMs under the A1B (higher emissions scenario) in the Hot Wet and Hot Dry scenarios.

Figure 4: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell A



[21] Llewelyn, et al., 2013.

Figure 5 shows the projected change in average daily maximum temperature for each month for the future period (2025-2055) compared to the baseline period (1950-1999) for each climate future in Grid Cell A. All of the climate futures are consistent in showing that average maximum temperatures will increase in all months, but they will increase more in the summer and fall months than in the winter and spring months.

Figure 5: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell A

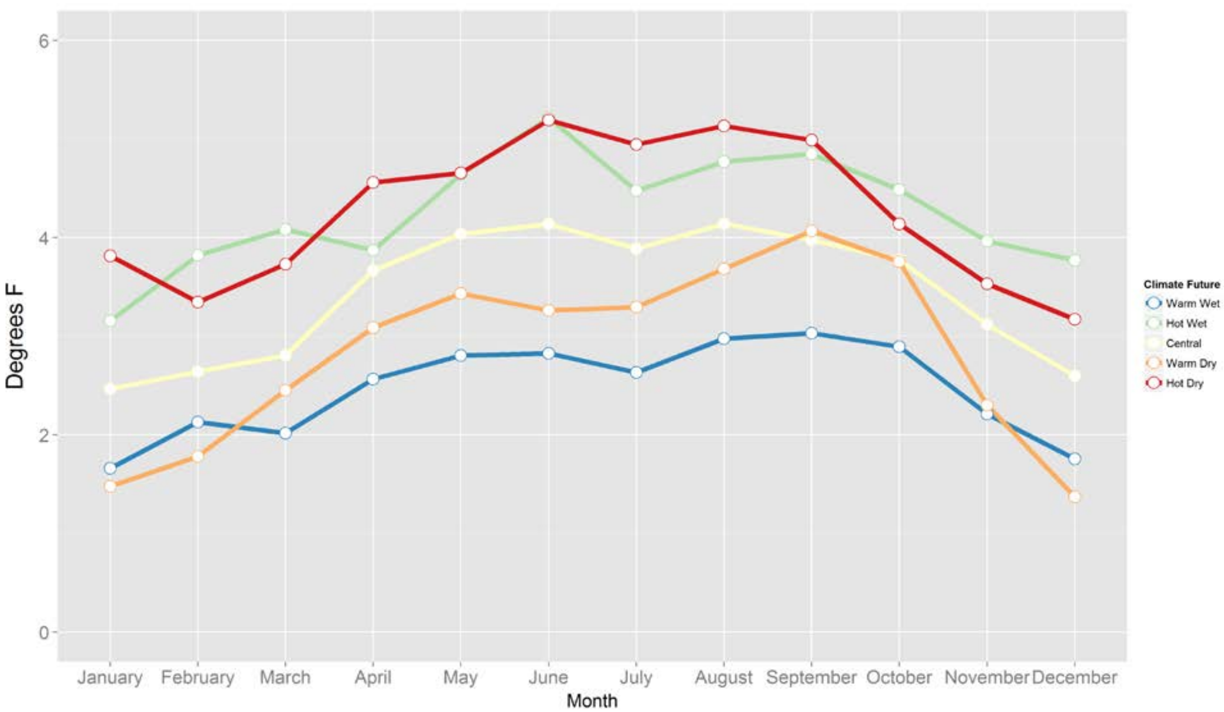


Figure 6 shows the change in the average number of days per year at or above 100°F in the future period (2025-2055), compared with the baseline period (1950-1999), for each climate future. These projections are displayed in box plots by future, and show the 25th-75th percentile values within the box and outliers above and below. The lines extending from the box show the 10th-90th percentile values. The horizontal lines within the boxes show the median value. Currently, an average year has zero days above 100°F in Grid Cell A. For the Warm Wet and Warm Dry futures the median value remains at zero, with extreme values below five days per year. For the hottest future (Hot Dry), the box plot shows a range from approximately two to ten days above 100°F, a median value of approximately six, and an extreme high value of approximately twenty-two. The Central future has a box plot range from zero to 2.5, a median value of approximately one day, and an outlier value of approximately seven days.

Figure 6: Average number of days per year at or above 100°F in the future period (2025-2055) for Grid Cell A

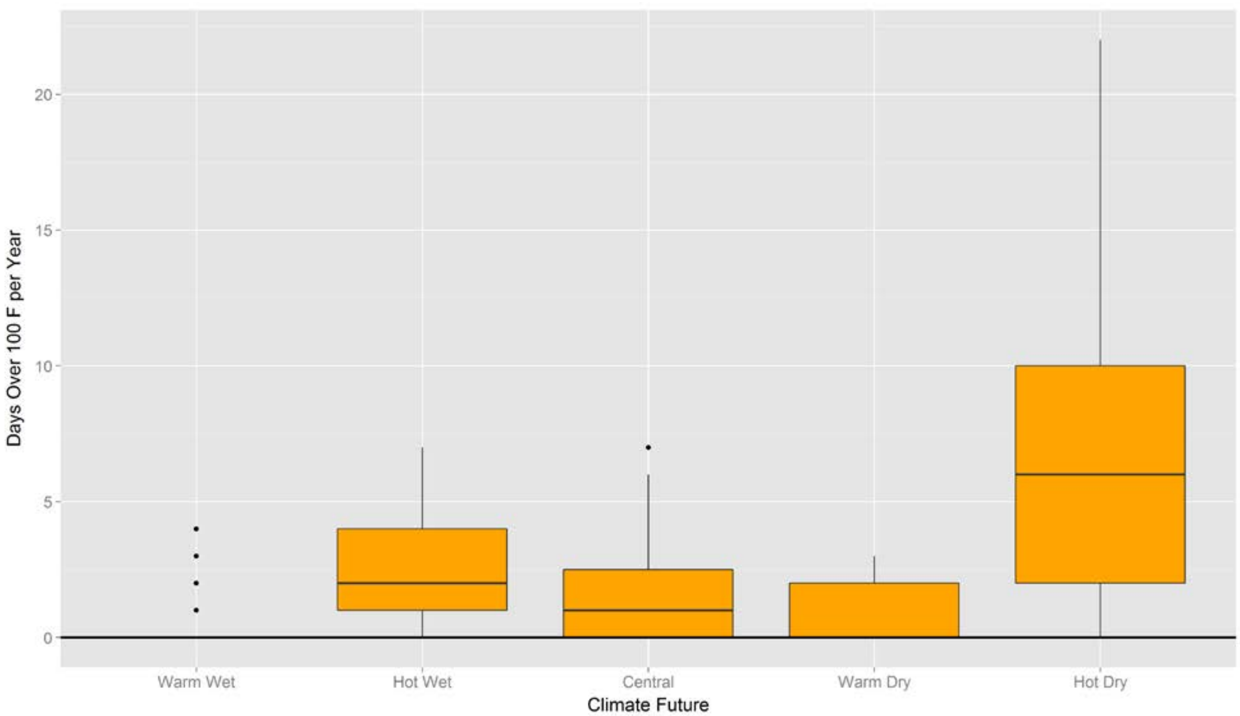


Figure 7 shows the projected maximum number of consecutive days above 100°F per year averaged over the future period (2025-2055) compared to the baseline period (1950-1999). In the case of Grid Cell A, there are no heat waves of multiple days above 100°F in the average baseline year, so the baseline median value is not visible on this graph. For 2040, the Warm Wet and Warm Dry futures still have median projected values of zero consecutive days with extreme high values around 0.1 consecutive days. The hottest climate future (Hot Dry) has a box plot range from approximately 0.1 consecutive days to 0.25 consecutive days, a median value of 0.2 consecutive days, and an extreme high of 0.6 consecutive days above 100°F. This figure suggests that there will still be very few consecutive days above 100°F in 2025-2055 in Grid Cell A. However, the area still may experience more heat waves which do not meet the 100°F threshold.

Figure 7: Maximum consecutive days per year at or above 100°F in the future period (2025-2055) in Grid Cell A

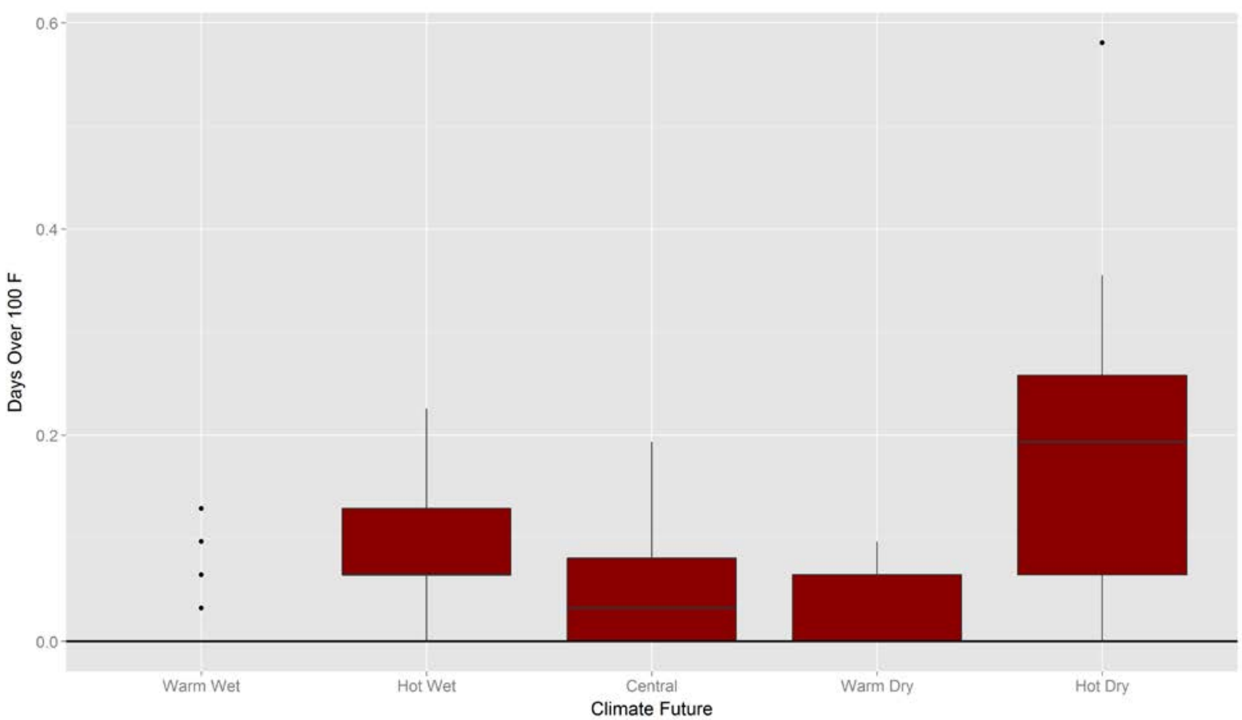


Figure 8 shows the projected change in average monthly precipitation in 2025-3055 by climate future compared with the baseline period (1950-1999). Although there is greater uncertainty about the direction of change (wetter vs. drier) depending on climate future, the climate futures generally agree that precipitation amounts will decrease in the spring and early summer months (April to June). The Central, Warm Dry, and Hot Dry climate futures also show precipitation reductions in the summer and fall months. It is important to note, however, that the magnitude of change is small, ranging from at most +/- 0.25 inches in a given month. It is also important to remember that even in scenarios where precipitation amounts increase by 2025-2055, the region may still experience more drought due to evapotranspiration caused by higher temperatures.

Figure 8: Change in average monthly precipitation in 2025-2055 compared with the baseline period (1950-1999) for Grid Cell A

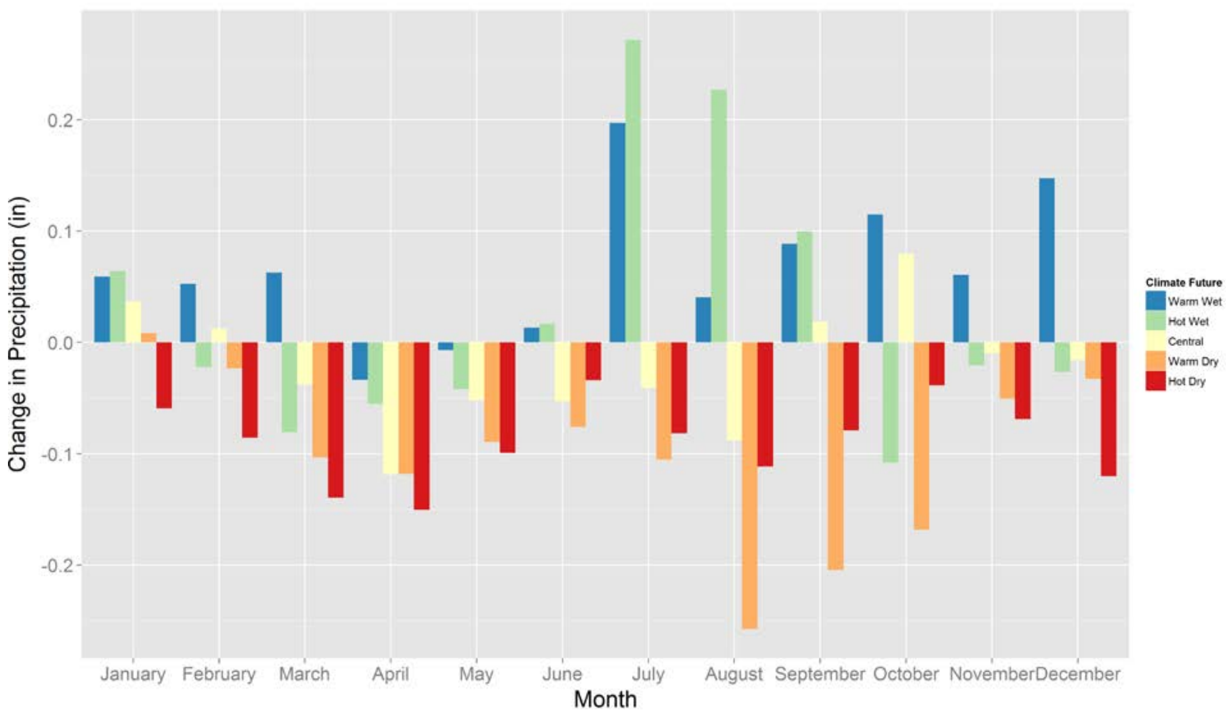
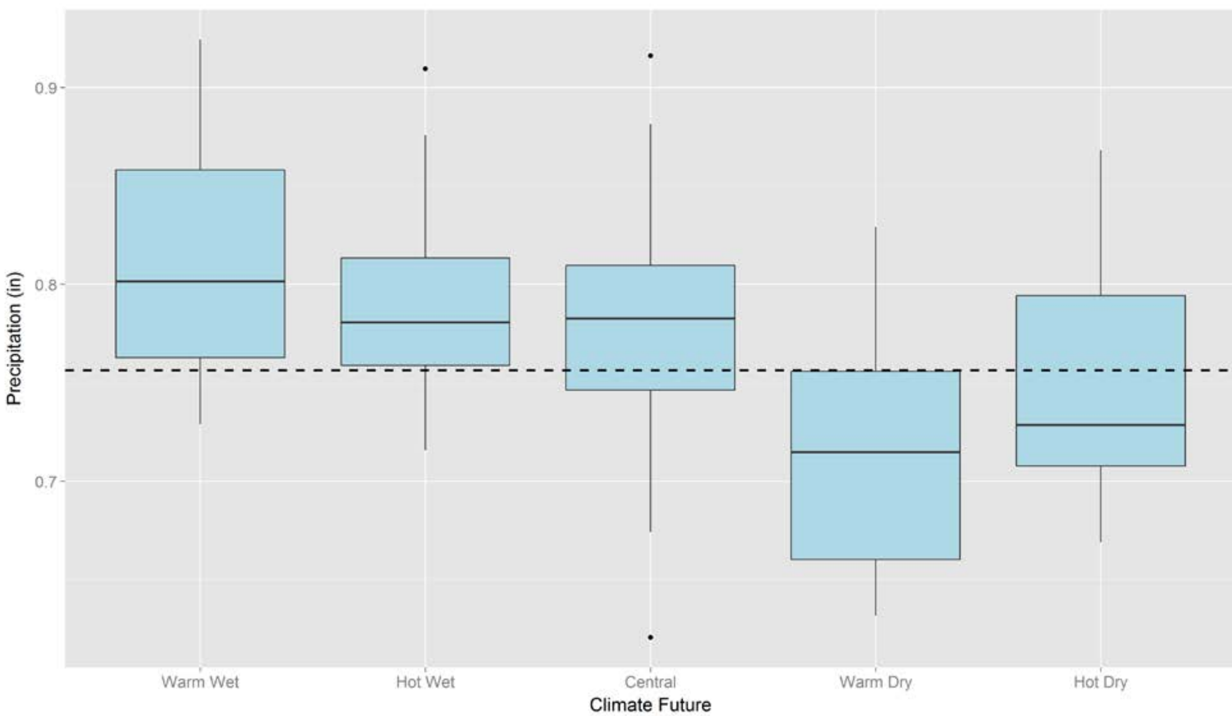


Figure 9 shows the maximum 24-hour precipitation amounts projected for 2025-2055, compared with the baseline period of 1950-1999 (dotted line). The projections show a slight increase (up to +0.2 inches) in the Warm Wet, Hot Wet, and Central futures and a slight decrease (up to -0.1 inches) for the Warm Dry and Hot Dry futures. However, even the highest magnitudes are less than a number of historic extreme precipitations events. This observation may be because the downscaled climate projections do not capture extreme events well since these events can occur in bursts that impact areas that are smaller than the size of the projection's grid cell or because these extreme events are rare enough that averaging projections over a 30-year time period smooths out these extreme events. There may also be limitations from the climate assumptions in the downscaled GCMs that limit the magnitude of projected extreme events.[22] Overall, this graph suggests that there is the potential for more flash flooding events in the future, but there is high uncertainty surrounding these projections.

Figure 9: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (dotted line)



Regional Variation in Climate Change Projections

Appendix A presents the climate futures outputs for the other four grid cells in the RPFO. As with the present climate in central New Mexico, there are regional variations in the downscaled climate projections. The primary factor driving this factor is elevation. Although the magnitude of change in annual mean temperature is consistent between grid cells, the grid cells at higher elevations (A, B, and C) have fewer days above 100°F and fewer consecutive days above 100°F in the 2025-2040 period than the grid cells in lower elevations (D and E). In sum, although temperatures are projected to rise throughout the RPFO, low-lying areas will be more vulnerable to the impacts from extreme heat.

[22] For more discussion of the challenges and limitations of using downscaled GCMs to estimate extreme events, see Volpe Center (in development), Central New Mexico Climate Change Scenario Planning Guidebook, Chapter 3.

Potential Impacts from Climate Change in the RPFO

Flood Risk

As discussed above, the *URGIA* report states that climate change may cause more intense storm events in central New Mexico, particularly from summer monsoons, and that the magnitude of maximum precipitation events may increase 10 to 30 percent by 2071-2100 compared with a 1971-2000 baseline.[23] However, current GCMs do not model extreme precipitation events well; they even project maximum precipitation values for the present day that are lower than actually experienced. Therefore, the climate futures projections do not allow for an accurate quantification of future extreme precipitation events.

Nonetheless, if there are more extreme precipitation events, or if the magnitude of these events increases, the risks of flash flooding will also increase. The impacts of flash floods may be highly localized based on topography and the locations where small but intense storms may occur. Impacts on transportation systems from flash flooding may include temporary inundation and closure, bridge scouring, road or trail erosion, culvert blockage, or landslides.

Figure 10 shows the currently mapped flood risk areas in the RPFO, using 2014 National Flood Hazard Layer Data from the Federal Emergency Management Agency (FEMA). The mapped flood hazard zones are zones that have a one percent probability of flooding in a given year, also known as the 100-year floodplain. These areas are primarily in areas adjacent to rivers, streams, and other water bodies. Transportation assets within these zones are already at risk from flooding; future increases in extreme precipitation may place additional areas at risk of flash floods. The central New Mexico region should undertake efforts to update the region's flood risk maps to prepare for future precipitation increases. In addition, collecting data about transportation assets in areas with potential flood risk, such as road or bridge elevation and culvert sizes, can help the BLM better understand which assets are vulnerable to damage from flash flooding.

Figure 10 also shows the areas where RPFO roads are currently eroded based on the RPFO's TTMP network data. Most of the recorded eroded road segments are in the northern area of the RPFO, near Cabezon Peak. These may be areas that are particularly vulnerable to flash flooding and erosion in the future. Figure 11 and Figure 12 show more detailed maps of the two areas in the RPFO with in the largest concentration of road segments in flood hazard zones, San Juan Basin Badlands TMA and the Petaca Pinta TMA, respectively.

[23] Llewelyn, et al., 2013.

Figure 10: Map showing 2014 flood hazard areas and current eroded BLM road locations

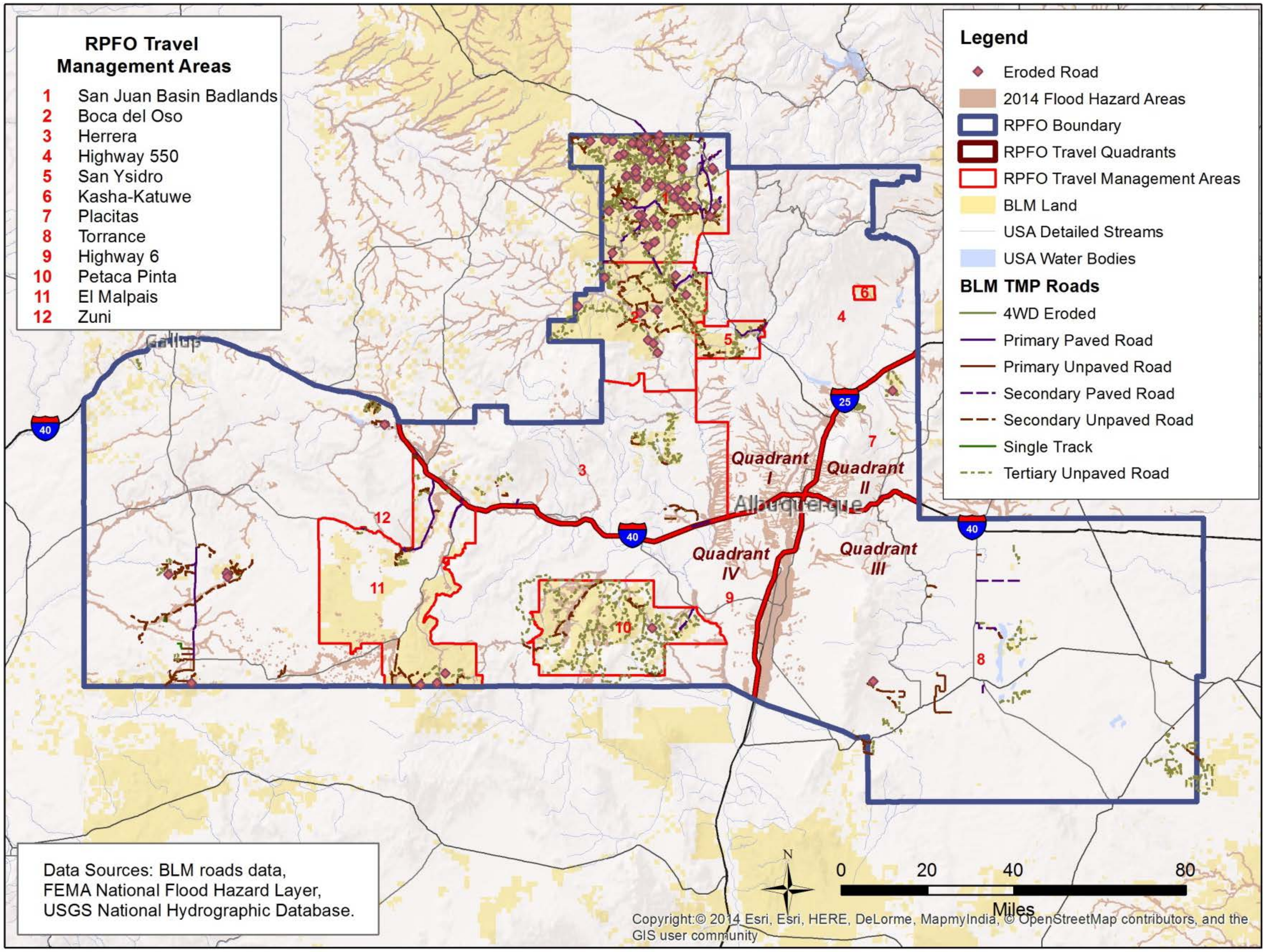


Figure 11: Detailed map of flood risk areas and eroded roads, San Juan Basin Badlands TMA

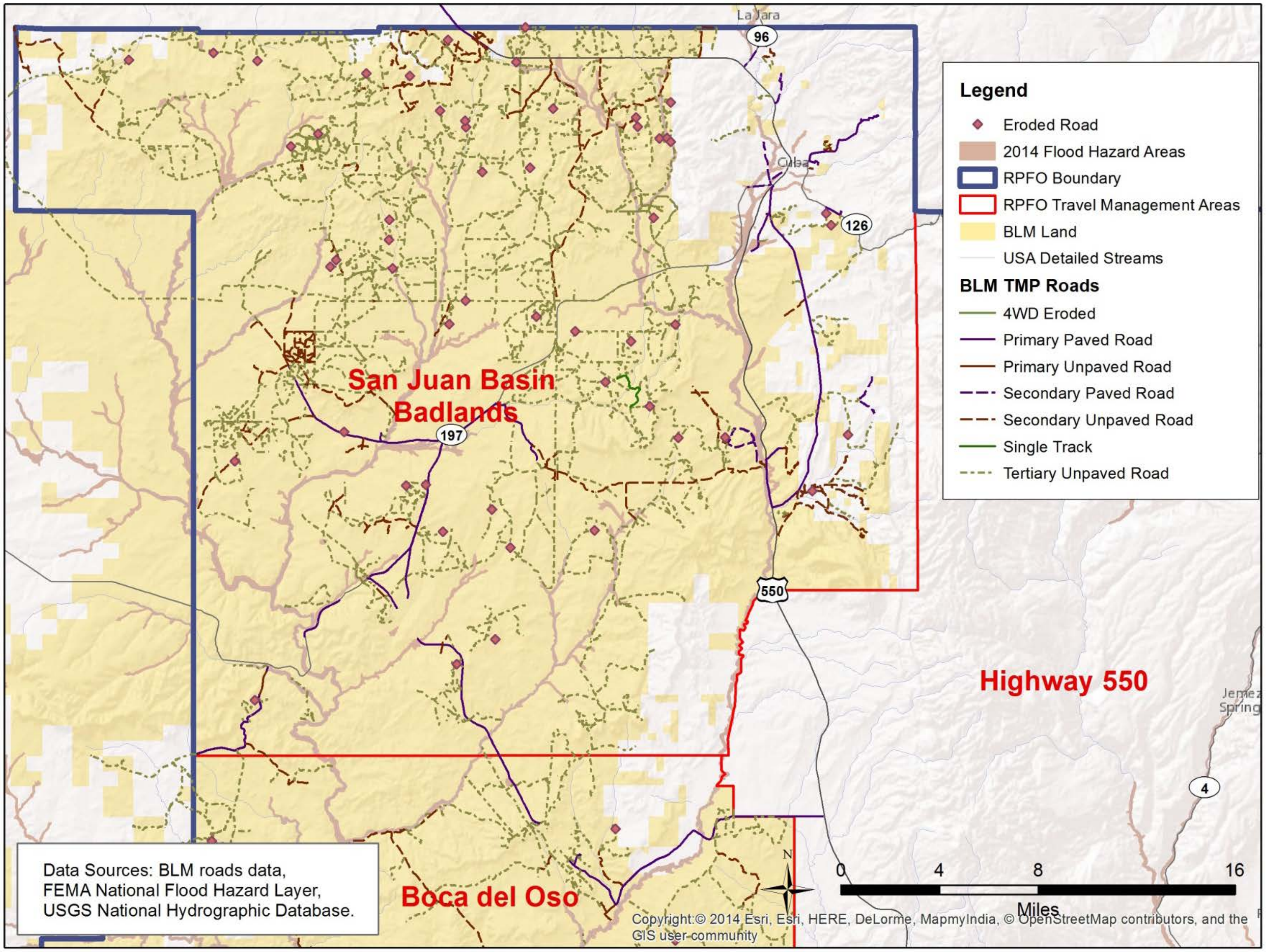


Figure 12: Detailed map of flood risk areas and BLM roads, Petaca Pinta TMA

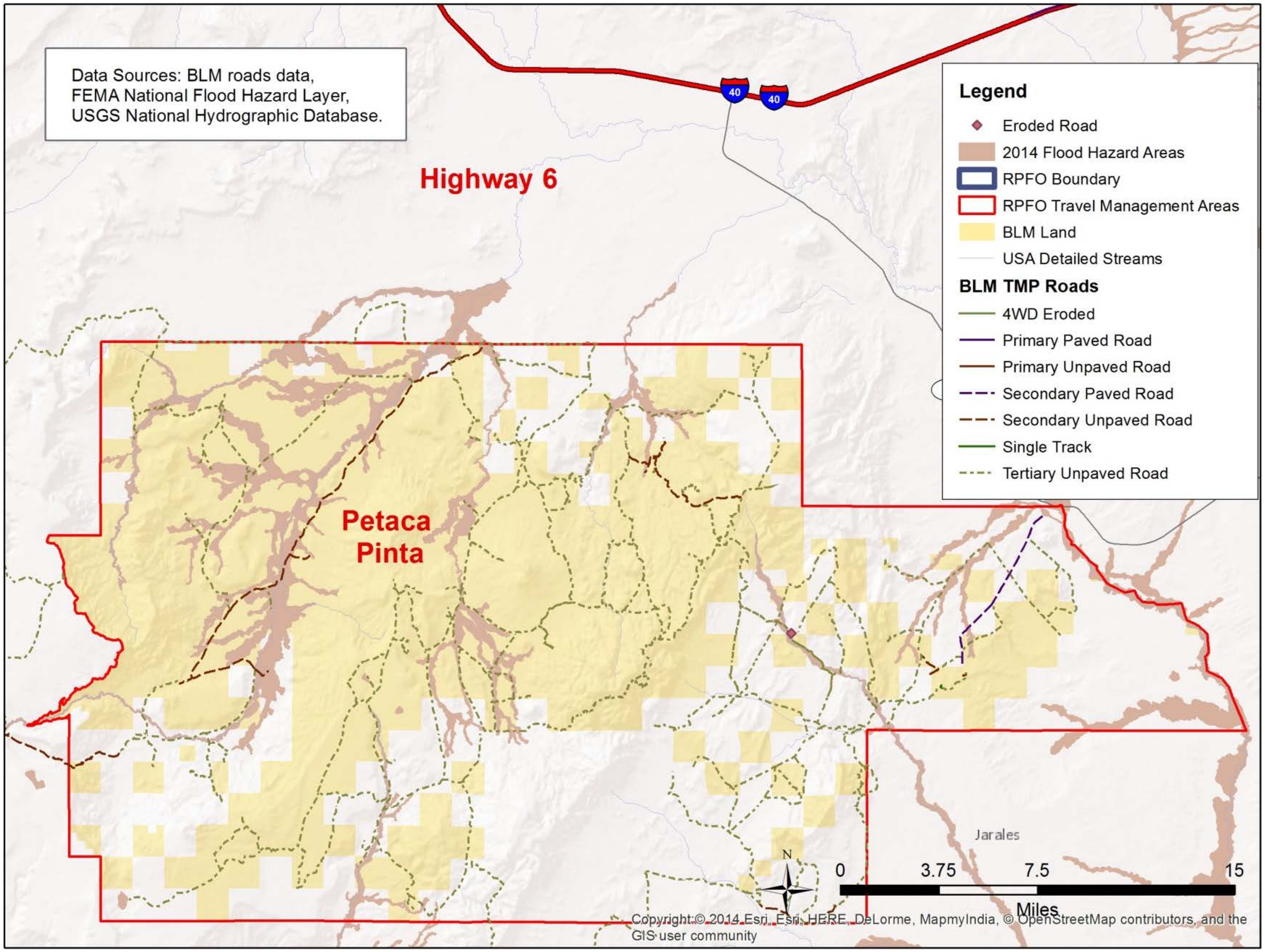


Table 1 shows the number of road miles that overlap with the mapped flood hazard areas. It shows that ten out of twelve of the TMAs have some road segments in the flood hazard areas, but 78 percent of all RPFO roads in flood hazard zones are located in four TMAs: El Malpais, Petaca Pinta, San Juan Basin Badlands, and Zuni. The two TMAs with the largest number of road miles in the flood hazard areas are the Petaca Pinta TMA and the San Juan Basin Badlands TMA. As Table 2 shows, 98 percent of RPFO roads in flood hazard areas are in the Arizona/New Mexico Mountains Ecoregion. These tables only show the roads that lie directly within current flood hazard areas; there are more road segments that are close to flood hazard areas and may be at risk in the future.

Table 1: Road miles in flood risk areas, by RPFO TMA

RPFO TMA	BLM Roads in Flood Hazard Zones (Miles)	Percent of All RPFO Roads in Flood Hazard Zones
Boca del Oso Travel Management Area	3.02	4%
El Malpais Travel Management Area	9.60	13%
Herrera Travel Management Area	0.76	1%
Highway 550 Travel Management Area	0.02	0%
Highway 6 Travel Management Area	2.97	4%
Petaca Pinta Travel Management Area	24.36	34%
Placitas Travel Management Area	5.19	7%
San Juan Basin Badlands Travel Management Area	14.57	20%
San Ysidro Travel Management Area	3.61	5%
Zuni Travel Management Area	8.45	12%
Total	**72.56**	**100%**

Table 2: Road miles in flood risk areas, by RPFO Ecoregion

RPFO Ecoregion	BLM Roads in Flood Hazard Zones (Miles)	Percent of All RPFO Roads in Flood Hazard Zones
Arizona/New Mexico Mountains	71.16	98%
Arizona/New Mexico Plateau	1.40	2%
Total	**72.56**	**100%**

Drought and Water Availability

Although there is uncertainty about whether the Rio Puerco will experience an increase or decrease in total annual precipitation by 2040, the literature generally agrees that the likelihood and intensity of drought and water scarcity will increase with climate change.[24] This is true even for GCMs that project increased precipitation. This is due to a number of related factors, mainly temperature-driven:

1. Hotter temperatures will lead to more evaporation, so the overall water budget for the region

[24] Garfin, et al., 2014; Weiss, 2014; Llewelyn, et al., 2013.

(precipitation minus evaporation) will decrease.
2. More precipitation in higher elevations will fall as rain instead of snow, leading to more punctuated pulses of precipitation rather than the more gradual timing of runoff from snowmelt.
3. Increased frequency, length, and intensity of heat waves and an increase of the number of days above 90 and 100 °F will increase the region's residents' demand for air conditioning, which will lead to an increased need for cooling water for power plant operations.
4. Projected population growth in the region will place increasing demands on water supplies.

The *URGIA*[25] and CLIMAS[26] also identified and distinguished between three main types of drought, caused by a combination of factors, which the region has experienced and which will be increasingly present as a result of climate change. These types of drought are:

- Meteorological drought – a period with below normal precipitation;
- Agricultural/ecological drought – a period of dry soils, which could be caused by low precipitation, high evaporation due to high temperatures, changes in land use, vegetation cover, or watershed hydrology; and
- Hydrological drought – a period with below normal stream flow and water storage, which could be caused by a number of precipitation, temperature, vegetation, land use, and regional water use trends.

Potential adaptation strategies for increased drought under future conditions include transitioning to drought-tolerant native plants in erosion control and vegetation management and reducing the BLM's water consumption by using water-efficient equipment and retrofitting administrative structures to use less water. Increased drought is also likely to increase problems associated with dust from gravel roads due to decreased soil moisture. This may require the BLM to increase its dust mitigation practices (described in more detail below).

Wildfire Risk

CLIMAS[27] and the *Third National Climate Assessment*[28] both discuss the potential for increased wildfire risk in the Southwest. Increased frequency, intensity, and duration of heatwaves, combined with drier conditions, are expected to increase the risk of wildfires, although neither report quantifies this risk. In addition, drier conditions may lead to changes in vegetation that would increase the region's susceptibility to wildfires.

Figure 13 shows the areas that are currently considered to be at risk for wildfires. Figure 14 and Figure 15 show more detailed maps of wildfire risk in the northeastern RPFO and southern RPFO, respectively, in areas where BLM land and transportation infrastructure are in or near areas with high wildfire risk. These maps use the fire risk model output data from the New Mexico Natural Resources Assessment, which The Nature Conservancy conducted for the New Mexico State Forestry Division.[29] This model identifies areas with a relatively high risk of destructive wildfire by combining rate of spread, flame

[25] Llewelyn, et al., 2013.
[26] Weiss, 2014.
[27] Ibid.
[28] Garfin, et al., 2014.
[29] The Nature Conservancy, 2009. New Mexico Conservation Science Wildfire Risk Data, http://nmconservation.org/projects/nm_natural_resources_assessment/.

length, crown fire potential, wildland urban interface (WUI), history of fire occurrence, and fire regime condition class.[30]

These maps show that fire risk varies across the RPFO, partly since several factors increase the relative risk, such as vegetation type and density, topography, and proximity to development. However, the ecoregions that generally have the highest wildfire risk in the RPFO are the Arizona/New Mexico Mountains and the Southern Rockies ecoregions. Roads in these areas are more likely to be at risk to damage from wildfires in the future as well as in the present.

Increased wildfire risk would have a number of implications for central New Mexico and the RPFO:

- Fire risks to ecosystems and sensitive species;
- Fire risks to neighboring residences and other property in the WUI;
- Fire risks to BLM property and assets, including transportation assets;
- Increased demand for BLM fire management, suppression, and response services (with budget implications);
- Post-fire risks of erosion or landslides, which could threaten BLM roads and other transportation assets; and
- Post-fire risk to ecosystems from erosion or invasive species.

The BLM's current fire management strategies and history of fires in the RPFO are detailed in the RPFO's Fire Management Plan.[31] The BLM's transportation infrastructure also plays an important role in BLM fire management: the BLM's transportation system provides means of evacuation from wildfires and access to wildfires for fire response. In addition, BLM roads may act as fire breaks. Therefore, the role a road plays in the BLM's fire management practices should be one consideration in developing and prioritizing the RPFO's road network.

[30] New Mexico State Forestry Division, 2010. Data atlases, New Mexico Statewide Natural Resources Assessment & Strategy and Response Plan, http://allaboutwatersheds.org/groups/SAS/public/2010-New-Mexico-Statewide-Natural-Resources-Assessment-and-Strategy-and-Response-Plans/view.

[31] BLM Rio Puerco Field Office, 2010. *Fire Management Plan*. http://www.blm.gov/pgdata/etc/medialib/blm/nm/programs/fire/fire_management_plans/rio_puerco_fmp.Par.22646.File.dat/RPFO_FMP_2010_final.pdf.

Figure 13: Map showing modeled fire risk in central New Mexico

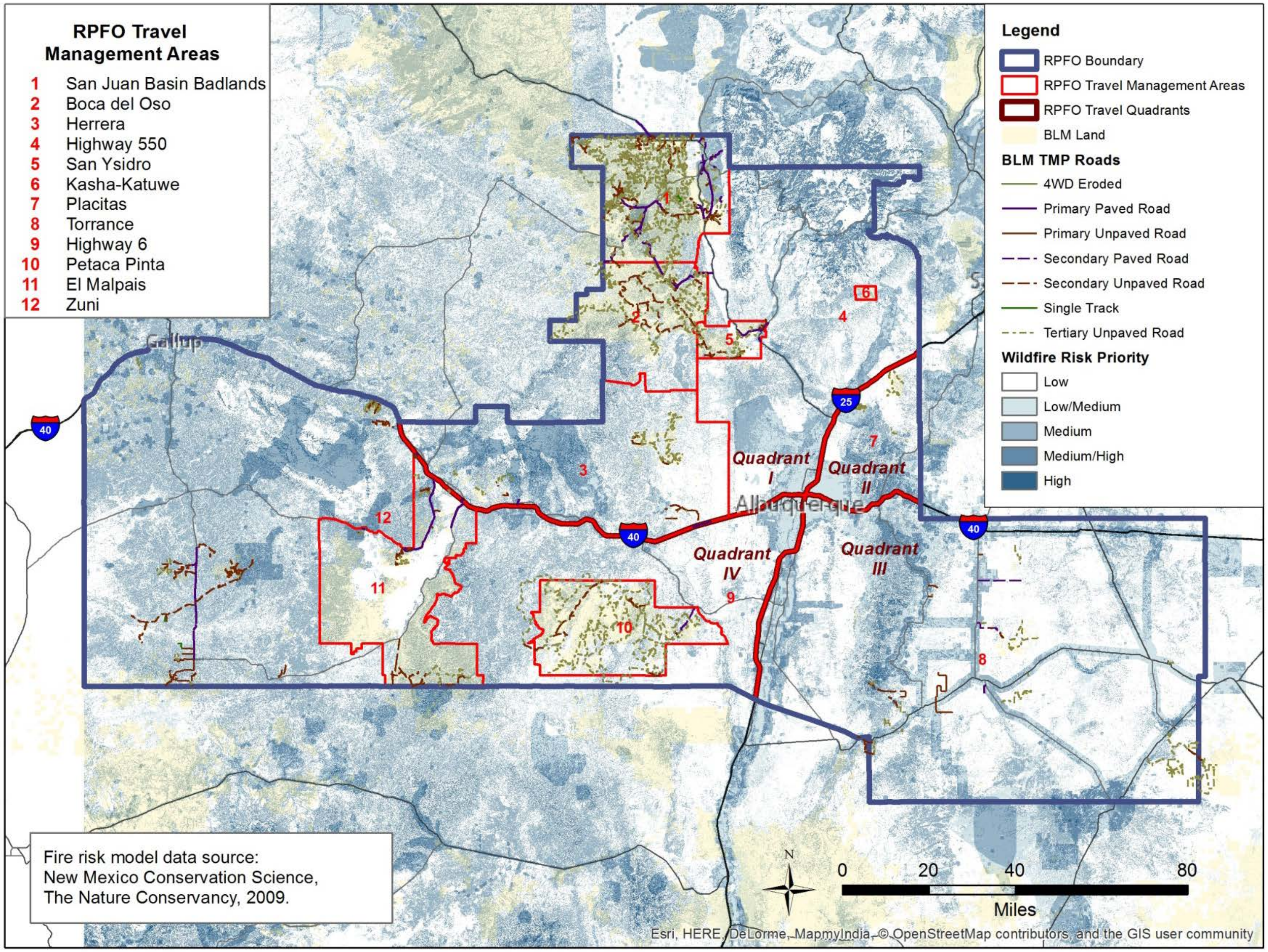


Figure 14: Detailed map of modeled fire risk, San Juan Basin Badlands and Boca del Oso TMAs

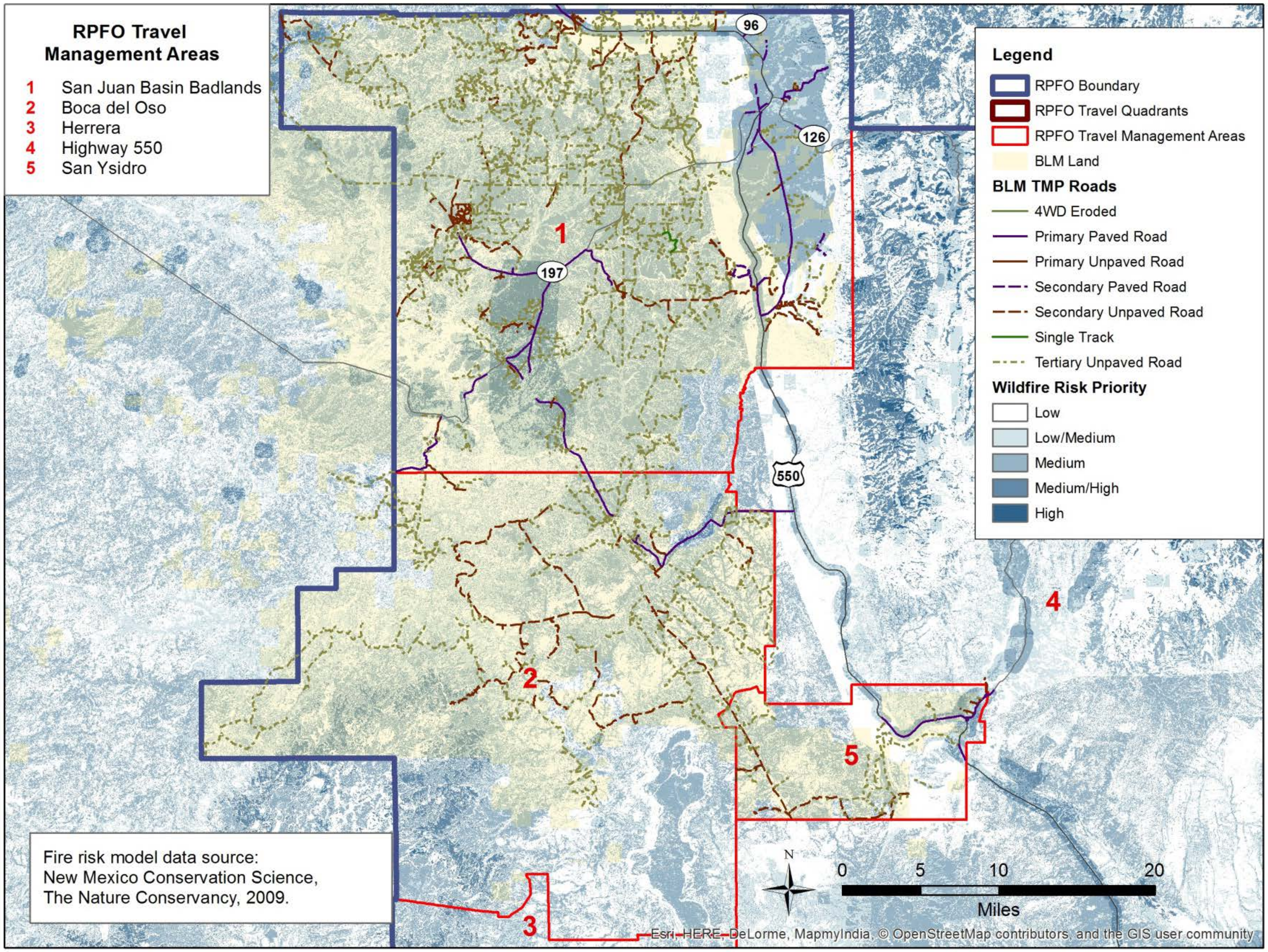
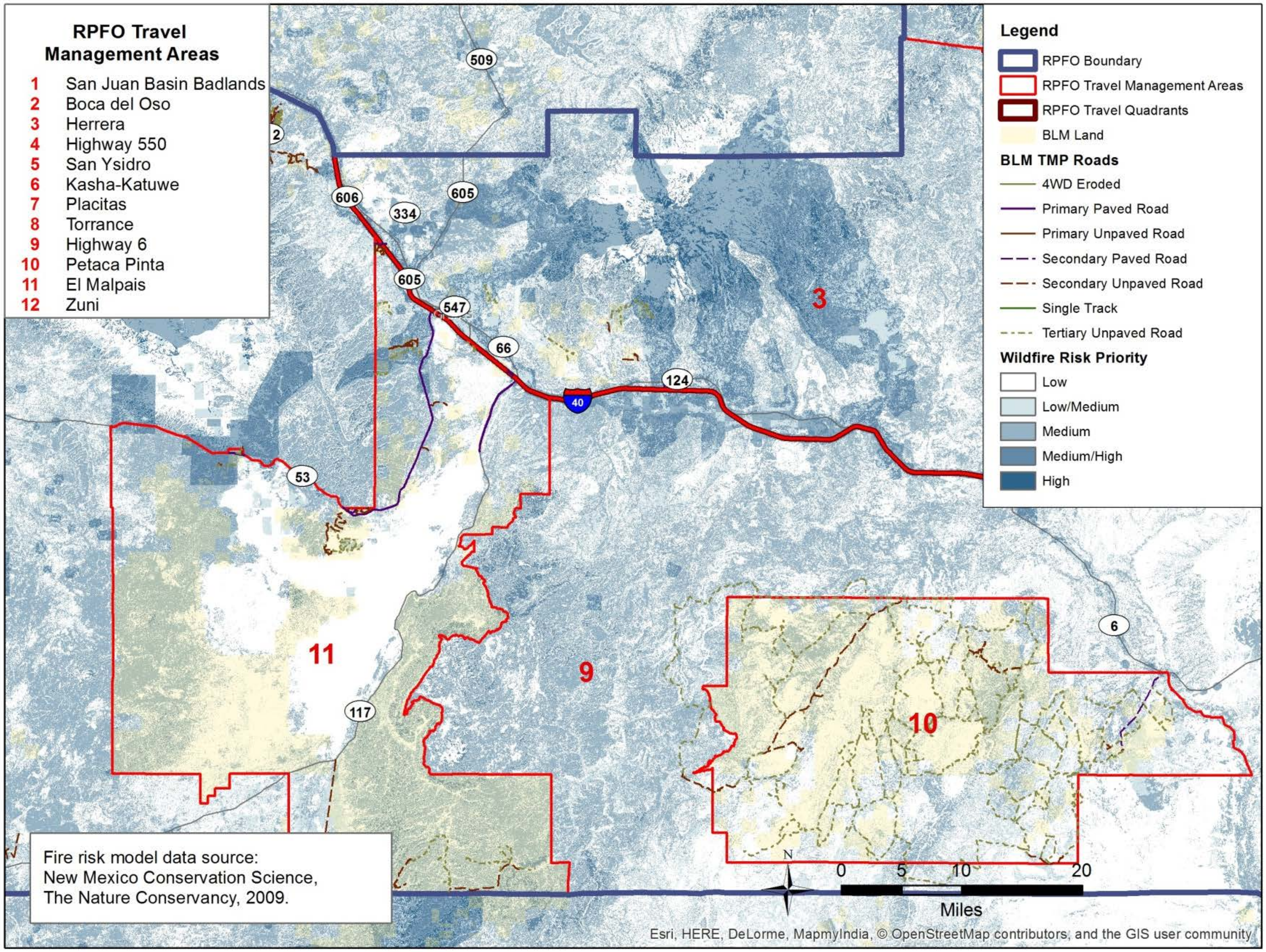


Figure 15: Detailed map of modeled fire risk, El Malpais, Herrera, Highway 6, and Petaca Pinta TMAs



Impacts to Natural Resources

The projected changes in temperature and precipitation, as well as their associated risks, have implications for natural resources in Rio Puerco. Increased risk of drought and wildfire, as well as changes in hydrological stream flow and timing, pose threats to native ecosystems and the species that rely upon them. Drought and hydrological changes may also impact water quality, which would have impacts on these ecosystems, as well.

Threatened and Endangered Species

The following threatened and endangered species in Central New Mexico face threats due to climate change in addition to the threats they currently face. Table 3 shows the threatened and endangered species in the RPFO identified by Ecosystems Management, Inc., in their report for the CCSP and lists the potential impacts from climate change and potential actions to increase their resiliency.[32]

[32] Ecosystems Management, Inc., 2014. *Climate Change Effects on Central New Mexico's Land Use, Transportation Systems, and Key Natural Resources.* Prepared for the Central New Mexico Climate Change Scenario Planning Project. Available upon request.

Table 3: Potential climate change impacts to threatened and endangered species in RPFO

Species	Habitat	Climate Change Threats	Potential Actions to Increase Species Resilience
Southwestern Willow Flycatcher[33] (Endangered)	Dense riparian habitats	Degradation of riparian zones, damage to habitat from wildfires	Protect and enhance riparian habitat, possibly provide food sources if migration timing diverges from timing of natural food availability
Rio Grande Silvery Minnow[34] (Endangered)	Rio Grande River	Decreased water availability and water quality	Regional water conservation efforts, reduced water diversions
New Mexico Jumping Meadow Mouse[35] (Endangered)	Persistent emergent herbaceous wetlands and riparian areas	Degradation of riparian zones, damage to habitat from wildfires	Protecting and enhancing riparian habitat
Mexican Spotted Owl[36] (Threatened)	Old-growth and mature forest, canyon riparian habitat	Degradation of old-growth and mature forests, increased wildfire risk	Protect old-growth and mature forests and reduce of habitat stressors through fire management, logging restrictions, or limiting habitat fragmentation from road construction. Preserve habitat connectivity.
Jemez Mountains Salamander[37] (Endangered)	Mixed-conifer forest in the Jemez Mountains	Increased wildfire risk, erosion risk	Protecting and enhancing forest habitat, avoiding habitat disturbance from roads, fire management, erosion control
Yellow-billed Cuckoo[38] (Threatened)	Mature riparian habitat	Degradation of riparian zones, damage to habitat from wildfires	Protecting and enhancing riparian habitat
Pecos Sunflower[39] (Threatened)	Wetlands in west-central and eastern New Mexico	Increased drought	Protecting and enhancing wetland habitat, regional water conservation

[33] U.S. Fish and Wildlife Service (FWS), 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B094.
[34] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=E07I.
[35] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A0BX.
[36] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B074.
[37] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=D019.
[38] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=B06R.
[39] FWS, 2014a. *Environmental Conservation Online System*. Species profile: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=Q0YJ.

Transportation and Natural Resources

The natural resource impacts discussed above will have implications for BLM ecological management and for the BLM's transportation system. The BLM's transportation system may further impact these natural resources in the ways listed below, which also include potential mitigation actions:

- Roads, parking lots, and other transportation infrastructure can impact local water quality through run-off and erosion. Roads and culverts may impede aquatic organism passage. Depending on future precipitation trends, the BLM may consider increasing culvert sizes to improve aquatic organism passage and reduce erosion and road damage from extreme precipitation events.
- Vehicle-wildlife collisions pose threats to terrestrial species. Ecologically sensitive road design or the construction of wildlife passage features (such as culverts) may help reduce risks to wildlife from vehicle collisions.
- Roads create noise and other edge effects that degrade habitat. Mitigation actions may include siting roads away from critical habitat to avoid habitat fragmentation, decommissioning non-critical roads and restoring them to a more natural condition, and using quiet pavements for paved roads in the RPFO.
- Unpaved roads can create dust from construction or travel activities, which can disturb nearby habitat. Mitigation actions may include reducing the volume or speed of travel during dry conditions, improving road drainage to prevent loose fine particles from accumulating, covering unpaved roads with gravel, spraying roads with water, or using other dust palliatives.[40,41]
- Roads are a primary factor in habitat fragmentation. Habitat fragmentation poses a threat to species in combination with climate change because it makes it more difficult for species to migrate as climate conditions change. Strategies to reduce habitat fragmentation from roads in the RPFO may include roadway design solutions, such as wildlife passage features, as well as reducing the density of roads by decommissioning and restoring roads that are not important parts of the RPFO transportation system.

Implications for Rio Puerco's Transportation System

Based on the climate projections and their impacts discussed above, there are a number of potential risks to the BLM's transportation system. These include risks from extreme heat, freeze/thaw cycles, localized flooding during extreme precipitation events, drought, and wildfires. Examples of potential risks and impacts to different types of transportation infrastructure are highlighted in Table 4.[42,43] In sum, all of the risks listed in the table below can increase maintenance and repair costs of transportation assets.

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[40] EPA, 2014. Dust Control Best Management Practices, http://water.epa.gov/polwaste/npdes/swbmp/Dust-Control.cfm.

[41] Alaska Department of Environmental Conservation, 2011. Top Ten Dust Control Techniques, https://dec.alaska.gov/air/anpms/Dust/topten_dustctrl2.htm#.

[42] National Cooperative Highway Research Program (NCHRP), 2014. *Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Practitioner's Guide and Research Report.* Report 750. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_750v2.pdf.

[43] Ecosystems Management, Inc., 2014.

Table 4: Potential impacts to transportation assets due to climate change.

Impacted Infrastructure	Potential Climate Change Risks and Impacts
Bridges, major structures, and culverts	Extreme precipitation events can increase the risk of bridge overtopping or result in bridge scour.
	Fires can cause added debris to collects upstream of bridges/large culverts, which can block the channel and result in overtopping. Large boulders and trees can damage structures.[44]
	Temperature extremes can increase stress on structural joints and cause thermal expansion of bridge decks.
	Freeze/thaw cycles accelerate deterioration of bridge deck pavement and bridge superstructure and substructure.
Storm drain systems and flood control infrastructure	Increased magnitude or frequency of extreme precipitation events can overwhelm flood control structures.
	High precipitation after drought periods results in higher runoff, higher velocities, and higher sediment loading, which can scour at culvert ends.
	Higher than design level flows with or without debris accumulation results in overtopping of roadways, railways, trails, etc.
Roadway maintenance	Increased magnitude or frequency of precipitation events, as well as high precipitation after drought periods, can lead to increased erosion of non-paved roads.
	High temperatures can lead to increased shoving and rutting of hot mix asphalt pavements.
	Increased drought and decreased soil moisture content may necessitate increased dust mitigation activities to reduce unpaved roads' impacts on nearby habitat.
Bicycle and pedestrian facilities	Erosion, flooding, and landslides can threaten bike and pedestrian trails. Freeze/thaw cycles and extreme heat can accelerate deterioration of paved multi-use paths or shoulder bike lanes.
Roadside vegetation	Changes in precipitation and temperature could necessitate changes in erosion control planting materials.
	Increased drought, magnitude or frequency of precipitation events, and wildfire destruction of vegetation can decrease slope stability and increase risk of landslides, slope failures, and floods from runoff.
Impacts to construction costs and schedules	Extreme heat days can necessitate changing construction schedules and a potential reduction in construction days. This may lead to added construction costs.

Because the vast majority of the RFPO's road system is made up of unpaved roads, the most relevant threats to its transportation infrastructure listed above are erosion due to flooding, blockage or damage to culverts and drainage structures, and post-fire damage. RPFO also has some paved roads, which may face higher maintenance costs due to higher temperatures.

[44] This has occurred in the Los Alamos area, where large trees were swept off of hillsides and into structures, and in southwestern New Mexico after the Gila fires.

Most of the climate change impacts in Table 4 are general to all of the RPFO transportation system, but some risks may be more prominent in different areas. For example, as Table 1 shows, 78 percent of all RPFO roads in existing flood hazard areas are in four TMAs: El Malpais, Petaca Pinta, San Juan Basin Badlands, and Zuni TMAs. These TMAs are therefore likely to be more vulnerable to damage from flooding and associated erosion impacts to roads, bridges, and culverts. Ninety-eight percent of the RPFO road segments in flood hazard areas are located in the Arizona/New Mexico Mountains ecoregion.

Likewise, extreme temperatures are more likely at lower elevations, as the climate futures analysis in Appendix A shows. The lower-lying areas that are more vulnerable to extreme high temperatures and heat waves generally correspond with the Arizona/New Mexico Plateau and the Southwestern Tablelands ecoregions. Roads in these areas are therefore more vulnerable to heat-related risks, such as pavement deterioration.

Wildfire risks vary across the RPFO, partly because there are many different factors that contribute to wildfire risk, including vegetation type and density, topography, and proximity to development. However, the ecoregions that generally have the highest wildfire risk in the RPFO are the Arizona/New Mexico Mountains and Southern Rockies ecoregions. Roads in these areas are therefore more vulnerable to damage from wildfires.

Chapter 3: Adaptation and Resilience Framework for Rio Puerco Transportation Planning

The project team used a conceptual framework to consider how the RPFO can reduce the impacts of climate change and prepare for its effects. This framework is based on research from the IPCC[45,46] the Third National Climate Assessment,[47] and FHWA's technical guidance on incorporating climate change mitigation and adaptation into metropolitan area transportation planning[48]. Two important concepts from these sources, adaptation and resilience, are described below:

- *Adaptation*. Adaptation refers to the process of preparing people and infrastructure for changes in climate. Adaptation may involve physical measures, such as designing or retrofitting infrastructure to function in different climate conditions, or societal measures, such as new operations or procedures for responding to extreme weather.

- *Resilience.* Resilience, a concept originally borrowed from engineering and ecology, refers to the ability of a system to withstand a shock. In the context of BLM transportation planning, resilience refers to the ability of the BLM's transportation system to adjust to changes in climate while minimizing stresses to the Rio Puerco's ecosystems, visitors, and neighboring communities. Actions to increase an area's resilience can consist of physical actions, such as infrastructure adaptation, land use, and transportation planning, to reduce vulnerability from extreme weather or other climate change impacts. Resilience could also include maintaining alternate transportation routes to support access or egress in the case of an extreme event; and social resilience measures, such as communications and community coordination.

Assessing Vulnerability

Understanding the vulnerability of the RPFO's transportation system to the impacts of climate change is an important step to determine how to adapt and increase the resilience of the system. Vulnerability should be considered as a product of the following:

1. *Exposure*. What climate stressors may a transportation asset be exposed to under future climate conditions? In general, Chapter 2 of this report explores potential climate stressors in the region, but the specific location of each asset must also be considered.
2. *Sensitivity*. To what degree will an asset be impacted by future climate stressors?

[45] IPCC, 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Summary for Policymakers. http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf*.

[46] IPCC, 2007b. *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html.

[47] Bierbaum, et al., 2014. Chapter 28: Adaptation. *Climate Change Impacts in the United States: The Third National Climate Assessment*, Melillo, et al. Eds., U.S. Global Change Research Program. http://nca2014.globalchange.gov/.

[48] FHWA, 2014. *Assessment of the Body of Knowledge on Incorporating Climate Change Adaptation Measures into Transportation Projects.* Prepared by ICF International for FHWA. http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/transportation_projects/index.cfm.

3. *Adaptive Capacity*. What is the ability of an asset or system to adjust to potential impacts from a climate stressor? Pertinent questions include:
   - What system redundancies, design features, or planned responses could reduce the impact from climate stressors?
   - What would the consequences of failure be from a particular asset or system?[49]

Strategies for Adaptation and Resilience

There are a number of different strategies the BLM could use to increase the resilience of its transportation system to climate change. When selecting an adaptation strategy, it is important to consider the purpose of the Rio Puerco TTMP and the role of the BLM transportation system.

Rio Puerco TTMP Purpose

BLM Travel and Transportation Management Plans (TTMPs) are "an interdisciplinary approach to travel and transportation planning and management that addresses resource uses and associated access to public lands and waters, including motorized, non-motorized, mechanical, and animal-powered modes of travel."[50] Travel and transportation are an integral part of virtually every activity that occurs on BLM-administered public lands within the RPFO. Recreation, management of livestock, wildlife, and commodity resources, rights-of-way, access to private inholdings, maintenance of electronic sites, and the day-to-day management and monitoring of the RPFO all rely on effective travel management planning. Travel management includes all forms of transportation, including travel by foot, horseback, and mechanized vehicles such as bicycles as well as the numerous forms of motorized vehicles from two-wheeled (motorcycles) and four-wheeled all-terrain vehicles (ATVs) to cars and trucks.

The objectives of the TTMP are to:

- Establish a long-term, sustainable, multi-modal transportation system to support public access and administrative transportation needs that meet the RPFO planning goals (Figure 16).
- Support the BLM's mission (Figure 16) and land use planning goals by designating an appropriate transportation network.
- Manage travel and transportation on BLM lands.
- Work collaboratively with the public, including tribal, state and local governments; user groups; and individuals to develop an appropriate transportation system on BLM-administered public lands, including motorized and non-motorized recreational trails.

As part of the Rio Puerco TTMP, staff will review existing roads and trails to determine which to include in the RPFO transportation network, designate uses for included roads and trails, and identify roads and trails for potential abandonment or decommissioning. The TTMP process provides an opportunity for the BLM to consider the role and importance of its transportation assets for the BLM mission and for surrounding communities. The TTMP also provides an opportunity to consider what infrastructure may be at risk from climate change and what, if any, strategy is most appropriate to increase the overall

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[49] FHWA, 2012. *Climate Change & Extreme Weather Vulnerability Assessment Framework.* http://www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/vulnerability_assessment_framework/.

[50] BLM, 2011a.

system's resilience.

Figure 16: The BLM's mission statement and RPFO Planning and Transportation Goals

The BLM's Mission:

"To sustain the health, diversity, and productivity of America's public lands for the use and enjoyment of present and future generations."

RPFO Planning and Transportation Goals:

The RPFO TTMP incorporates the following goal areas and associated questions:

Land Tenure Adjustments
What land tenure adjustments are needed to improve access to and management of public lands?

Mineral and Energy Development
What will be the transportation needs and interfaces with mineral and energy development and other designations?

Recreation and Visitor Services
What facilities, roads, trails, and restrictions will be necessary to provide the recreational opportunities recreational sites will be managed for?

Visual Resource Management
What types of transportation and infrastructure will be compatible with Visual Resource Management Prescriptions?

Special Designations
What types of transportation and infrastructure will be compatible with Special Designations and can serve neighboring resource management conflicts?

Public Land-Urban Interface
The demand of the public land-urban interface will be higher and more diverse per acre on BLM lands adjacent to high population densities. With only general land designations (no Special Designations), what transportation network design is capable of addressing the various user types and the very large expected user numbers?

Role of the Rio Puerco Transportation System

The RPFO transportation system is used for motorized and non-motorized travel for recreational and non-recreational purposes. Activities in the Rio Puerco range from low-impact activities such as hiking and camping to higher-impact mineral and energy development needs. Other activities include recreational uses (e.g., off-road vehicle use), administrative uses (e.g., fire management and habitat restoration), access to private holdings, and other resource use (e.g., livestock grazing).[51] User groups include BLM staff, recreational visitors, resource users, and local communities who use BLM roads for general transportation access. Increased urbanization and population in the region has increased recreation on BLM land, increasing demand on natural areas and the RPFO's transportation system.

Potential Adaptation Strategies for Rio Puerco Transportation Systems

There are a variety of strategies BLM can consider implementing in the context of potential climate change impacts on the RPFO transportation system. These strategies can be divided into three main categories. These categories are borrowed from literature on adaptation to sea level rise,[52,53] but they provide a useful framework for evaluating potential actions for the Rio Puerco as well.

- **Protection:** building or strengthening protection structures that guard against climate change impacts. Strategies for the BLM could range from strengthening control dams to prevent asset damage from flooding and erosion to building retaining walls to control slope erosion.
- **Accommodation:** increasing the flexibility or resilience of an asset to climate change impacts. For the RPFO, accommodation strategies can involve engineering or ecological efforts, such as widening culverts under roads to accommodate increased flows, building or enhancing stormwater management infrastructure, and restoring vegetation impacted by drought to decrease erosion. These strategies could also be policy decisions, such as changing the designation of an asset or temporarily closing or restricting access to at-risk assets. The RPFO should also consider planning for or maintaining alternate transportation routes to support access in case of an extreme event such as wildfire or flooding.
- **Retreat:** removing an asset from risk or de-emphasizing reliance upon an asset. For the RPFO, route abandonment/decommissioning would be the best option if the agency decided protection or accommodation would be too costly or infeasible to implement. Seasonal closures could be a hybrid approach between accommodation and retreat, allowing use of a road segment during the dry season but restricting or prohibiting access when the road is at risk for flooding or erosion. Another option would be a passive management approach, whereby the BLM would recognize that an asset at risk to damage may not be feasible to maintain or reconstruct in the future but will remain a part of the transportation system until it is impacted.
- **Maintenance:** examples of adaptive maintenance activities include:
    - Prior to and following storm events, clear culverts and stormwater management and

[51] BLM, 2001. *Rio Puerco Resource Management Plan: Update Document.* http://www.blm.gov/pgdata/etc/medialib/blm/nm/field_offices/rio_puerco/rio_puerco_planning/rpfo_rmp_docs.Par.13395.File.dat/aufo_rmp_update_00_01.pdf.

[52] IPCC, 2001. Climate Change 2011: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge. http://www.ipcc.ch/ipccreports/tar/wg2/.

[53] For example, see: Kirshen, et al., 2008, *Climate change and coastal flooding in Metro Boston: impacts and adaptation strategies.* *https://www.cityofboston.gov/images_documents/Coastal%20Flooding%20Metro%20Boston_tcm3-31975.pdf*.

    - drainage structures of debris to prevent blockage.
    - Maintain drainage structures, such as water bars, to prevent erosion of road surfaces.
- **Disaster Recovery:** after events, such as flooding or wildfires, the BLM can reduce vulnerability to future events by increasing the resiliency potential of repaired or reconstructed assets. Examples of disaster recovery activities that could increase resiliency include:
    - After wildfires, clear debris from culverts and drainage infrastructure to prevent blockage. Undertake erosion control measures in burned areas, such as planting new vegetation, especially in areas with slopes of 15 percent or greater. Consider temporary fences in areas with livestock grazing to help re-establish vegetation. Restore roads damaged by wildfire suppression activity.
    - After damage by flooding or erosion, consider building roads or bridges back in a more resilient fashion, for instance by increasing culvert diameters or raising bridge heights to prevent damage by similar or larger storms in the future.

Implementing Adaptation and Resilience Strategies

Deciding which strategies to use on what assets, and when, will require the BLM to consider each asset's role within its transportation system. Protection and accommodation strategies are more appropriate for road segments that are high-traffic, primary access routes that are at risk from flooding or wildfire. By contrast, low volume roads that do not provide critical access or which can easily be replaced by existing alternative routes may be more appropriate for passive management or decommission if they are vulnerable.

When choosing an adaptation strategy, BLM should review a variety of considerations, including:

- Vulnerability of an asset in the short-, medium-, and long-term, and potential magnitude of consequences if the asset is damaged;
- Existing and planned asset use, and importance of asset to the public and BLM staff;
- Cost savings from avoided impacts vs. implementation costs;
- Feasibility, efficacy, and ability to withstand a range of climate hazards; and
- Potential negative or positive impacts on other areas (e.g., flood control in one area could negatively impact nearby natural resources).

Table 5 presents a list of questions that may help the RPFO determine the relative importance and vulnerability of its transportation assets. The answers to these questions can inform which adaptation strategies are most important and under what timeframe they should be implemented.

Table 5: Potential questions to assess the relative importance and vulnerability of different transportation assets

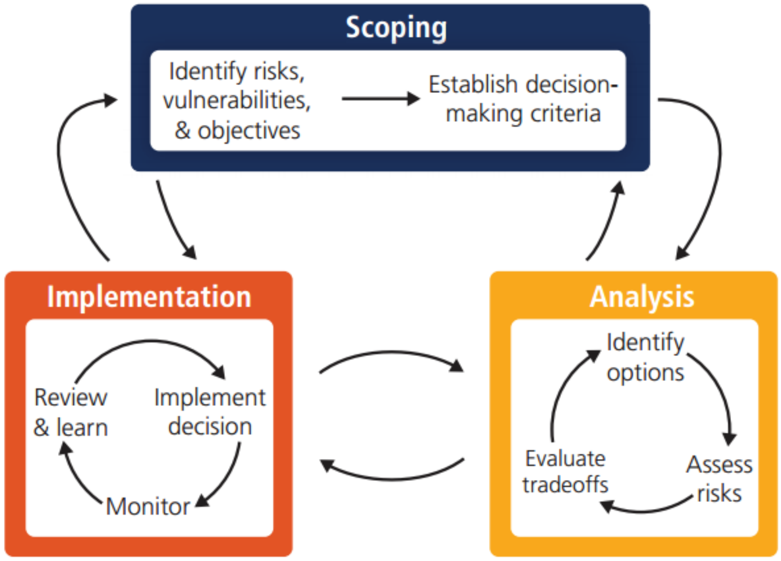
Asset Importance
What is the current level of use of this asset? (e.g., volume of travel)
What kinds of use does this asset support? (e.g., recreational, administrative, community access, resource extraction)
What is the expected level of use of this asset in the future?
Does this asset provide the sole means of access for key resource or recreational destinations?
Does this asset serve as a critical evacuation route?
Is this asset important for BLM administrative access?
Do neighboring communities rely on this asset for access?
Asset Vulnerability
How vulnerable is this asset to current climate conditions? Does it have a history of damage from flooding, wildfires, or erosion?
What is the potential vulnerability of this asset in the future due to climate change?
Adaptive Potential
Are there feasible adaptation actions that can be implemented to increase resilience?
Are adaptation options cost beneficial? Do the cost savings from avoided damage or increased maintenance costs outweigh the costs of adaptation?
What is the preferred timing of adaptation actions? Should they be implemented in the short, medium, or long term?
Are there any adaptation actions that provide co-benefits, such as ecosystem restoration, habitat connectivity, or greenhouse gas mitigation?
Are there any adaptation actions that could negatively impact other assets or natural resources that should be avoided or mitigated?

Timeframes for Adaptation Strategies

To assess the vulnerability of its transportation assets to climate change and determine the appropriate response(s), BLM can consider how historical and current climate conditions have impacted the system. However, because of the uncertainty of the severity and timing of climate change impacts in the future, the IPCC recommends using an iterative risk management, or adaptive management, process to make decisions about responding to climate change (Figure 17).[54] Accordingly, BLM can consider climate change impacts when revisiting its TTMP in the future.

[54] IPCC, 2007a. *IPCC Fourth Assessment Report: Climate Change 2007*. http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3s3-5-1-1.html.

Figure 17: Iterative adaptation process diagram



Source: IPCC, 2014[55]

To develop an adaptive management approach to climate change and transportation planning, the BLM should develop a plan for data collection, monitoring, and adaptation thresholds. For example, the BLM could designate a particular threshold, such as a certain increase in extreme temperatures (e.g., days above 90 °F) that would trigger increased wildfire resilience planning, or an increase in flood exposure (e.g., number of flooding events per year), which would trigger projects that increase culvert diameters and erosion control. This iterative, data-driven approach would allow the BLM to monitor conditions at RPFO and make informed decisions about when adaptation options become appropriate and would help the BLM prepare despite current uncertainties about the magnitude and timing of change. The BLM's Assessment, Inventory, and Monitoring Strategy for Integrated Renewable Resources Management provides a framework for standardized data collection that can aid the FPFO in its adaptive management monitoring and decisionmaking.[56]

One example of an adaptive management strategy for climate change resilience planning is the San Francisco Bay Area's Adapting to Rising Tides project, in which participating agencies developed a series of adaptation options with timeframes based on when certain sea level rise thresholds are met.[57]

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[55] IPCC, 2014. Summary for Policymakers. *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. *http://ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf.*

[56] BLM, 2011b. Assessment, Inventory, and Monitoring Strategy for Integrated Renewable Resources Management. http://www.blm.gov/style/medialib/blm/wo/Information_Resources_Management/policy/ib_attachments/2012.Par.53766.File.dat/IB2012-080_att1.pdf.

[57] San Francisco Bay Conservation and Development Commission, 2014. *Adapting to Rising Tides website.* http://www.adaptingtorisingtides.org/.

Chapter 4: Potential Greenhouse Gas Mitigation Strategies at Rio Puerco

The BLM, like all Federal agencies in the U.S., has been directed by the President to measure, manage, and reduce its GHG emissions.[58] This chapter discusses strategies that the BLM could employ at the RPFO to mitigate climate change by reducing GHG emissions. The first section discusses regional case studies and potential opportunities for collaboration. The second section discusses potential opportunities for the RPFO to reduce transportation-related emissions to or within the RPFO.

Case Studies and Local Mitigation Efforts

Efforts to reduce transportation-related GHG emissions at similar BLM field offices and other locations within central New Mexico can help inform climate change mitigation efforts at the RPFO and may provide potential partnership opportunities. The examples below may provide examples for the RPFO to emulate or partnership opportunities for the RPFO.

Red Rock Canyon National Conservation Area Transportation Feasibility Study

In 2012, the BLM conducted a Transportation Feasibility Study for the Red Rock Canyon National Conservation Area, located near Las Vegas, Nevada. Red Rock Canyon experiences heavy congestion on its scenic drive and associated parking areas due to high volumes of visitors hiking, climbing, and sightseeing along the drive. The feasibility study examined four transportation alternatives that combined parking expansion, transit service, and management strategies to address parking congestion. BLM's efforts to reduce the amount of visitor time spent in private vehicles most likely would also serve to reduce GHG emissions produced by vehicles in the area, although GHG reduction was not specifically considered. [59] The analysis in this study may be relevant for areas of the RPFO since the RPFO also includes recreation areas and opportunities in close proximity to a rapidly growing city in the Southwest.

Valle de Oro National Wildlife Refuge (NWR) Alternative Transportation Planning

The FWS's Valle de Oro NWR is a new urban refuge located five miles south of downtown Albuquerque. Despite its close proximity to the city, the Valle de Oro NWR is primarily accessible only by private vehicle due to a lack of bicycle and pedestrian facilities and transit options. The FWS worked with Bernalillo County transportation planners to apply for Federal Lands Access Program (FLAP) funding to design and construct a multi-use trail that connects the refuge to the neighboring Mountain View community. This project was shortlisted for programming in 2014. In addition, refuge staff are collaborating with regional partners to identify and develop opportunities to connect the refuge to the Rail Runner and ABQ Ride transit services. This work contributes to FWS Urban Refuge Initiative goals by providing greater access to natural areas for those without cars and has the potential to reduce GHG

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[58] Executive Order No. 13514, 3 C.F.R. 248, 2009.

[59] BLM, 2012b. *Red Rock Canyon National Conservation Area Transportation Feasibility Study.* http://ntl.bts.gov/lib/45000/45800/45802/DOT-VNTSC-BLM-12-01.pdf.

emissions from people driving private vehicles to get to the site.[60]

Valles Caldera Preserve Transit Shuttles

The U.S. Forest Service's Valles Caldera National Preserve is located in the northern part of the RPFO's geographic area and is near BLM land, including the Cabezon Peak area. Two shuttle routes provide access to recreational sites within the preserve for hikers and mountain bicyclists throughout the summer season (mid-May through September).[61] These shuttle services fulfill complementary goals of enhancing visitors' experiences, reducing congestion, and reducing GHG emissions from visitor travel within the preserve. In 2012, the Paul S. Sarbanes Transit in Parks (TRIP) Program provided Valles Caldera funding to implement a solar-powered public transportation system for backcountry visitation. A pilot project is currently in progress to test the feasibility of a long-term shuttle service.[62]

Regional Land Use and Transportation Mitigation Strategies in Central New Mexico

As part of the CCSP, participants developed a paper detailing potential yet realistic strategies for the reduction of GHG emissions in central New Mexico.[63] Most of the strategies in this paper have been or will be considered for potential application in central New Mexico and, with MRCOG's concurrence, could be included in the region's Metropolitan Transportation Plan. The strategies fall into six broad categories:

- **Land Use Strategies:** including zoning changes, encouragement of urban infill development, transit-oriented development, and urban growth boundaries/infrastructure dependent growth policies.
- **Integrating Transportation Investments with Land Use Strategies:** including improving bicycle and pedestrian infrastructure improvements; public transportation service, facilities, and assets; and routine accommodation of bicycles and pedestrians in future roadway projects.
- **Transportation Demand Management (TDM) Strategies:** including road pricing, high occupant vehicle facilities, parking management and pricing, car sharing, bike sharing, ridesharing, employer commuter programs, transit incentives, and a potential statewide mileage-based user fee.
- **Transportation System Management (TSM) Strategies:** including traffic signal management, incident management, intersection improvements, and roadway connectivity standards.
- **Vehicle Improvement Strategies:** including electric vehicle infrastructure support, heavy-duty vehicle retrofits, and truck stop electrification technologies.
- **Other Considerations:** including reducing the emissions from construction activities when maintaining or constructing new transportation facilities and reducing the emissions associated with transportation facilities by increasing their energy efficiency.

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[60] FWS, 2014b. *Innovative Regional Partnerships: Valle de Oro National Wildlife Refuge*. http://www.volpe.dot.gov/sites/volpe.dot.gov/files/docs/RegionalPartnersCS_090514_FINAL.pdf.

[61] Valles Caldera National Preserve, 2014. Shuttle website. http://www.vallescaldera.gov/comevisit/shuttle/.

[62] Volpe Center, 2014a. Forest Service Transit in Parks Archive website. http://www.volpe.dot.gov/transportation-planning/public-lands/forest-service-transit-parks-archive.

[63] Volpe Center, 2014b. Transportation-Related Greenhouse Gas Mitigation Strategies and Potential Applications in Central New Mexico. Developed for the Central New Mexico Climate Change Scenario Planning Project, available upon request.

Many of these strategies, such as zoning changes, would be implemented by municipalities or local transportation agencies. However, the BLM may be a partner or contribute to some of these regional strategies as appropriate. For example, the RPFO could:

- Support regional conservation activities;
- Work with local communities to ensure bicycle and pedestrian connectivity on RPFO roads;
- Support any regional transit efforts related to the RPFO; or
- Work to increase the fuel efficiency of the RPFO vehicle fleet, transportation facilities, and construction projects).

Opportunities for Climate Change Mitigation at the Rio Puerco

For the RPFO, strategies for reducing transportation-related GHG emissions fit into three main categories:

- Reducing GHG emissions from BLM staff travel to or within RPFO lands;
- Reducing GHG emissions from visitor travel to or within RPFO lands; and
- Reducing GHG emissions from RPFO transportation facilities.

Reducing GHG Emissions from BLM Travel at the RPFO

To reduce GHG emissions from BLM staff travel to or within the RPFO, the BLM could retrofit or replace its vehicles to increase their fuel efficiency. The RPFO could also encourage BLM staff to carpool to work or when traveling for administrative purposes within the RPFO.

Two examples of resources that FLMAs have created to analyze all GHG emissions (not just transportation-related emissions) and develop recommendations for mitigation activities at the public lands unit level are the NPS Climate Leadership in Parks (CLIP) and the FWS Climate Leadership in Refuges (CLIR) tools.[64,65] Both of these tools provide a systematic way for public land units to inventory GHG emissions from unit operations and estimate the impacts of alternative mitigation strategies. The main difference between the two tools is that CLIP only estimates NPS staff and visitor transportation emissions within park units whereas CLIR also estimates emissions from staff and visitor travel to and from refuges. The BLM could develop a similar tool to help units like RPFO analyze potential emissions reduction strategies, or the RPFO could adopt a similar approach to analyze the relative benefits of different mitigation actions.

Reducing GHG Emissions from Visitor Travel at the RPFO

The RPFO could reduce visitor emissions by developing alternative transportation options to RPFO sites, such as transit or bicycle and pedestrian trails. These options would not be feasible or appropriate

[64] NPS, 2014. The Climate Leadership in Parks (CLIP) Tool, Climate Friendly Parks. http://www.nps.gov/climatefriendlyparks/CLIPtool/.
[65] FWS, 2012. Shared Stories and Practices: CLIR Tool Calculates Greenhouse Gas Emissions. http://www.fws.gov/home/climatechange/stories/clir-tool-calculates-refuge-greenhouse-gas-emissions.html.

everywhere, but these strategies may be appropriate for recreational sites with large, concentrated visitation or that are located near communities or existing transit systems. It may be difficult or infeasible to serve some of the RPFO's more dispersed, remote recreation sites with trails or transit, except for large special events where transit could help connect a site to an off-site park-and-ride.

The RPFO could also encourage use of existing transit or trail options. For example, there is anecdotal evidence that some mountain bicyclists use the Rail Runner from Albuquerque or Santa Fe to access BLM trails.[66] The RPFO could encourage visitors to use transit and trails to access RPFO sites by providing readily accessible visitor information promoting these options.

Reducing GHG Emissions from RPFO Transportation Facilities

The RPFO could also reduce transportation-related GHG emissions by reducing the fuel or energy use of RPFO transportation facilities, such as maintenance or storage structures. The RPFO may accomplish this through energy efficiency retrofits, such as replacing light bulbs or improving heat insulation, or by developing clean energy sources, such as installing solar panels at transportation facilities. The CLIP and CLIR tools also analyze GHG emissions from public lands structures and may provide a useful model for analyzing the relative benefits of different transportation facility GHG reduction strategies.

[66] Volpe Center, 2010. The Bureau of Land Management Alternative Transportation Systems Inventory Report. Prepared for the Bureau of Land Management, Department of the Interior.

Chapter 5: Conclusion

The BLM should consider how a changing climate may affect its transportation systems in the future when undertaking long-range planning in order to make better decisions that in the future can help reduce maintenance and disaster relief costs and improve service to the public. The current RPFO TTMP provides an opportunity for the BLM to consider potential climate change impacts along with other factors as it designates the RPFO transportation system and plans for its future. This report presented and analyzed the potential impacts on the RPFO from climate change, a framework for increasing the adaptation and resilience of the RPFO transportation network, and potential climate change mitigation strategies that the RPFO could adopt.

Potential Climate Change Impacts to the RPFO Transportation System

Based on research on climate change impacts in the U.S. Southwest and the CCSP's climate futures analysis of downscaled climate change projections for six grid cells in central New Mexico, this report shows that there is notable uncertainty about the magnitude of temperature changes in the future, ranging from approximately +1.4°F to +5.1°F mean annual temperature increases by 2025-2055 compared with the historic baseline. For precipitation, climate change projections show a potential range of change from -2.0 inches per year to +2.0 inches per year compared with the historical baseline. Because of the uncertainty inherent in climate change projections, it is important for the RPFO to plan by considering multiple possible futures.

Despite the uncertainty, the BLM should prepare for the following trends and their associated impacts:

- Increasing average and extreme temperatures, especially during the summer and fall months;
- Increasing water scarcity and drought due to a variety of causes;
- Increasing likelihood of flash floods due to heavy precipitation events;
- Increasing likelihood of more intense and frequent wildfires; and
- Implications from hotter and drier conditions, such as impacts to natural resources.

These changes in the climate of central New Mexico could have the following primary impacts on the Rio Puerco transportation system:

- Flooding of roads and bridges;
- Direct wildfire damage to transportation infrastructure;
- Erosion and landslides due to flooding or wildfire damage;
- Blockage or damage to culverts and other drainage structure; and
- Higher pavement maintenance costs due to higher temperatures.

Adaptation and Resilience Framework

To prepare for the potential impacts of climate change, the RPFO should consider the role of its transportation system and the diverse uses of its transportation assets (access for recreation, resource extraction, neighboring communities, and BLM administration, etc.). When analyzing potential adaptation options, the RPFO should consider the vulnerability of transportation assets, their role and importance within the RPFO transportation system, and their adaptive potential in order to make more informed decisions about repairing or improving existing infrastructure, and constructing new infrastructure. Adaptation strategies fall under the general categories of protection, accommodation, retreat, maintenance, and disaster recovery.

Because the timing and magnitude of climate change is uncertain, this report recommends that the BLM should use an adaptive management approach to planning for climate change adaptation at the RPFO. For example, the BLM could designate a particular threshold, such as a certain increase in extreme temperatures (e.g., days above 90 °F) that would trigger increased wildfire resilience planning, or an increase in flood exposure (e.g., number of flooding events per year), which would trigger projects that increase flood resilience. This adaptive approach would be appropriate, given the iterative nature of the BLM's TTMP process.

Climate Change Mitigation Strategies for the RPFO

In addition to preparing to adapt to the impacts of climate change, it is important for the BLM and other agencies to adopt strategies to mitigate climate change by reducing their GHG emissions. For the RPFO, there are three main strategies, with associated actions, that the BLM could take where feasible and appropriate:

- Reducing GHG emissions from visitor travel to and within the RPFO:
  - Develop new alternative transportation options to RPFO recreation sites, such as multi-use trails or transit;
  - Encourage the use of existing transit and trail connections through visitor information; and
  - Partner with local transportation agencies, communities, and other FLMAs to support regional efforts to improve public transportation and bicycle and pedestrian travel options.
- Reducing GHG emissions from BLM travel to and within the RPFO:
  - Increase the fuel efficiency of BLM fleet vehicles and
  - Encourage BLM staff to carpool to RPFO sites.
- Reducing GHG emissions from RPFO transportation facilities:
  - Increase the energy efficiency of RPFO transportation facilities, such as maintenance or storage structures, and
  - Generate clean energy at RPFO transportation facilities, for instance by installing solar panels on structures.

Regional Collaboration

It is important to remember that the BLM is not alone in its efforts to adapt to and mitigate the effects of climate change. The CCSP is a collaborative regional effort including MRCOG, state and local governments, FLMAs, and other Federal agencies, all of whom recognize the importance of acting to reduce the region's vulnerability and decrease the region's GHG emissions. Ultimately, the BLM can work with its Federal, state, and local partners to support regional adaptation and mitigation efforts, and to gain regional support for the BLM's strategies. To maximize its success in addressing climate change, the BLM should collaborate with other agencies planning for climate change in central New Mexico, recognize synergies between agencies' approaches, and understand the impacts that its adaptation and mitigation actions will have within the region.

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Appendix A: Climate Futures Analysis by Ecoregion

Appendix A provides the climate futures outputs for each grid cell analyzed in the RPFO. See Figure 3 for a map of the grid cell locations.

Grid Cell A: El Malpais NCA, Arizona / New Mexico Mountains and Plateau

Grid Cell A is located in the El Malpais National Conservation Area near Grants, NM. It straddles the boundary between two BLM ecoregions: Arizona / New Mexico Plateau and Arizona / New Mexico Mountains. The outputs for Grid Cell A are analyzed in more depth above.

Figure 18: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell A

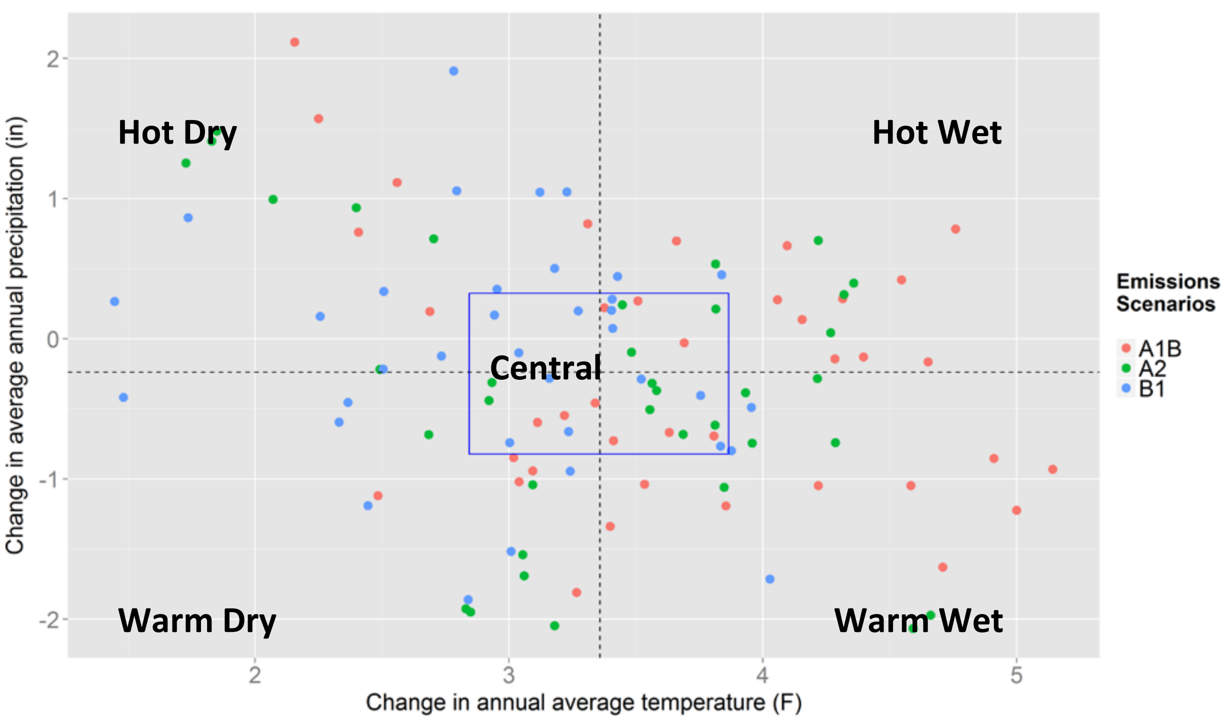


Figure 19: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell A

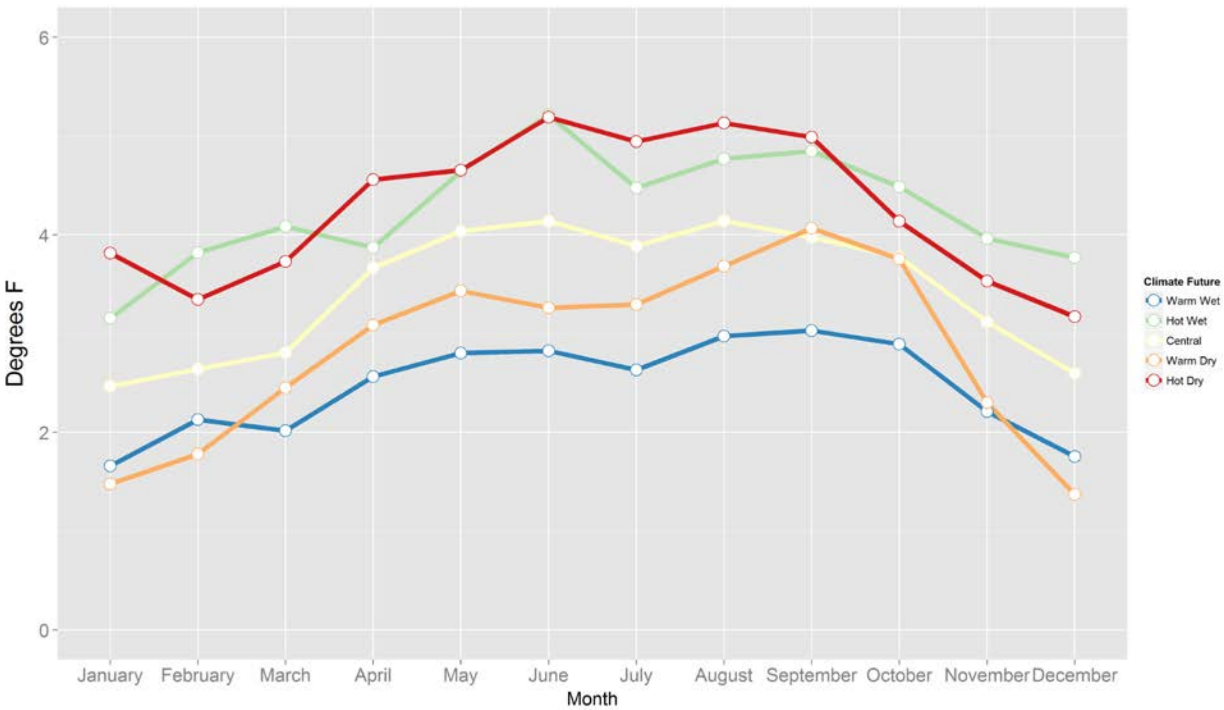


Figure 20: Average number of days per year at or above 100°F in the future period (2025-2055) for Grid Cell A

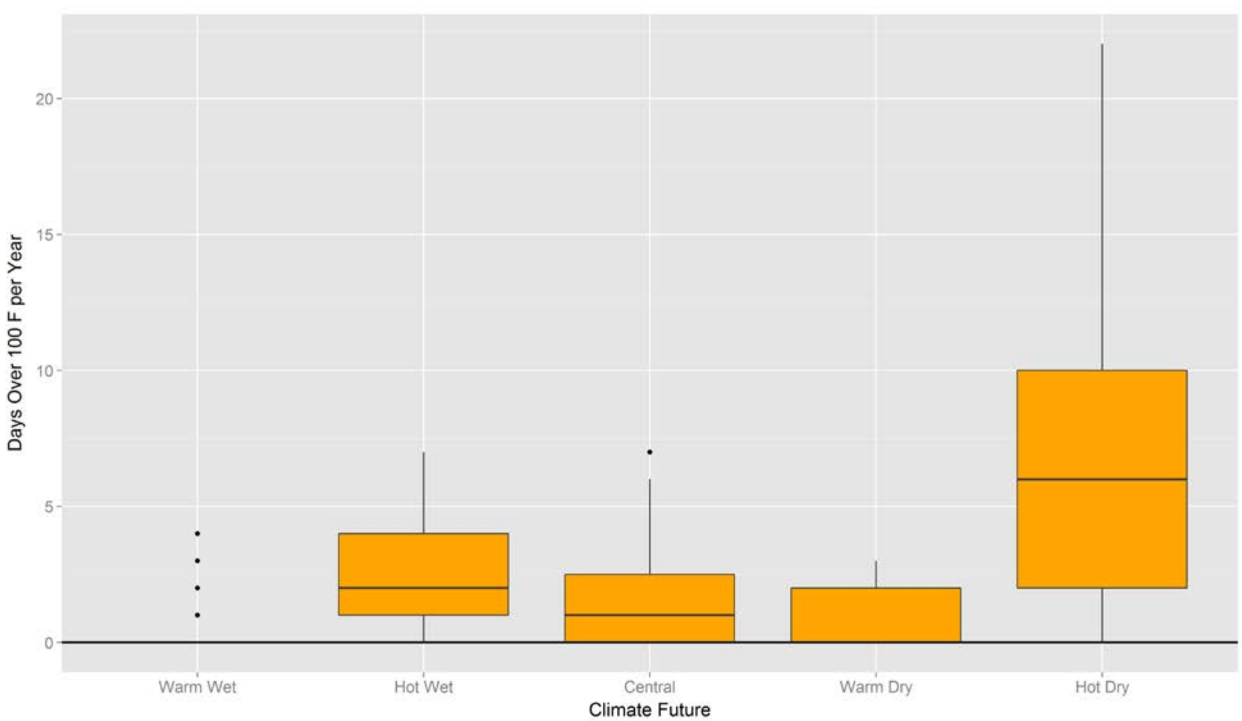


Figure 21: Maximum consecutive days per year at or above 100°F for 2040 in the future period (2025-2055) in Grid Cell A

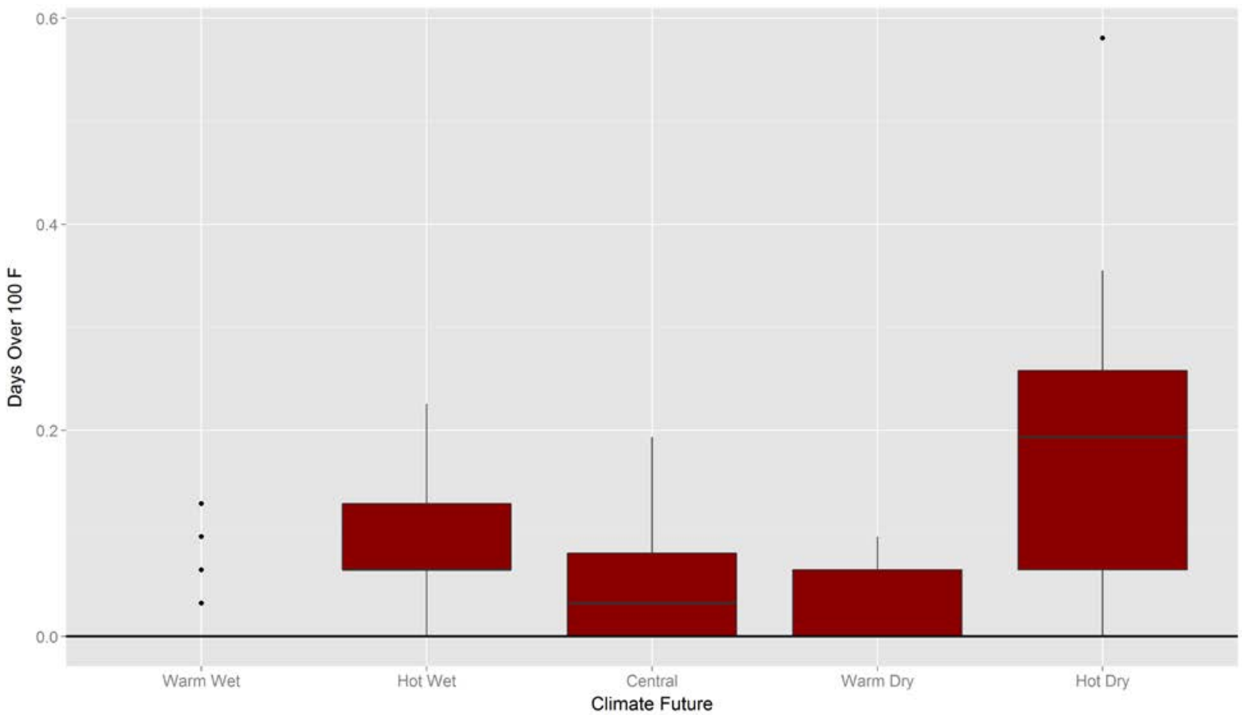


Figure 22: Change in average monthly precipitation in 2025-2055 compared with the baseline period (1950-1999) for Grid Cell A

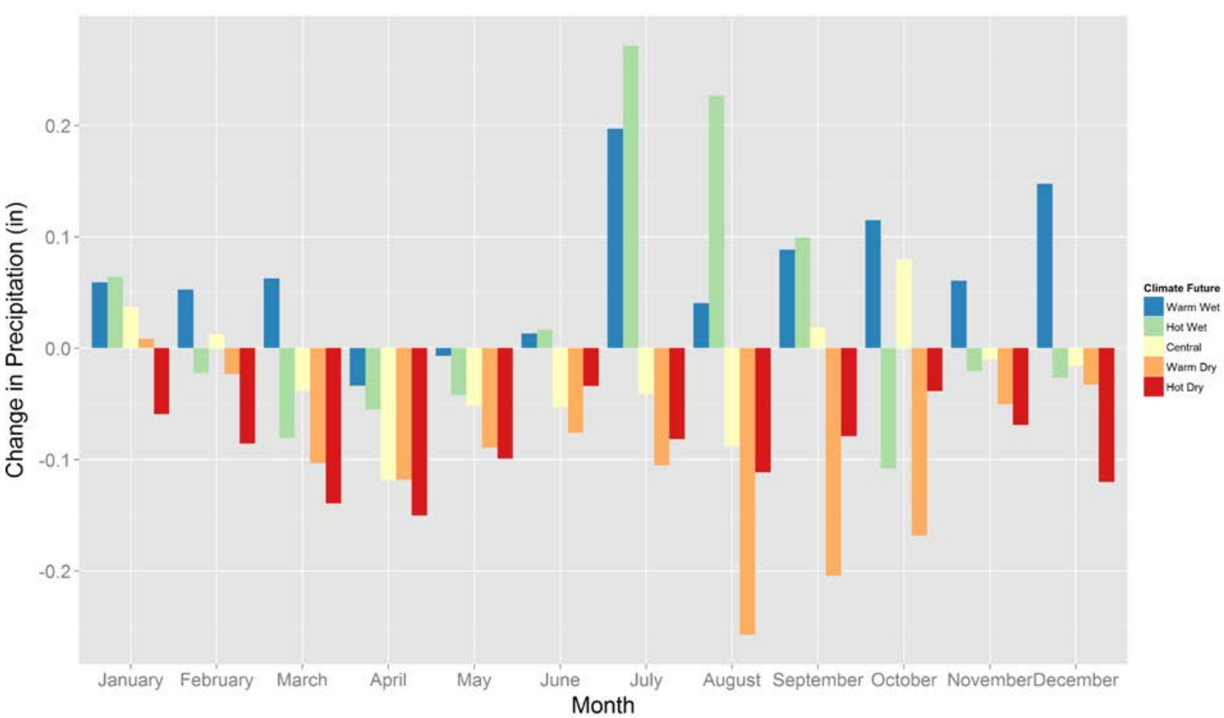
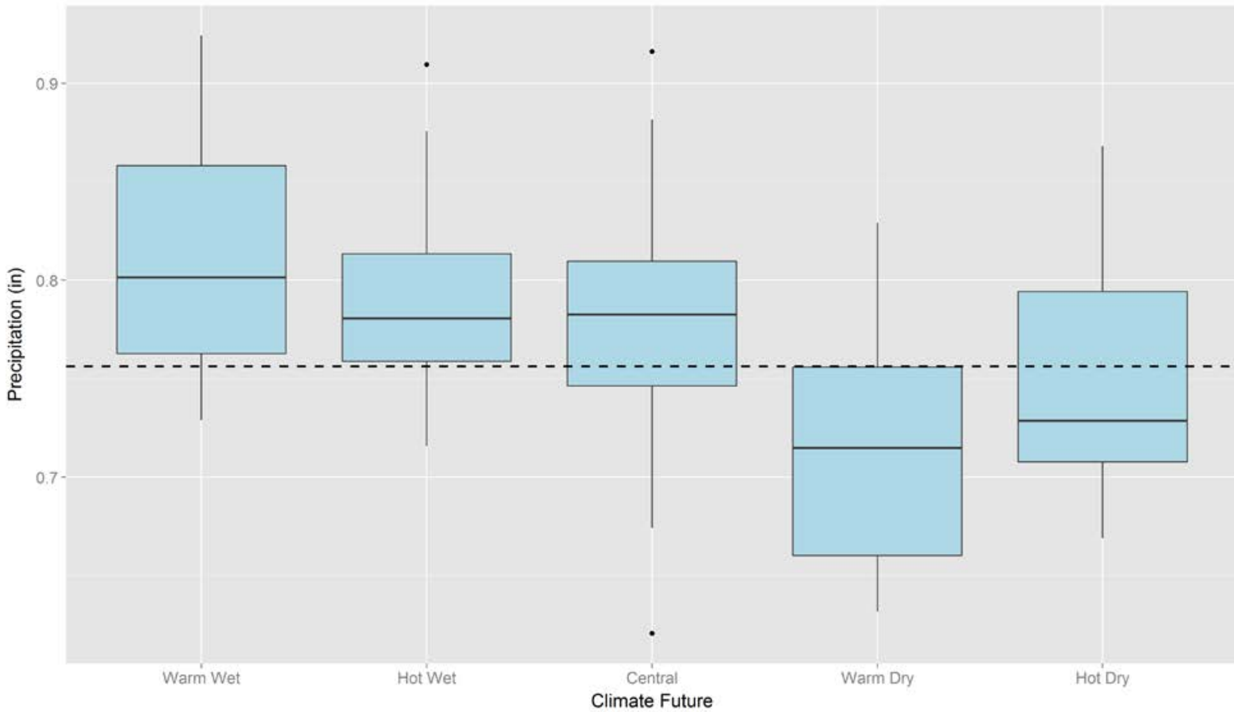


Figure 23: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (dotted line)



Grid Cell B: Santa Fe National Forest, Southern Rockies

Grid Cell B is in Santa Fe National Forest (near BLM land at Cabezon Peak). This grid cell is in the Southern Rockies ecoregion.

Figure 24: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell B

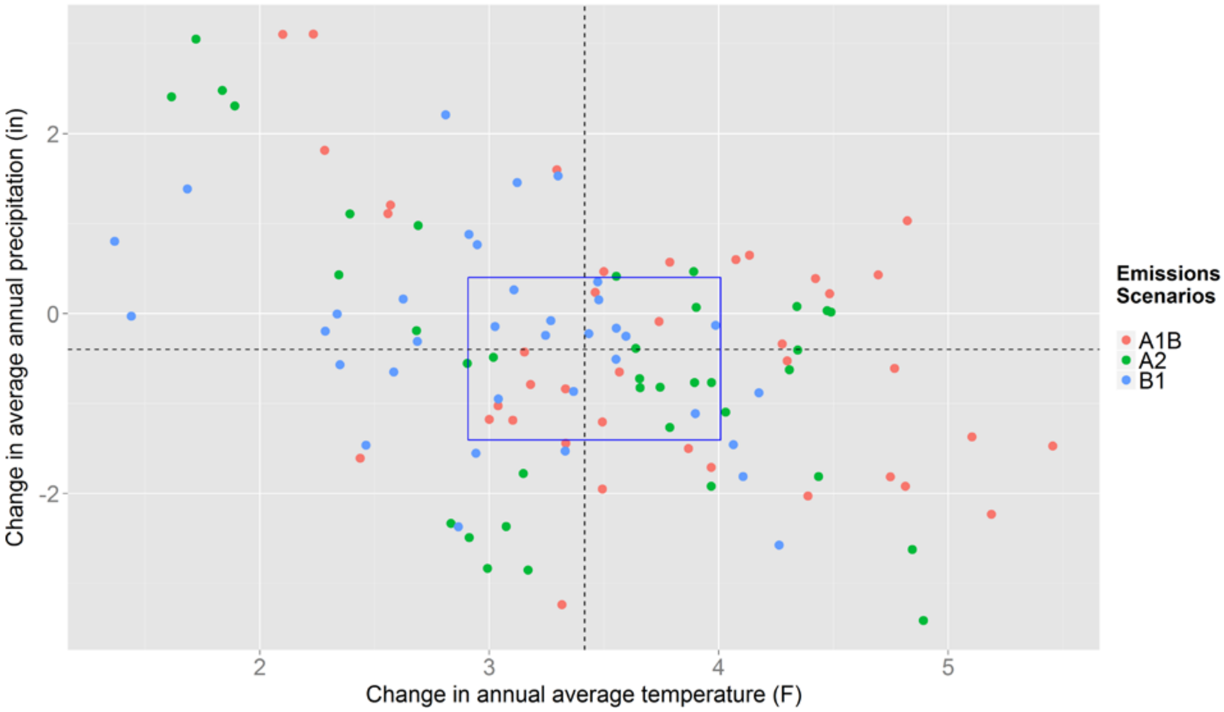


Figure 25: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell B

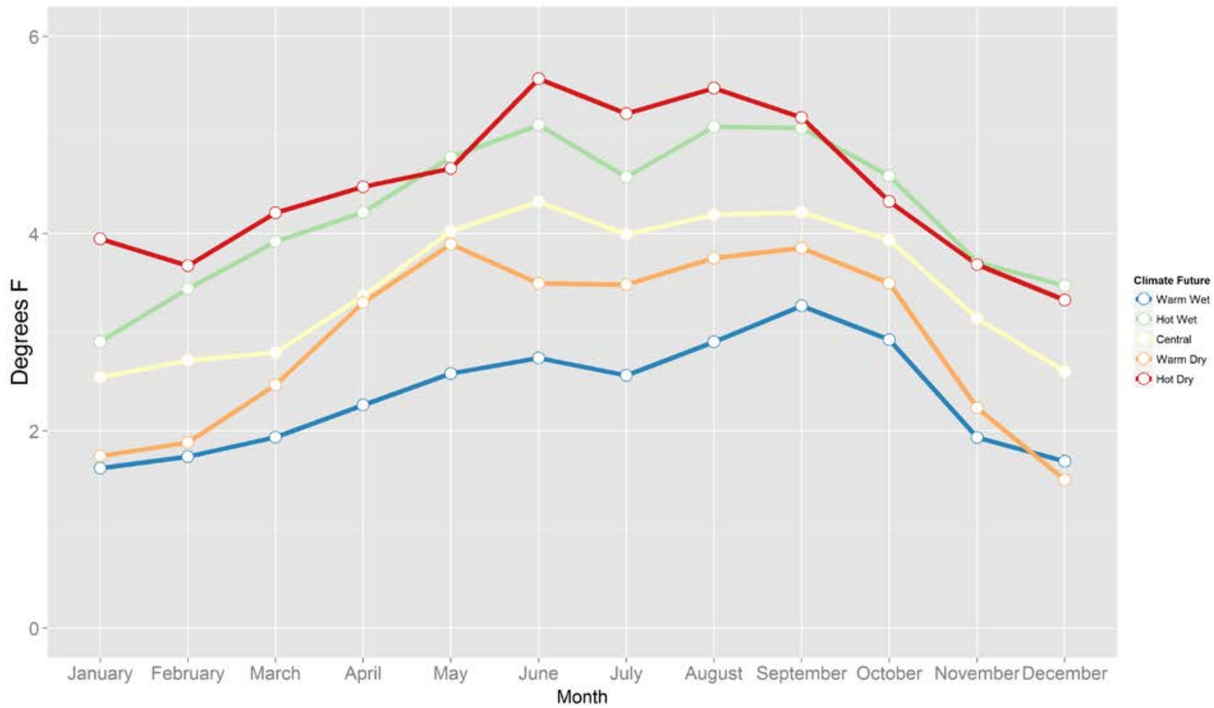


Figure 26: Average number of days per year at or above 100°F in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell B

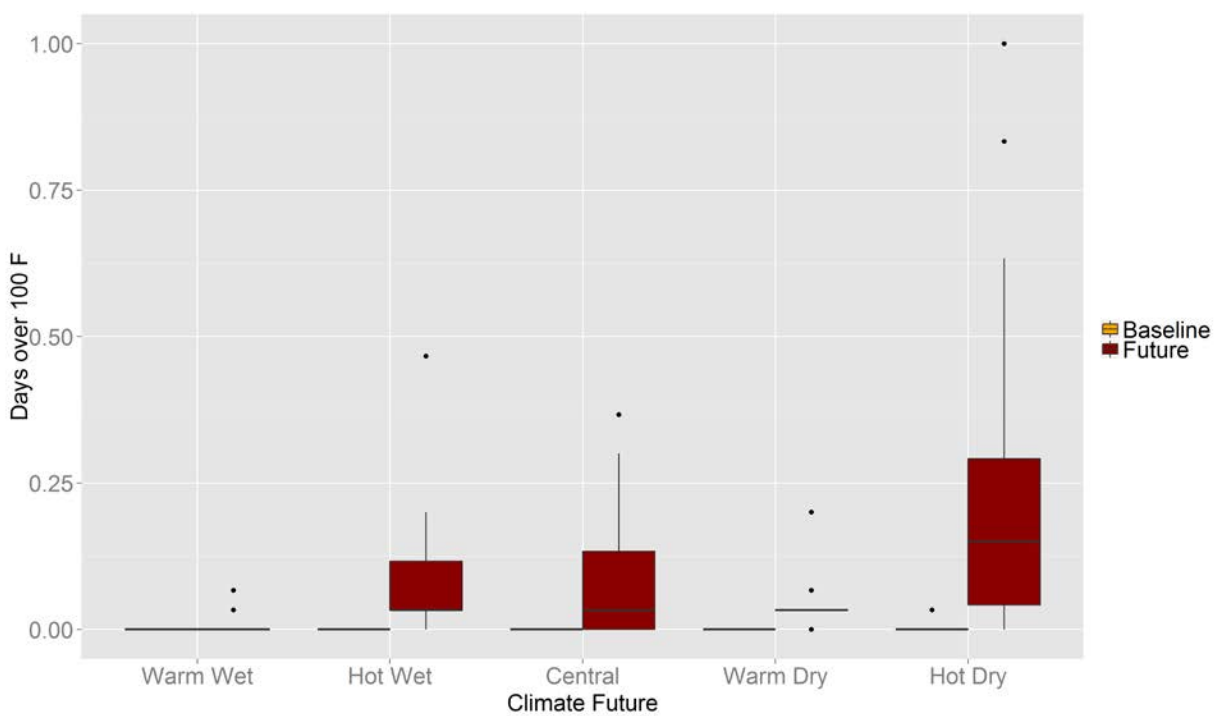


Figure 27: Maximum consecutive days per year at or above 100°F in the future period (2025-2055) compared with the baseline period (1950-1999) in Grid Cell B

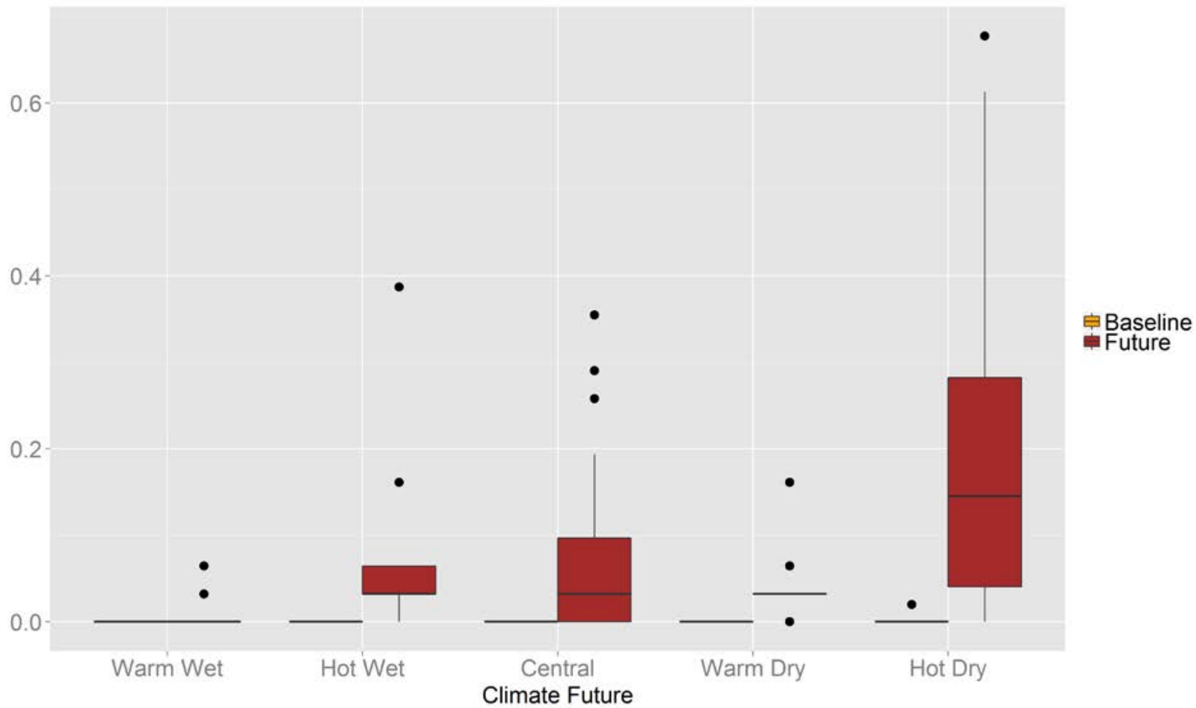


Figure 28: Change in average monthly precipitation in 2025-2055 compared with the baseline period (1950-1999) for Grid Cell B

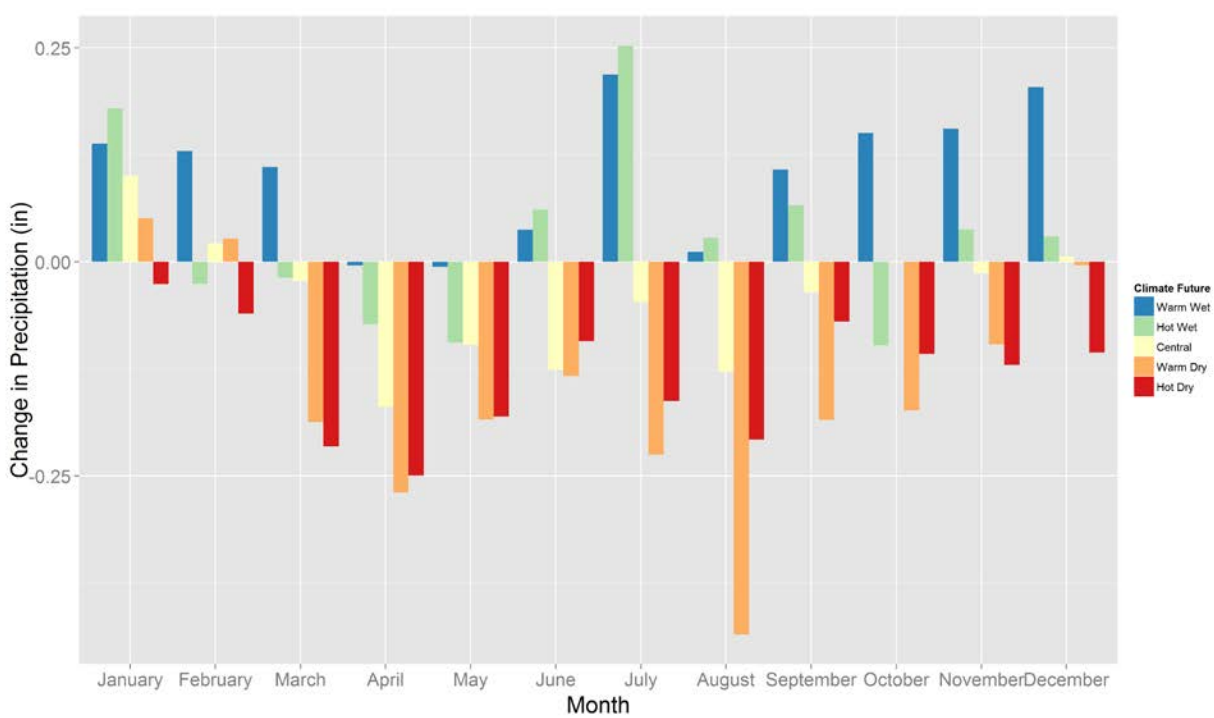
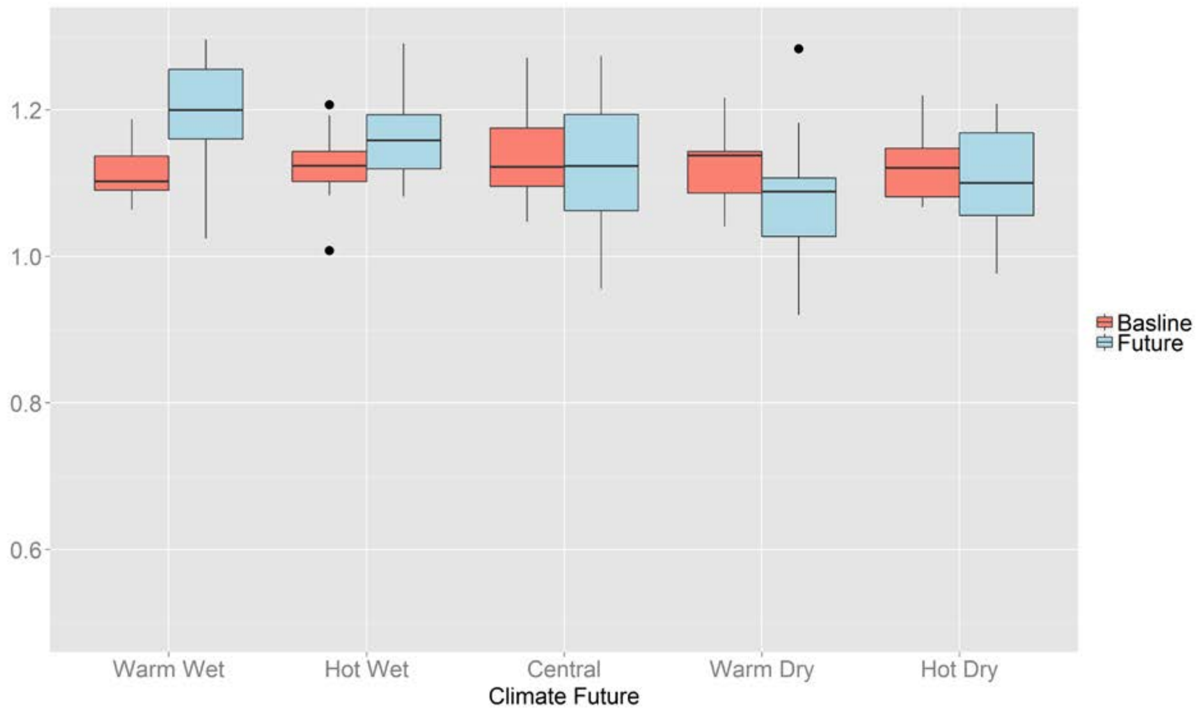


Figure 29: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (red box plots) for Grid Cell B



Grid Cell C: Cibola National Forest, Arizona / New Mexico Mountains

Grid Cell C is located in Cibola National Forest, which is in the Arizona / New Mexico Mountains ecoregion.

Figure 30: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell C

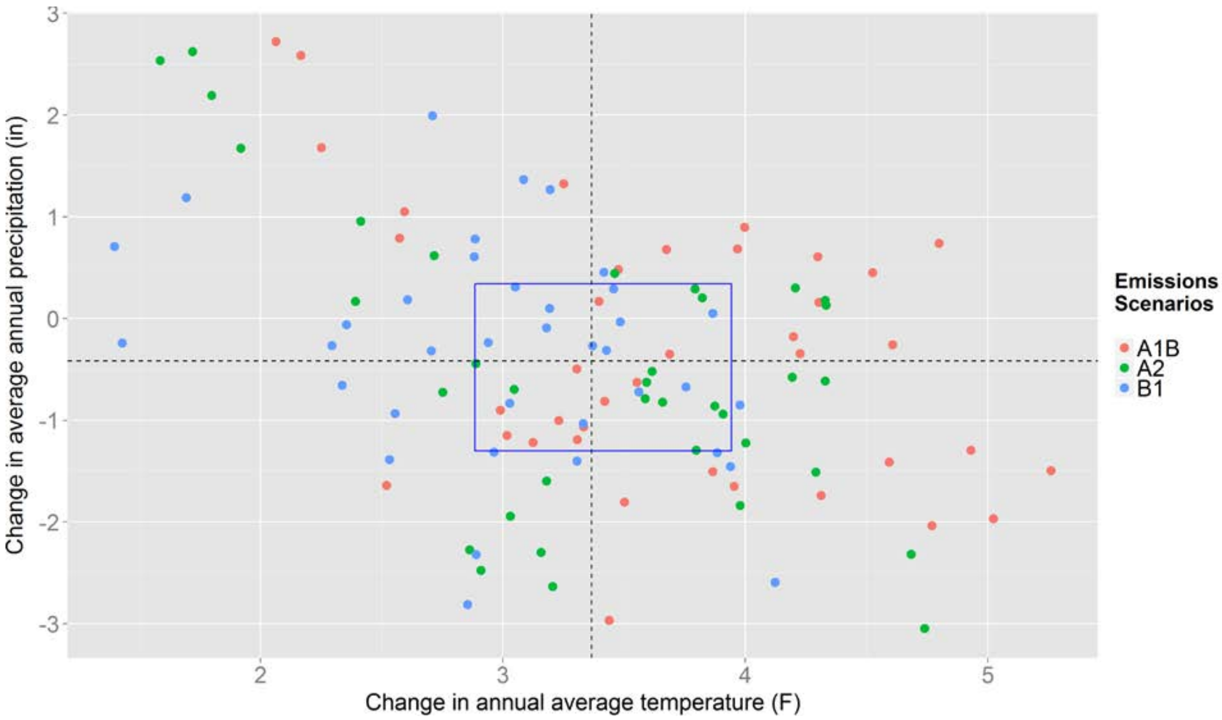


Figure 31: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell C

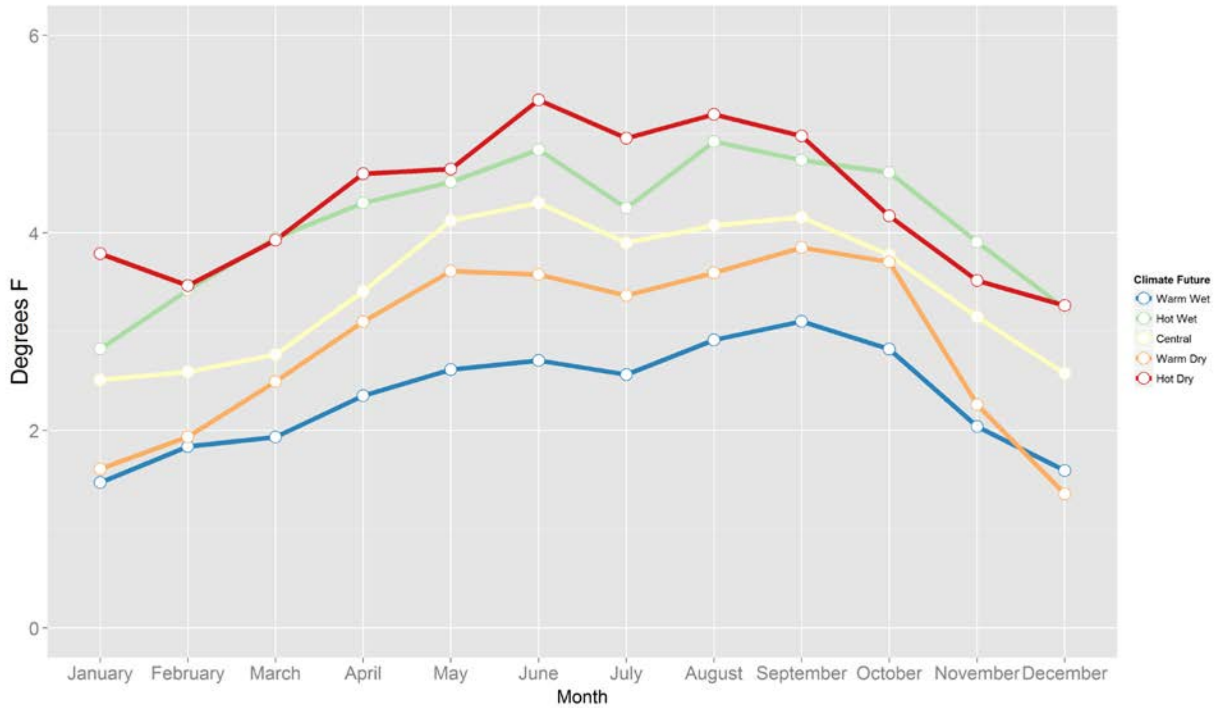


Figure 32: Average number of days per year at or above 100°F in the future period (2025-2055) compared to the baseline period (1950-1999) for Grid Cell C

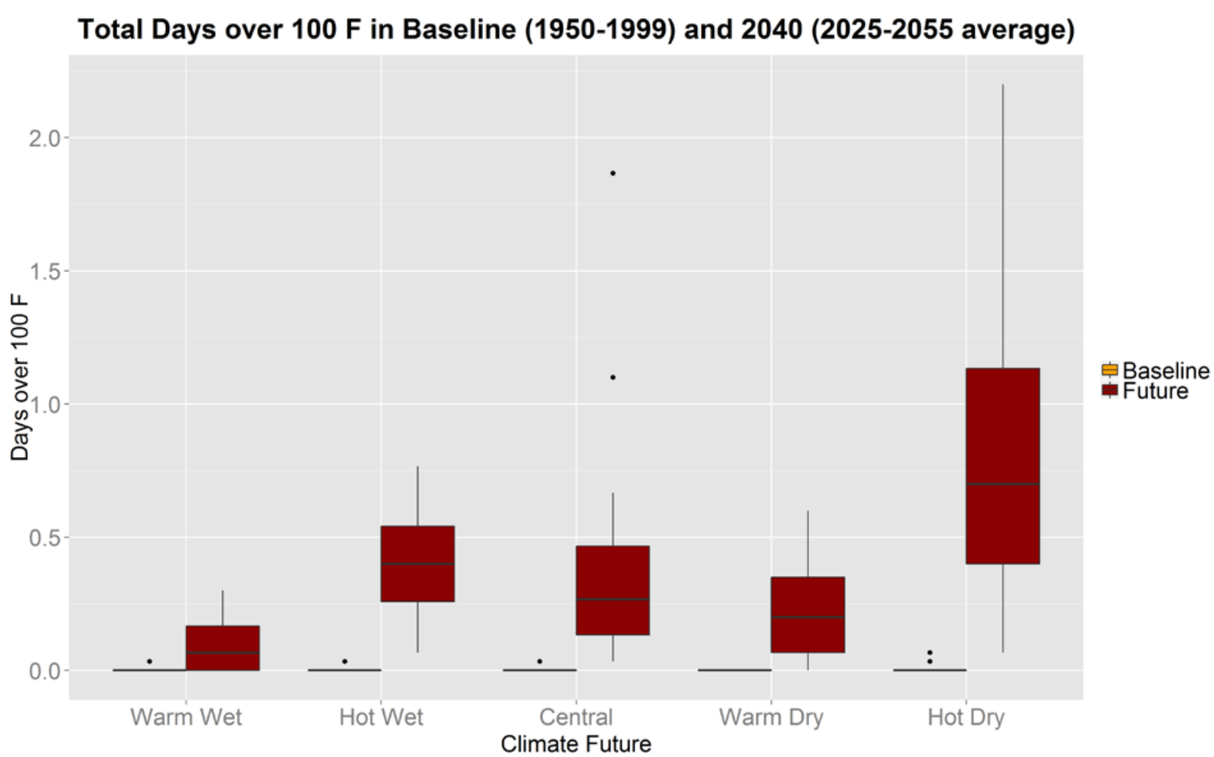


Figure 33: Maximum consecutive days per year at or above 100°F for the future period (2025-2055) compared to the baseline period (1950-1999) in the future period (2025-2055) in Grid Cell C

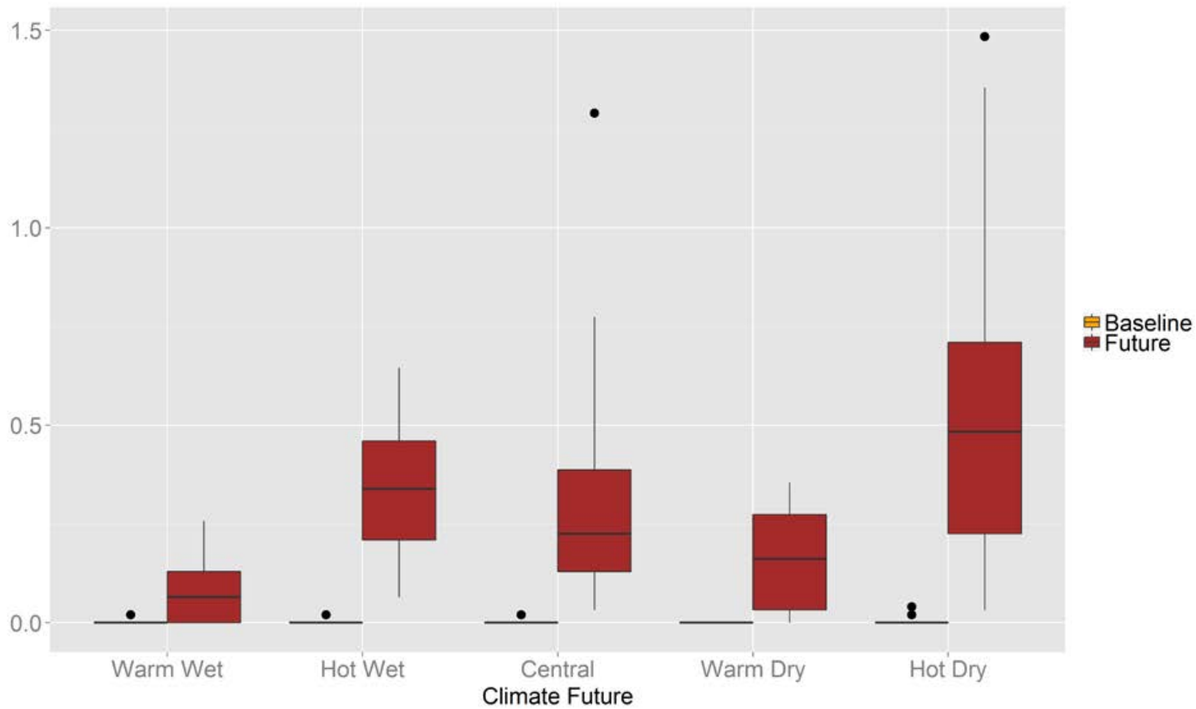


Figure 34: Change in average monthly precipitation in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell C

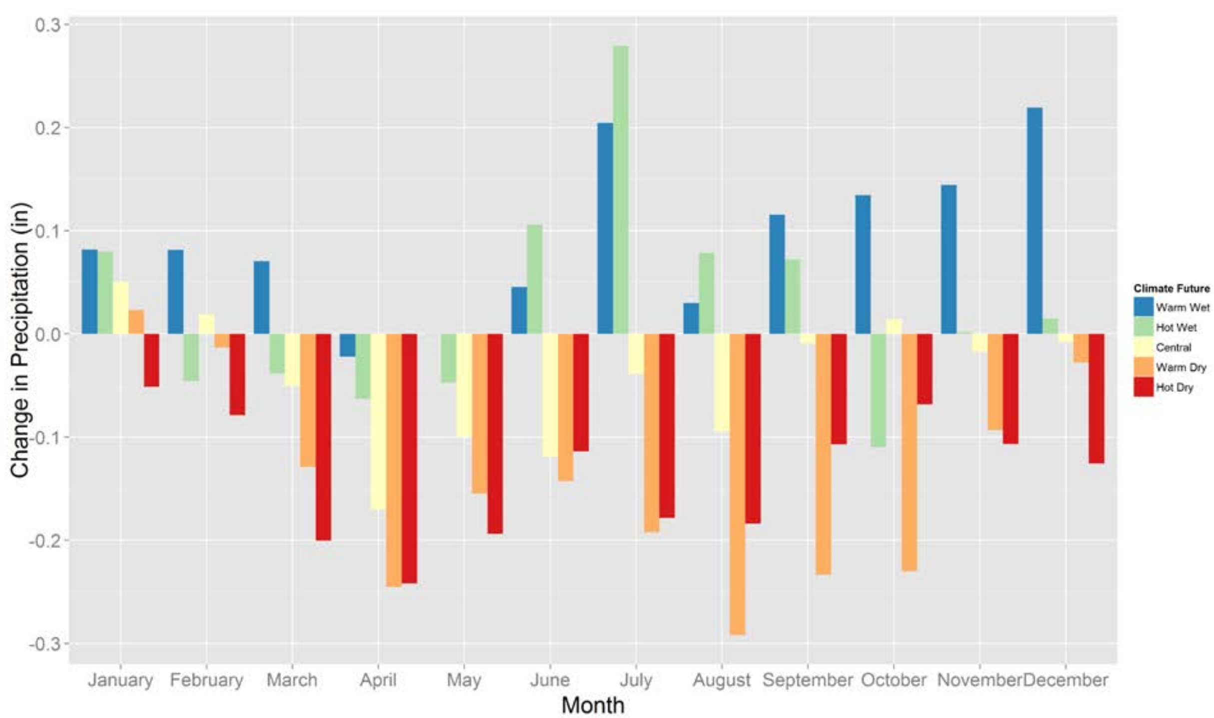
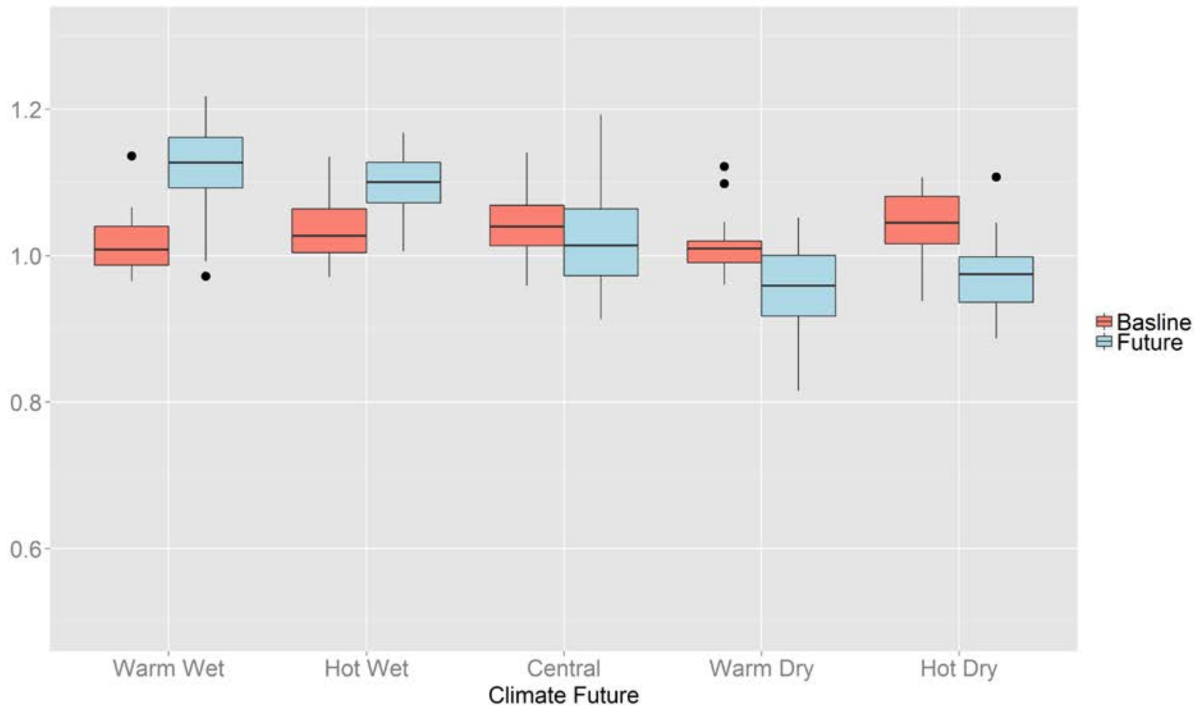


Figure 35: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (red box plots) for Grid Cell C



Grid Cell D: Desert Area near Estancia, Southwestern Tablelands

Grid Cell D is in the desert southeast of Albuquerque near Estancia and is located in the Southwestern Tablelands ecoregion.

Figure 36: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell D

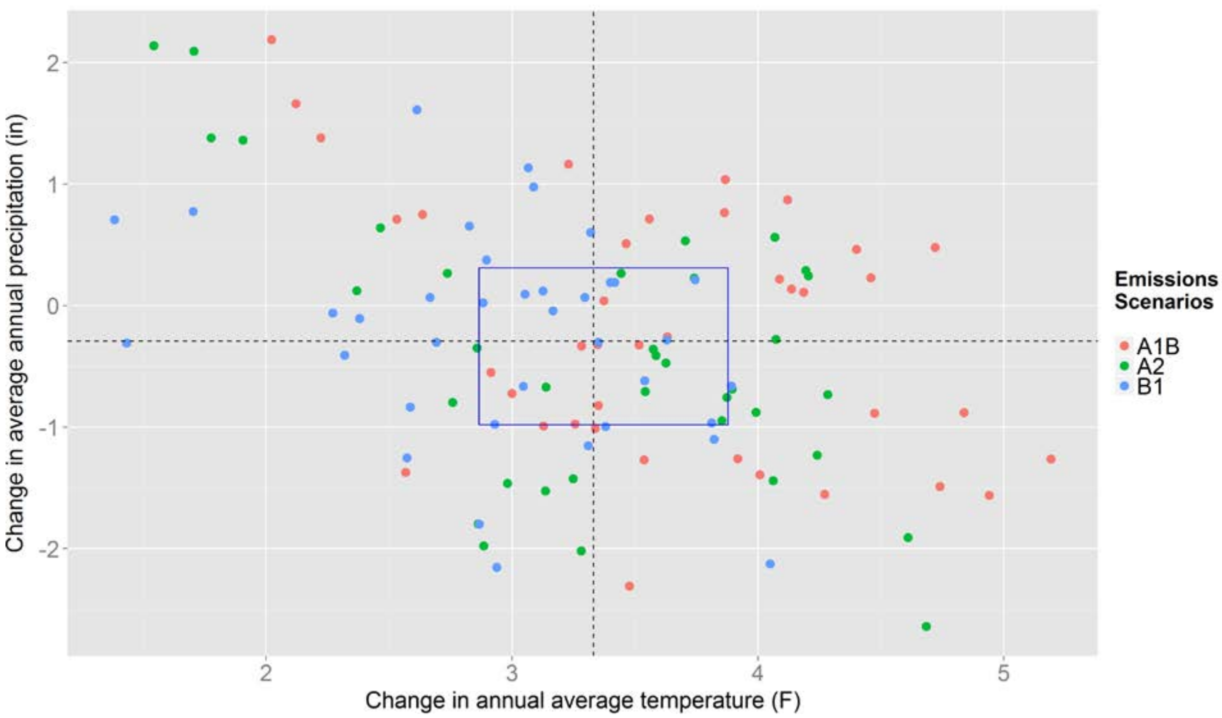


Figure 37: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell D

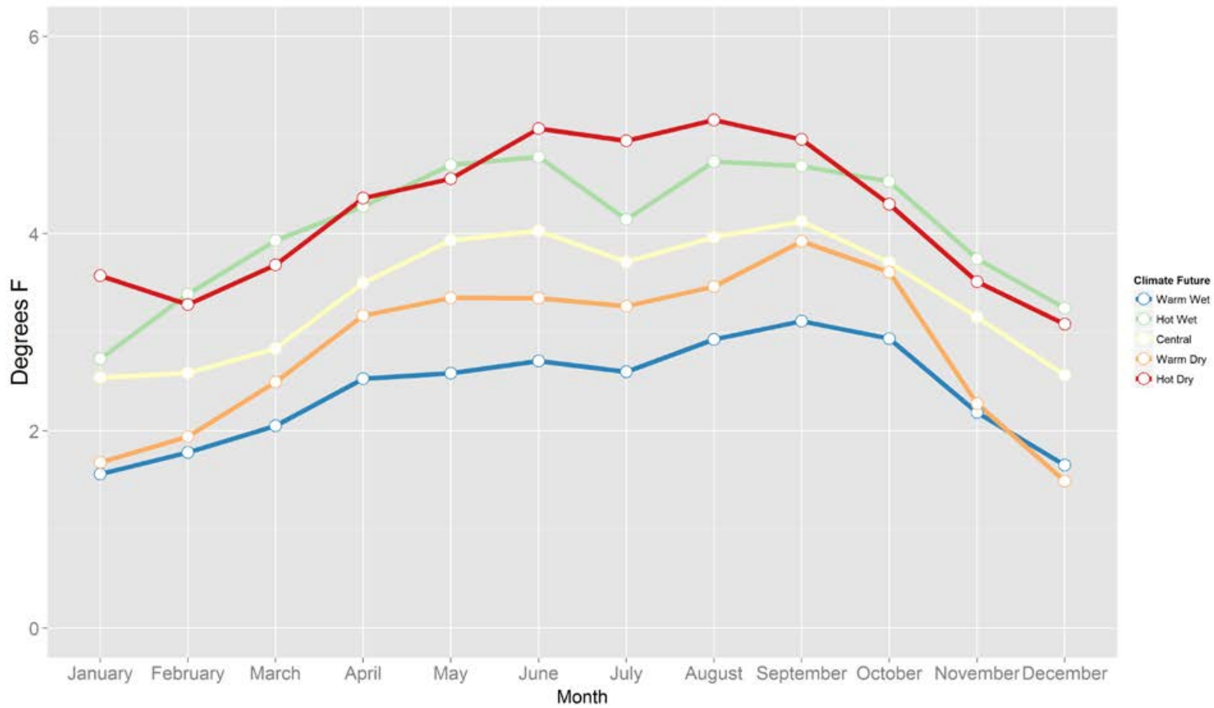


Figure 38: Average number of days per year at or above 100°F in the future period (2025-2055) compared to the baseline period (1950-1999) for Grid Cell D

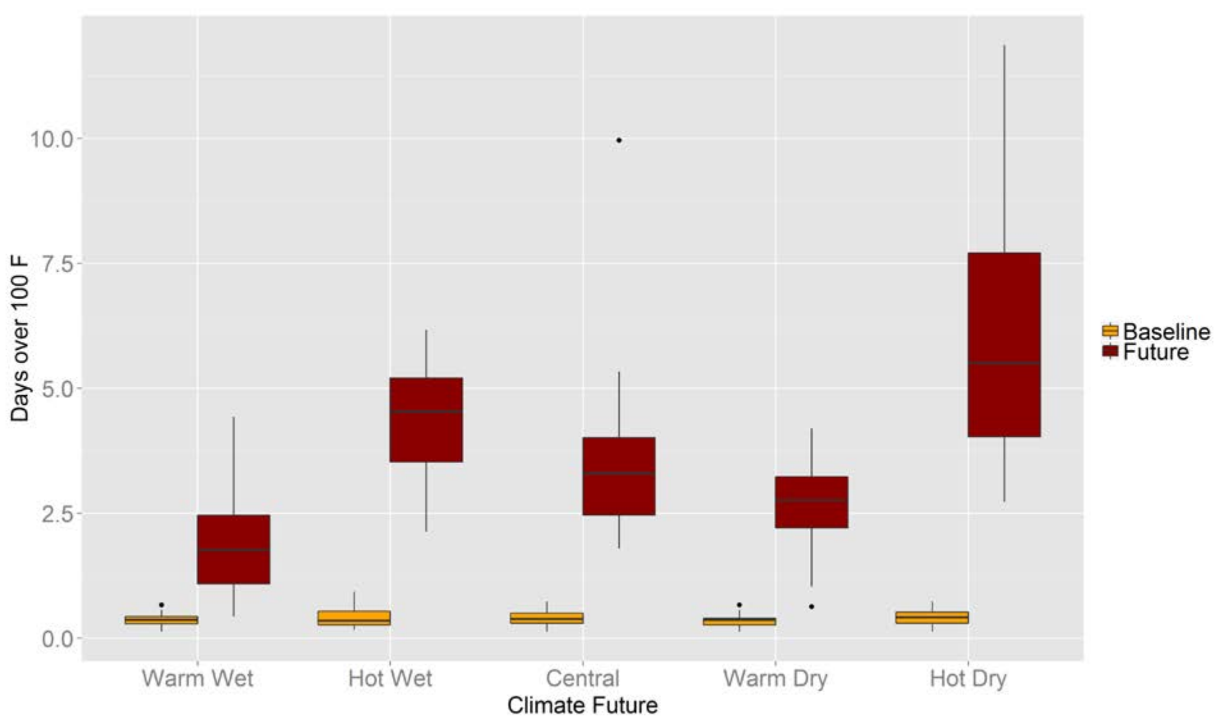


Figure 39: Maximum consecutive days per year at or above 100°F in the future period (2025-2055) compared with the baseline period (1950-1999) in Grid Cell D

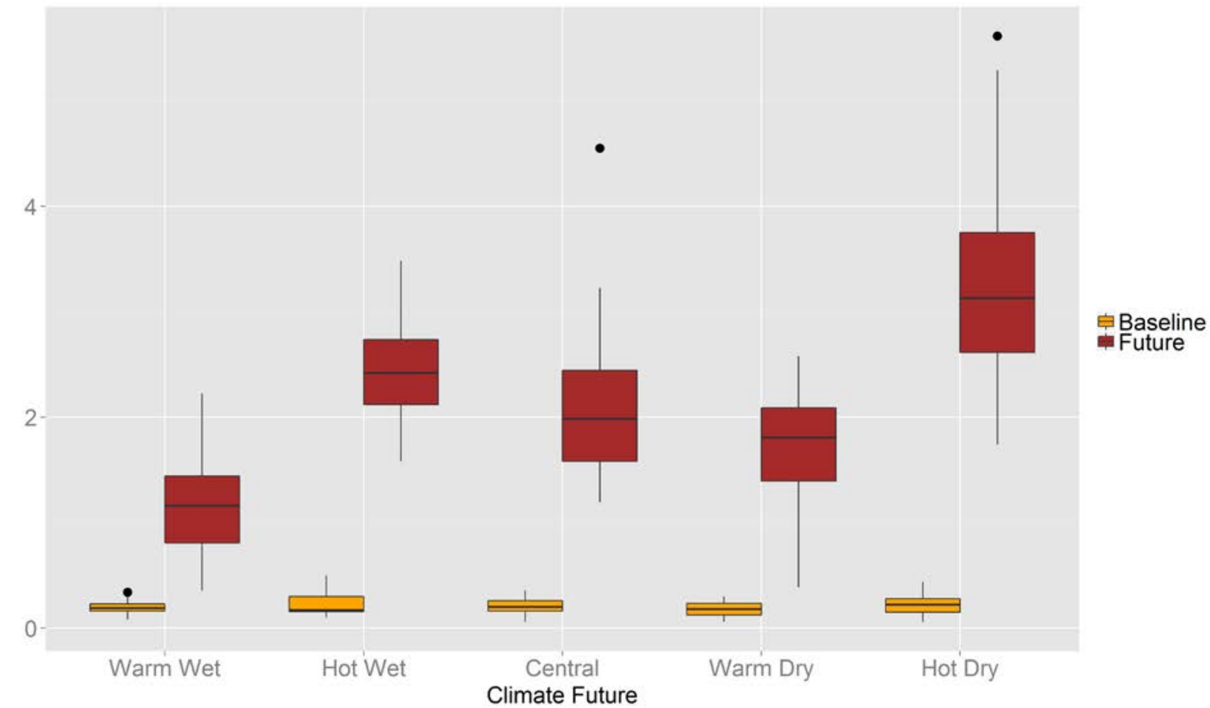


Figure 40: Change in average monthly precipitation in 2025-2055 compared with the baseline period (1950-1999) for Grid Cell D

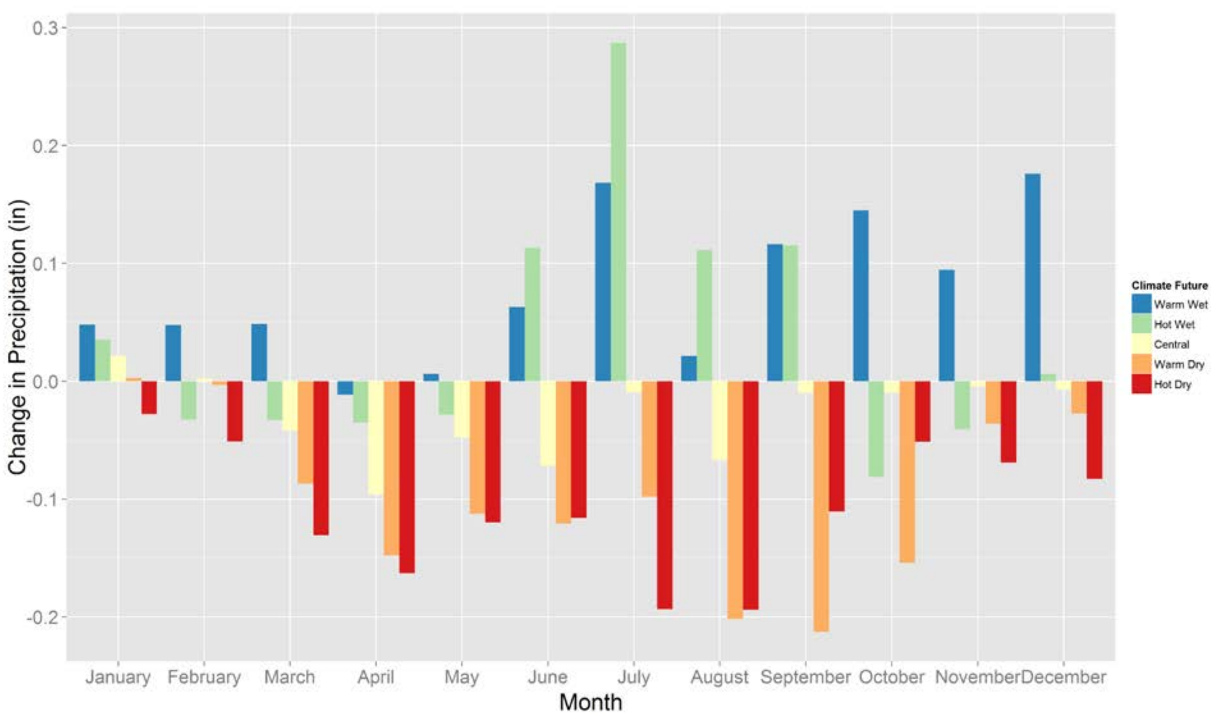
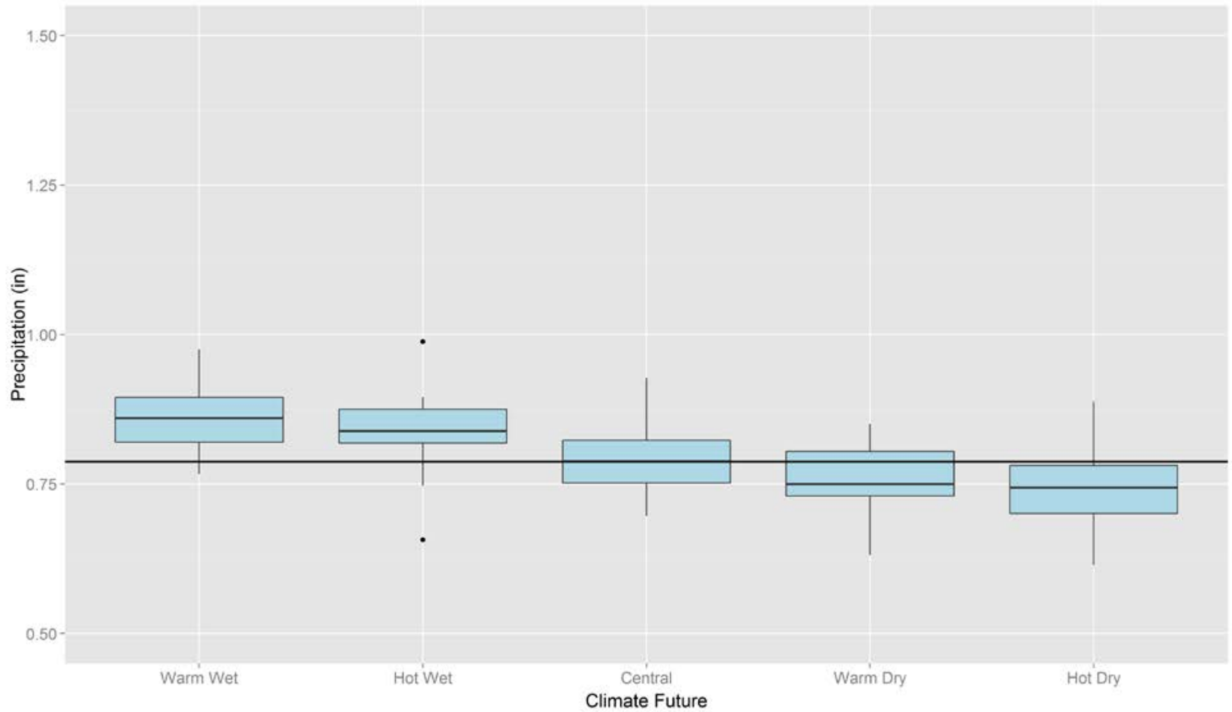


Figure 41: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (black line represents median) for Grid Cell D



Grid Cell E: Southwest Albuquerque, Arizona / New Mexico Plateau

Grid Cell E is located in southwestern Albuquerque, in the BLM's Arizona / New Mexico Plateau ecoregion.

Figure 42: Scatter plot of projected changes in mean annual precipitation and temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell E

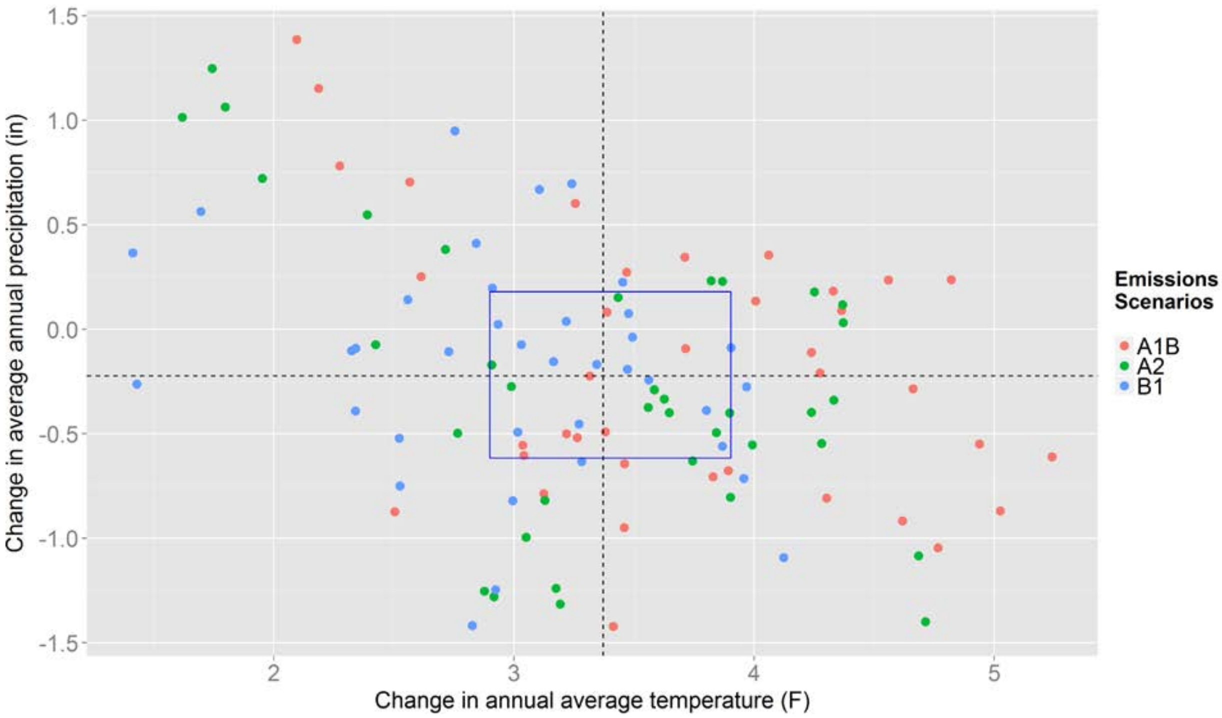


Figure 43: Change in average daily maximum temperature in the future period (2025-2055) compared with the baseline period (1950-1999) for Grid Cell E

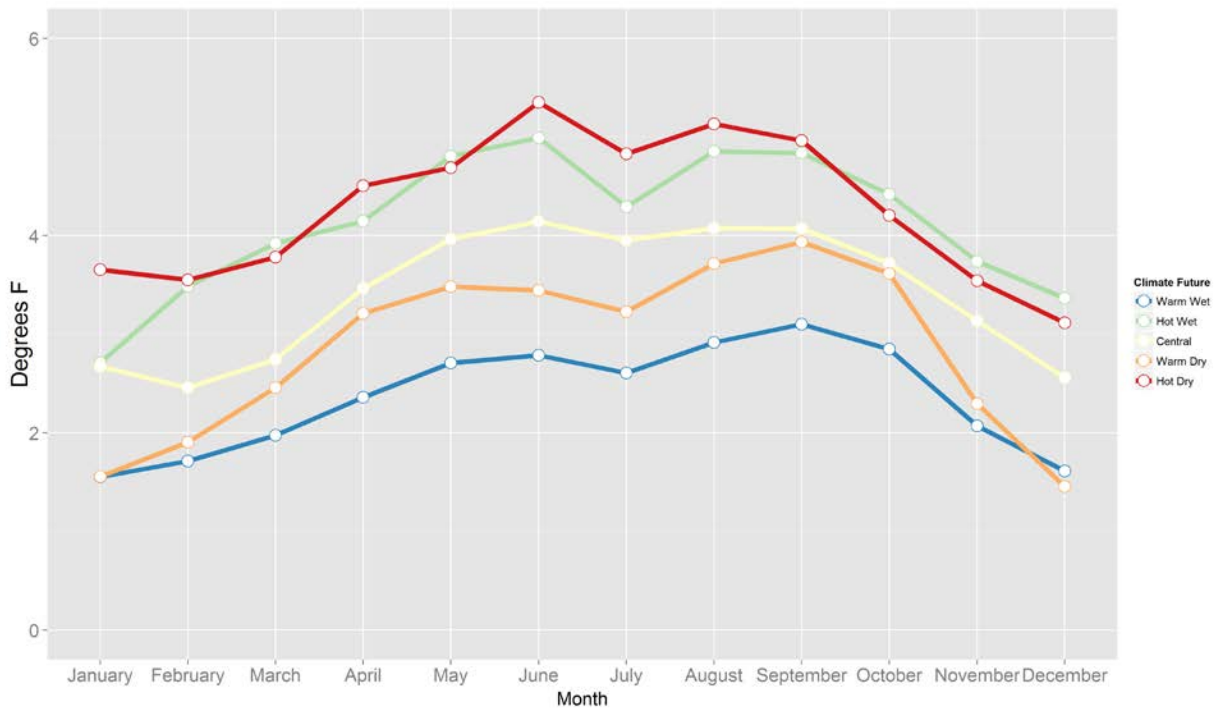


Figure 44: Average number of days per year at or above 100°F in the future period 2025-2055 (box plots) compared to the baseline period 1950-1999 (black line represents median) for Grid Cell E

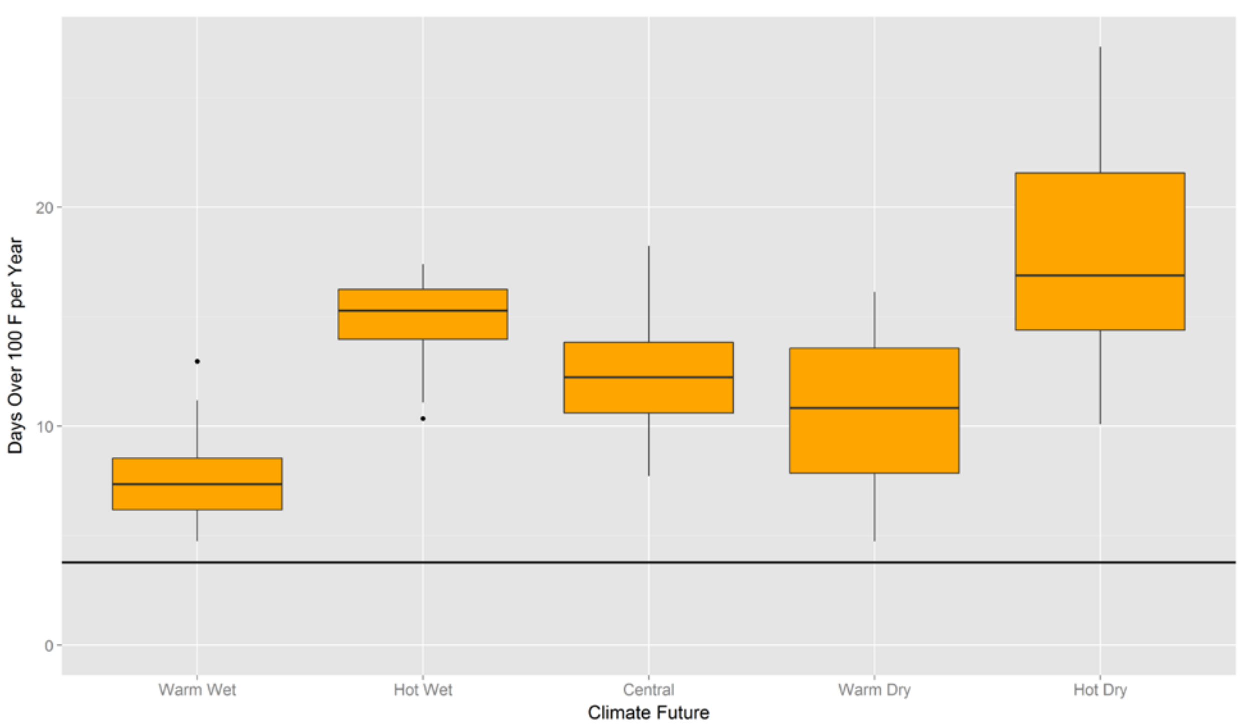


Figure 45: Maximum consecutive days per year at or above 100°F in the future period 2025-2055 (box plots) compared with baseline period 1950-1999 (black line represents median) in Grid Cell E

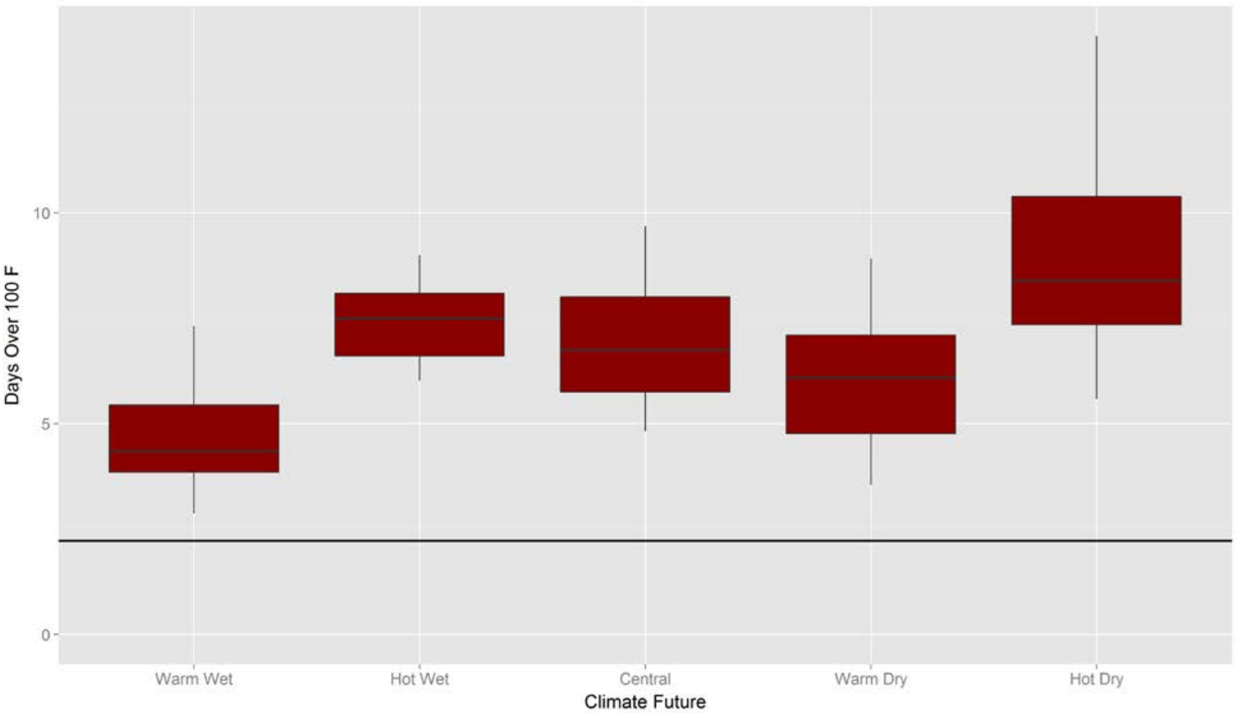


Figure 46: Change in average monthly precipitation in 2025-2055 compared with the baseline period (1950-1999) for Grid Cell E

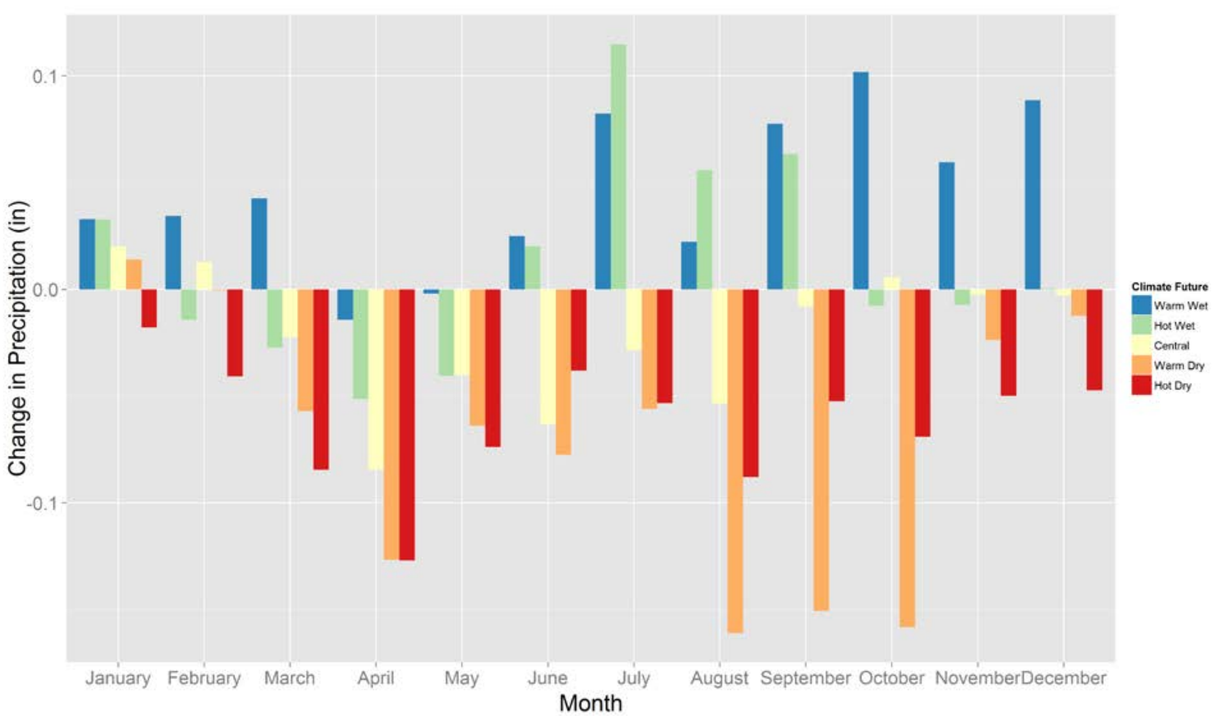
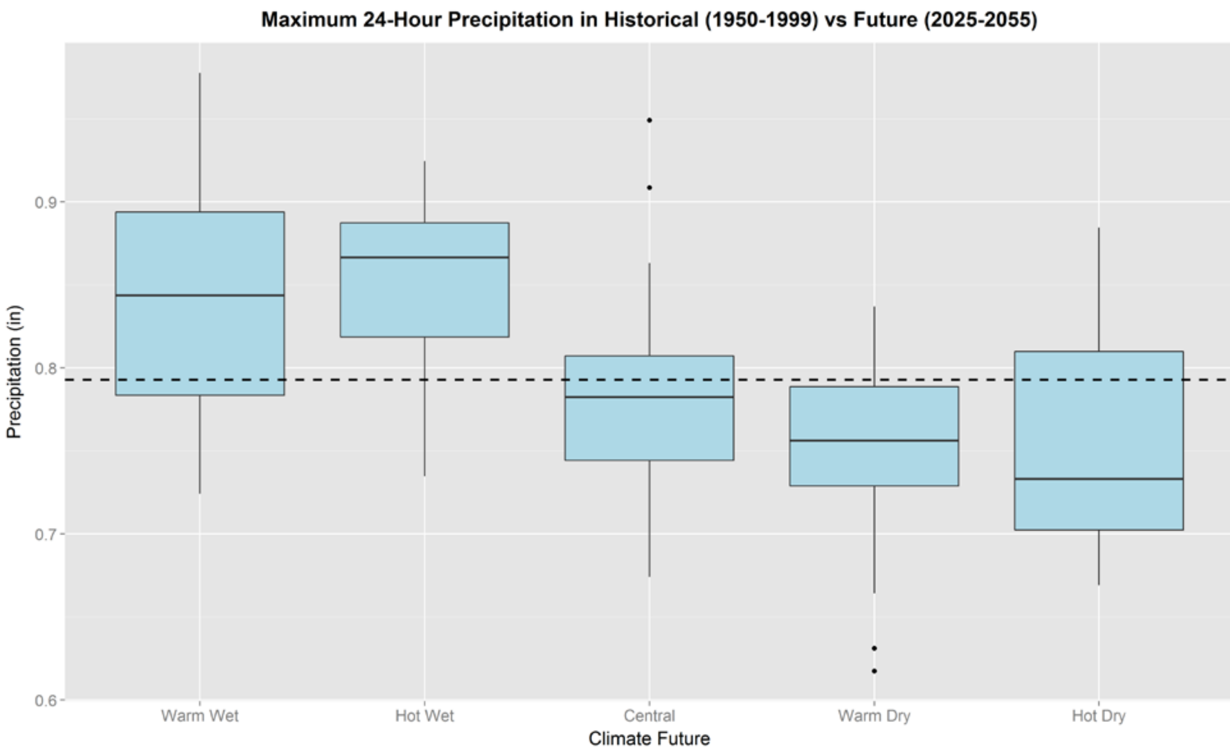


Figure 47: Maximum projected 24-hour precipitation amounts in 2025-2055 (blue box plots) compared with the baseline period 1950-1999 (dotted line represents median) for Grid Cell E



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