Integrating Climate Change in Transportation and Land Use Scenario Planning

An Example from Central New Mexico

April 2015

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The Central New Mexico Climate Change Scenario Planning Project, an Interagency Transportation, Land Use, and Climate Change Initiative, utilized a scenario planning process to develop a multiagency transportation- and land use-focused development strategy for the Albuquerque region of New Mexico to achieve a reduction in future greenhouse gas emissions and to prepare for the potential impacts of climate change on the region. The outcomes of this scenario planning process informed and supported the region's long-range transportation planning and other related efforts as well as the planning efforts of local, State, and Federal agencies. Project members collaborated to document steps and offer observations and recommendations that will inform future applications of the project's methodology. This information is presented in this report, and the appendices provide supporting documentation. Lead project sponsor was the Federal Highway Administration, with co-sponsors the Bureau of Land Management, the Fish & Wildlife Service, and the National Park Service.

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Project members collaborated to document steps and offer observations and recommendations that will inform future applications of the project's methodology. This information is presented in this report, and the appendices provide supporting documentation. Additional documentation of technical reports prepared by scenario planning consultants are available at **www.volpe.dot.gov/NMScenarioPlanning.**

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This report was prepared by the U.S. Department of Transportation John A. Volpe National Transportation Systems Center (Volpe Center) in Cambridge, MA, for the Federal Highway Administration (FHWA), Fish and Wildlife Service (FWS), and the Bureau of Land Management (BLM). Benjamin Rasmussen of the Volpe Center led the project team, which included James Andrew, David Daddio, and Erica Simmons, each members of the Transportation Planning Division. Alexander Epstein of the Energy Analysis and Sustainability Division and Paige Colton of the Organizational Performance Division were also involved with this project. The project utilized technical analysis provided by Ecosystems Management Incorporated, led by Mike Tremble, and a team from the University of New Mexico, led by Dr. Greg Rowangould. The project team would like to thank the sponsors of this project, Planning Group and Technical Committee members, and local and regional stakeholders, in particular Aaron Sussman, Kendra Watkins, and Caeri Thomas of the Mid-Region Council of Governments, for their participation and contributions.

Executive Summary

Project Description

Located in an arid Southwest part of the country, the Albuquerque, New Mexico region (Figure 1) is projected to grow by more than 50 percent over the next 25 years to nearly 1.4 million people. Accommodating this growth while meeting community goals for the environment, economy, and character of the region, poses a challenge. The transportation planning body for the area, the Mid Region Council of Governments (MRCOG), embarked on a scenario planning effort to test out the impact of different transportation and land use scenarios on progress towards community goals. Federal grant funding and technical assistance enabled the region to integrate an analysis of strategies to reduce greenhouse gas (GHG) emissions and improve resilience to climate change impacts, such as wildfires and flooding. Called the Central New Mexico Climate Change Scenario Planning Project (CCSP), the partnership aimed to: a) provide analysis to MRCOG to help the region improve sustainability through its metropolitan transportation plan (MTP), and b) demonstrate a process that could be replicated in other regions of the country (especially inland areas) for using scenario planning to respond to the challenges of climate change in conjunction with other community goals.

Figure 1: Project Study Area in Central New Mexico.

The CCSP resulted in a preferred land use and transportation scenario for the region that accommodates anticipated growth. By considering future climate change impacts and GHG emission reduction strategies, the scenario is more resilient and sustainable than the trend or status quo. Regional stakeholders selected this Preferred Scenario from a range of scenarios based on information provided by local climate projections, transportation and land use modeling, and other data and analytics. These stakeholders guided and responded to the scenario analysis through their participation on project advisory committees and at two workshops. MRCOG, the Federal interagency partners, and project consultants conducted analyses in line with workshop feedback to define the Preferred Scenario and inform MRCOG's update to its 2040 MTP, which was adopted by its policy board in 2015.

Approach

Project Definition

During the project definition phase, the project team identified roles and responsibilities for the large number of partners, including MRCOG, the U.S. Department of Transportation (U.S. DOT), Federal agencies that own major tracts of land in the region (Bureau of Land Management [BLM], National Park Service [NPS], Fish and Wildlife Service [FWS], and U.S. Forest Service [USFS]); local jurisdictions; local public agencies responsible for transportation, land use, water provision, flood control, emergency management, etc.; and additional Federal agencies with expertise in these topic areas. The partners established goals and objectives, including: 1) advance climate analysis in scenario planning, 2) impact decision-making, 3) develop a transferrable process, and 4) build partnerships.

Regional Assessment and Data Collection

The project team analyzed climate change projections to estimate possible climate futures for the region (Figure 2) and the potential impacts on the local community. The team analyzed data about the region's population trends that affect how growth will be accommodated within the context of a changing climate.

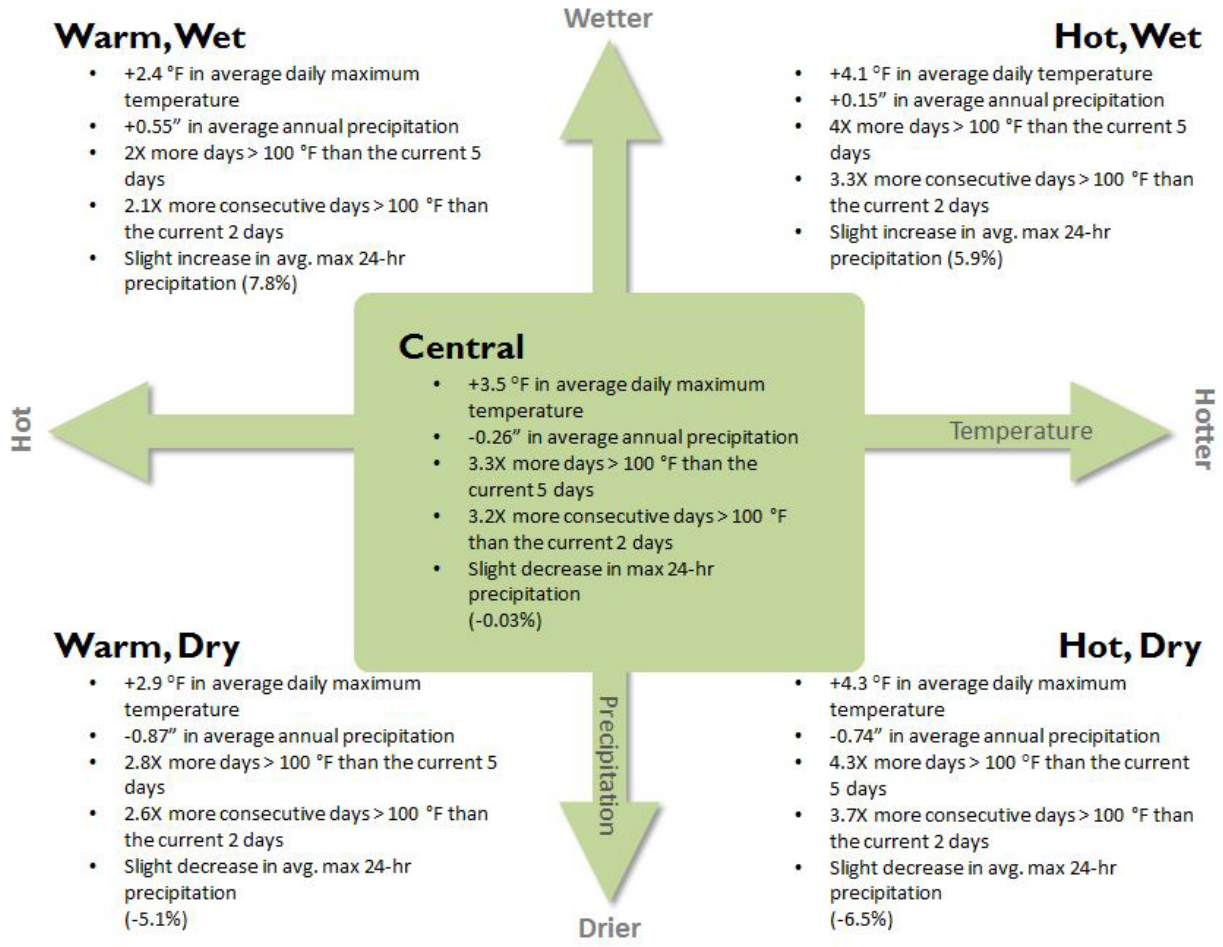

Figure 2: Central New Mexico 2040 Climate Futures. Source: Volpe Center.

Scenario Development and Assessment

MRCOG first developed conceptual scenarios that reflected regional priorities identified during public outreach. At the same time, the project team set up technical committees of local stakeholders to identify and discuss likely climate change impacts in the region and potential GHG emission reduction strategies that could be feasible in Central New Mexico. Local stakeholders including local transportation and land use planners and land management agency representatives considered these scenarios at two workshops. After considering the conceptual scenarios at the first workshop, MRCOG developed three scenarios based on stakeholder input, which were discussed at the second workshop. These were 1) Trend: currently planned zoning and 2035 transportation system; 2) Preferred: development incentives and zoning changes to increase high density development in identified activity centers, investments in bus rapid transit, and a 2040 transportation system that emphasizes maintenance of the existing transportation system; and 3) Constrained: same land use strategies as the Preferred but with fewer projects

due to lower than anticipated Federal funding levels.

Workshop participants evaluated the scenarios based on traditional transportation and land use performance measures as well as measures related to GHG emissions and climate change adaptation (water consumption and development in areas at risk for flooding and wildfire as well as in crucial habitat areas). The project team gauged the performance of the scenarios on these and other measures using a suite of methods. The team's primary method was to use MRCOG's travel demand and land use models.

MRCOG's 4-step travel demand model simulates the impact of changes to the transportation network. Alternative networks, such as the provision of new transit service, impacts mode split, travel times, and vehicle miles traveled. The project team used the EPA's MOVES model to calculate emission results based on outputs from the travel demand model. The team also evaluated several GHG emission reduction strategies using off-model methods and local data such as bicyclist surveys and traffic studies.

The land use model (UrbanSim) forecasts future land use patterns. By using travel conditions provided by the 4-step model along with various model inputs (including zoning and other land use policies) to evaluate markets for land, housing, and jobs, the model tries to simulate the urban development process. The model provides detailed forecasts of household and job location; these forecasts can then be linked back to the travel demand model, which in turn is used to evaluate travel conditions for a future time period. This approach contrasts with other scenario planning efforts that rely on workshop participants identifying specific areas for development. While the process used by the project team may lead to less dramatic differences between scenarios, it is better at recognizing and accounting for existing constraints within the market for land development.

Key Results and Findings

Workshop participants directed MRCOG staff to improve upon the Preferred Scenario as an alternative to the Trend Scenario. While MRCOG ultimately adopted the Trend Scenario because it reflected the pattern of development expected from existing local plans, it adopted the Preferred Scenario as the policy direction the region will work toward over the five-year life of the MTP.

The Preferred Scenario that emerged from this project performed better than the Trend and Constrained Scenarios on almost all measures of GHG emission reduction and resiliency to climate change impacts (Figure 3) as well as other, more traditional transportation performance measures. Aside from significant investments in the region's public transit system, most of the benefits from the Preferred Scenario came from land use policy changes that targeted development in several activity centers, improved development review processes, and increased density in the core urban area of the region. These policies resulted in reduced driving and a smaller developed footprint (Figure 4), which in turn reduced GHG emissions and development in risk areas.

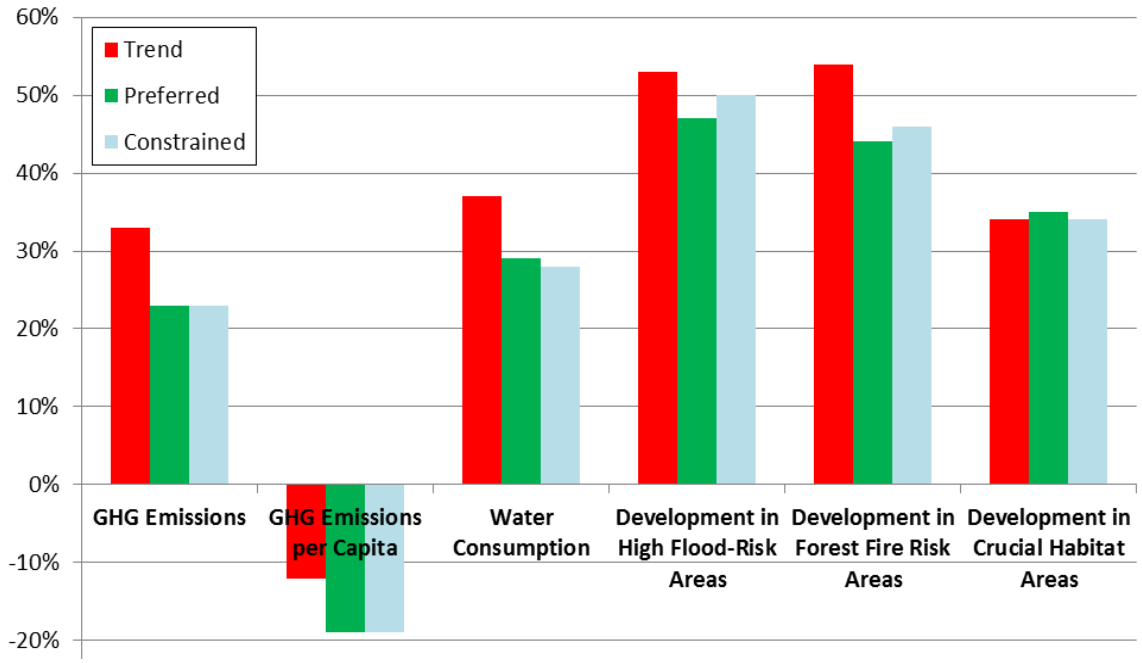

Figure 3: Percent Change by 2040 from 2014 for Each Scenario. Source: EMI and UNM

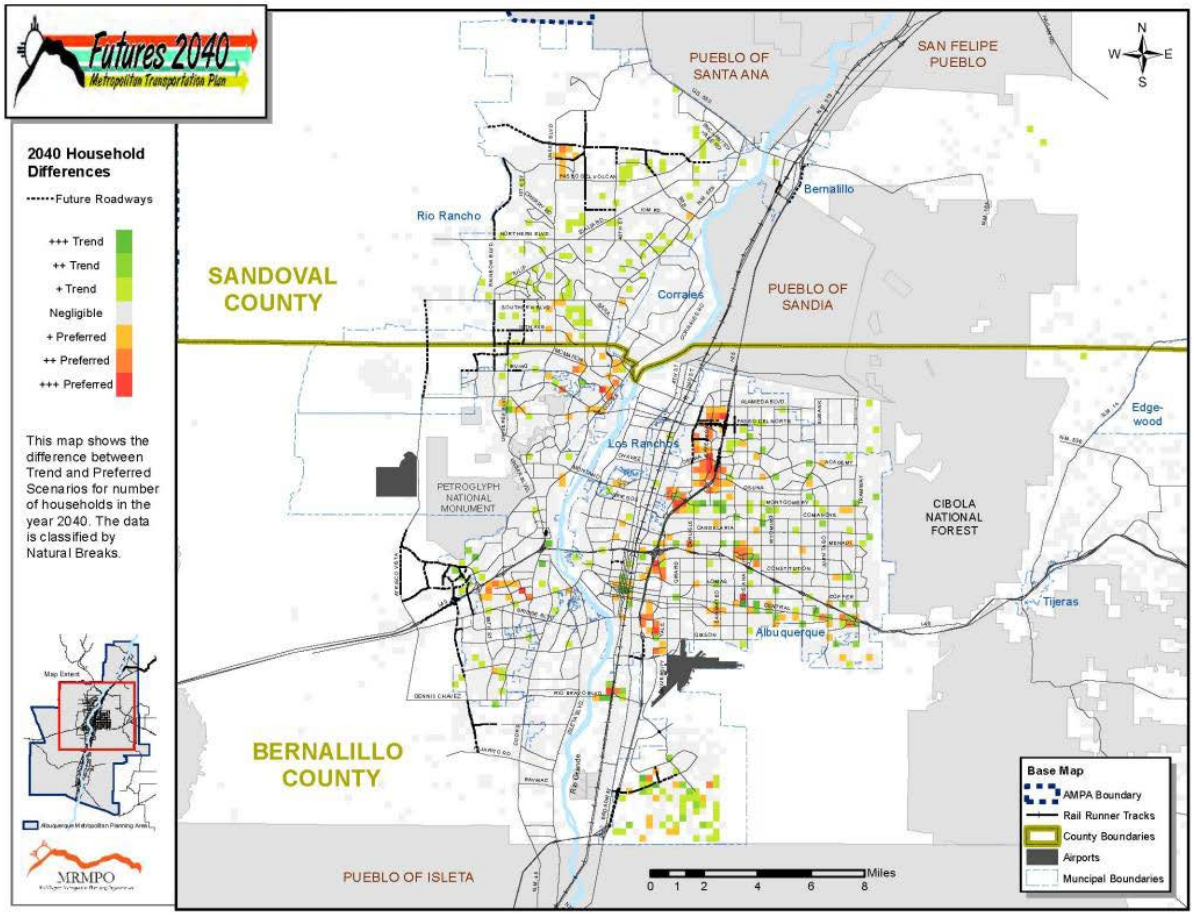

Figure 4: Differences in Numbers of Households in 2040 between the Trend and Preferred Scenarios

GHG emissions in all scenarios show a decrease per capita due to Federal fuel economy standards[1]. Reduced driving as a result of policies in the Preferred Scenario then lowers emissions below the Trend Scenario. In addition, the project's off-model analysis, which is not included in these figures, shows additional strategies that would create further GHG emission reductions below the Preferred Scenario (5.8 percent for VMT tax of $0.03 per mile, 3.8 percent for urban growth boundary, 0.4 percent for added bicycle infrastructure, and 0.2 percent for traffic signal enhancement). Many of the strategies that reduce GHG emissions also benefit other community goals such as reducing congestion and improving transportation choices.

The climate resilience measures indicate reduced growth in water consumption and reduced development in flood risk, wildfire risk, and crucial habitat areas as compared to the trend. These improvements are important as analysis shows water availability decreasing by one third as the climate warms, a six-fold increase in acreage burned in wildfires per 1.8 degree Fahrenheit increase in average temperature, and increased stresses on ecosystems and endangered species.

While the improvements in sustainability and resiliency may seem modest, they are significant given the difficulty of achieving absolute reductions in emissions with 50 percent population growth and incremental policies as well as considering that most existing development patterns are fixed. They are also in line with similar analyses conducted for other regions. Achieving more ambitious targets would require additional efforts.

Successful Approaches and Recommendations

- The project used some successful methodologies that other regions interested in pursuing a climate change scenario planning process can apply:

    a. Integrated land use and travel demand models. Use of a land use model produces better informed projections of future development than conventional scenario planning, which largely reflects community aspirations alone. Integrating a land use model with a travel model provides more policy sensitivity and a stronger analytical basis for evaluating scenarios.

    b. Off-model GHG emission analysis. This project layered on GHG emission reduction strategies not easily modeled in the travel demand model using local data such as bicyclist surveys and traffic studies.

    c. Wildfire analysis using modeled fire behavior parameters (rate of spread, flame length, crown fire potential) and ecological conditions to calculate fire risk allowed for a more in-depth analysis of wildfire risk.

    d. Analysis of the effect of different land use patterns on water consumption using data from the local water utility. This type of analysis is important for other areas facing drought and water availability decreases.

[1] The modeling for this project used fuel assumptions from Phase 1 of the light duty vehicle fuel economy standards. The second phase of these standards should result in further reductions in GHG emissions than are forecasted in this study.

e. Integration of climate analysis into the transportation plan. By integrating climate analysis into the MTP, MRCOG mainstreamed climate analysis into its transportation planning. Experience suggests that this is more efficient and effective in meeting climate change-related goals.

f. Leveraging of partnerships and existing studies. For instance, the US Bureau of Reclamation's *Upper Rio Grande Impact Assessment* and contact with the authors proved highly valuable in analyzing climate data and impacts.

- The project also developed recommendations for future climate change analysis and scenario planning efforts:

    a. Plan for climate change beyond traditional planning time frames. While the MTP horizon year is 2040, projects built under the plan, and the built environment created over this timeframe may have lifetimes extending well past 2100. Those projects will be influenced by larger climate change impacts projected for the end of the century and beyond.

    b. Conduct early exploratory analysis well before formal plans need to be developed. While the timing of the project coincided well with the development of the region's MTP, this meant MRCOG was hesitant to model changes in transportation investments that departed greatly from those already under discussion by member jurisdictions. Earlier analysis would have allowed for consideration of more differences in transportation investments and more transformational policies. This early analysis could then be coupled with refined analysis as the MTP is developed.

    c. Develop a complete picture of climate change impacts specific to the region before developing conceptual land use and transportation scenarios. Use both stakeholder knowledge (for example State DOT maintenance staff knowledge of roads that flood under current conditions) and analytical methods (for example geographic system overlays, analysis of climate data such as temperature and precipitation and secondary impacts such as flooding and wildfires), to identify key vulnerabilities and potential strategies that can be integrated into the scenarios.

Conclusions

The project successfully integrated climate change analysis into the region's scenario planning process, and this analysis was then incorporated into the 2040 MTP. The project allowed MRCOG to introduce the idea to stakeholders that some growth patterns are more sustainable and robust to climate change impacts than others. The project helped make connections between local and Federal agencies with diverse missions. It provided basic climate data for the Central New Mexico region that multiple sectors can now use.

This project demonstrated that it is feasible and useful to consider both resilience to climate change impacts and GHG mitigation within a single planning framework. The project's successes and limitations provide helpful lessons for any entity embarking on a planning effort that wishes to address climate change adaptation and/or mitigation.

1 Introduction

Metropolitan regions across the country are already feeling the effects of climate change in diverse ways and to varying degrees, as described in the **National Climate Assessment**.[2] To prepare for further climate change, a variety of transportation, land use, and natural resource investment strategies exist that regions can pursue to become more resilient while concurrently reducing their greenhouse gas (GHG) emissions. The Central New Mexico Interagency Transportation, Land Use, and Climate Change Scenario Planning Project (or Climate Change Scenario Planning Project [CCSP]) sought to use scenario planning to advance climate change analysis, impact decision-making, develop a transferrable process, and build partnerships throughout the region and across the country.

The CCSP was a joint project between the Federal Highway Administration (FHWA), the United States Department of Transportation (U.S. DOT) John A. Volpe Center National Transportation Systems Center (Volpe Center), and the Mid-Region Council of Governments (MRCOG), the region's metropolitan planning organization (MPO), with financial and project oversight provided by FHWA, the National Park Service (NPS), the United States Fish and Wildlife Service (USFWS), and the Bureau of Land Management (BLM). With FHWA oversight, the Volpe Center provided project management, managed project consultants, coordinated with partnering agencies, and provided technical assistance, while MRCOG led the effort for incorporating climate change adaptation and mitigation into its Metropolitan Transportation Plan (MTP) process.

1.1 Report Purpose and Audience

The purpose of this report is to document the processes, successes, and lessons learned during this project in order to provide other regions with a framework and recommendations on how to replicate or build upon this process in the future.

Federal, State, regional, and local agencies can use and adapt the methodology and lessons from this project to work collaboratively to reduce GHG emissions and assess, mitigate, and adapt to potential climate change effects at the scale of regional planning. General observations and recommendations are applicable to other areas, especially non-coastal areas, throughout the United States and elsewhere. This report is intended to serve as a resource for organizations interested in, or that stand to benefit from, incorporating climate change resilience and GHG emission reduction strategies into their own transportation and land use planning, particularly MPOs and regional planning organizations (RPOs), but also State departments of transportation (DOTs) or other State agencies, counties, and cities. Federal land management, transportation, natural resource, and emergency preparedness staff, as well as any Federal land-owning agency, may also be interested in understanding the described process and how it can be incorporated into and used to support local transportation, land use, and climate change mitigation and adaptation initiatives.

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[2] 2014 National Climate Assessment, U.S. Global Change Research Program. **http://nca2014.globalchange.gov/**

1.2 Project Background

Scenario planning is a methodology that involves stakeholders' consideration of a range of possible development alternatives under a range of possible futures. The CCSP is the second in a series of climate change scenario planning projects managed by the Volpe Center with FHWA, and builds from the experiences gained over the course of the first of this series, which took place in Cape Cod, Massachusetts, in 2011. The approach, results, and lessons learned from the Cape Cod project are detailed in the project report, **A Framework for Considering Climate Change in Transportation and Land Use Scenario Planning**, and are summarized below.

1.2.1 Cape Cod Climate Change Scenario Planning Project

In 2009, an interagency working group selected Cape Cod as a pilot region to facilitate and enhance integrated regional and intermodal gateway mobility planning at the State, regional, and local levels. The Volpe Center initiated the resulting Interagency Transportation, Land Use, and Climate Change Pilot Project (Pilot Project) in early 2010 along with FHWA, NPS, and FWS. These agencies viewed the Pilot Project as an opportunity to achieve transportation-based GHG reductions and adaptation to climate change and to pilot and evaluate scenario planning as a method for doing so.

The project evaluated opportunities for reducing GHG emissions and adapting to climate change's potential impacts on human infrastructure and natural systems. The Pilot Project used a scenario planning process as the method by which these climate change considerations would be tested in discussions of land use and transportation policy and planning.

The Pilot Project was issue-focused on climate change and multiple agency involvement. Rather than developing broad transportation and land use goals or determining strategies for goals that had already been established through a planning process, the project started with the goals of reducing GHG emissions and preparing for climate change impacts through agencies' and other stakeholders' transportation and land use decisions. The project used scenario planning as a method to engage and inform a broad group of stakeholders around climate change issues through an integrated planning approach.

This project did not immediately result in the development of a regional transportation plan, nor did it lead to decisions about development patterns at the neighborhood or parcel level or prescribe zoning or development types. Instead, participants worked at a regional level to indicate the desired locations for preservation, development, and improvements to transportation infrastructure and services based on GHG emissions and identified vulnerable areas due to projected impacts from climate change (Figure 5). The impact of these regional decisions was then evaluated by important indicators, or performance measures, such as VMT reduced and percentage of population in vulnerable areas.

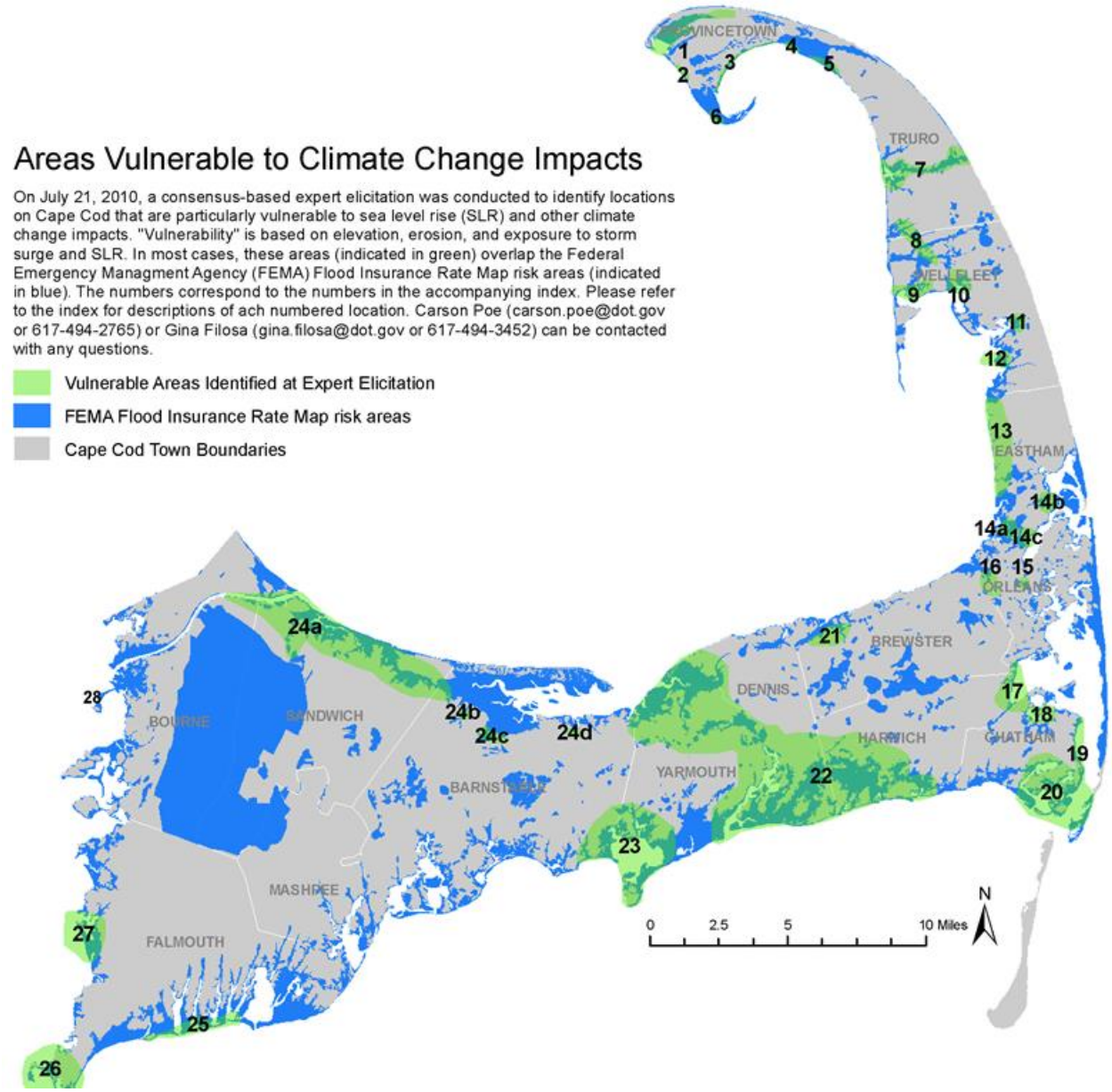

Figure 5: Vulnerable Areas Identified in the Cape Cod Scenario Planning Project. Source: Volpe Center.

This process allowed for the testing of relationships among transportation, land use development, GHG emissions, and climate change impacts and raised awareness about the implications of transportation and land use decisions on climate change issues. The outcomes of the scenario planning process helped inform future versions of Cape Cod's Regional Transportation Plan as well as other State, local, and Federal agency transportation and development plans for the region. However, the the project was conducted separate from those processes.

1.2.2 Selection of Central New Mexico

To build on the Cape Cod Scenario Planning Pilot Project experience, FHWA allocated funding for a second project to incorporate climate change into a long-range scenario planning process. Since FHWA's previous climate change planning efforts have concentrated in coastal areas, such

as Cape Cod, FHWA decided to focus the next phase of the pilot on an inland region of the country where climate change effects will be distinct from those on the coast.

The Cape Cod Pilot Project revealed some limitations of conducting scenario planning separate from an established planning process such as a long-range transportation plan (LRTP). A key project lesson was that such an effort would be much improved by cultivating local ownership of the scenario planning process and building local capacity for its implementation. As FHWA and the interagency partnership that directed the Cape Cod Pilot Project discussed the second phase of the pilot, they chose to partner with an agency that requested technical assistance in bringing climate change into its existing transportation and land use planning process.

In April 2013, FHWA released a solicitation for applications for Federal technical assistance to inland regional government entities. The awarded applicant would receive assistance to incorporate awareness of climate change effects and their possible impacts on transportation infrastructure and land use into a scenario planning exercise to inform its LRTP. The project would also explore potential strategies for adaptation to climate change and local mitigation of its primary cause, GHG emissions.

Submissions were evaluated based on the following criteria:

- Demonstrated interest and support;
- Potential benefit from technical assistance offered;
- Impact on decision-making (i.e., potential for the findings of the project to influence specific transportation, land use, hazard mitigation, and environmental decisions and planning documents);
- Availability of local match, staffing, resources, and data;
- Type and severity of issues faced by the study area;
- Willingness and plans to share findings and processes nationally; and
- Existing collaborative approaches and partnerships.

Located in Albuquerque, New Mexico, MRCOG was selected for the CCSP through this competitive solicitation process. MRCOG proposed incorporating climate change into a scenario planning process to inform the development of its 2040 MTP. MRCOG applied to be able to 1) assess the likely effects of climate change under a range of climate futures; 2) measure how resilient to these effects the region would be if it adopts different transportation and land use strategies; 3) mitigate the cause of climate change while pursuing other more common transportation and land use objectives to reduce congestion and delay; and 4) improve the economic performance of the region.

MRCOG had limited experience applying scenarios to its previous iterations of the MTP and had never before included climate change considerations into its planning processes. The primary reason for MRCOG's participation in this project was local desire for Albuquerque to become less car-focused and more transit-friendly, as well as concerns about water availability after a decade of prolonged severe drought. As described later in Chapter 2, the CCSP was largely structured around the needs of MRCOG in developing scenarios to inform the 2015 update to the MTP and relied heavily on the transportation and land use modeling activities of MRCOG and project consultants to evaluate scenarios.

1.3 Conceptual Framework: Climate Change Mitigation, Adaptation, and Resilience

The project team used a conceptual framework for considering several interrelated topics related to how regions can reduce the impacts of climate change and prepare for its effects. This framework is based on research from the Intergovernmental Panel on Climate Change (IPPC),[3,4] the 2014 National Climate Assessment (NCA),[5] and FHWA's technical guidance on incorporating climate change mitigation and adaptation into metropolitan area transportation planning.[6] The framework's concepts are defined below:

- *Mitigation*. Mitigation refers to activities to reduce the severity of future climate change by reducing GHG emissions. In transportation, climate change mitigation activities include a) increasing fuel efficiency, b) transitioning to alternative fuel or electric vehicles, c) increasing the efficiency of the transportation network so that vehicles emit the least emissions per mile traveled, d) reducing vehicle miles traveled (VMT) within a metropolitan area, or e) reducing emissions associated with building and maintaining transportation infrastructure.
- *Adaptation*. Adaptation refers to adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects. Adaptation may involve physical measures, such as designing or retrofitting infrastructure to function in different climate conditions, enhancing landscape connectivity to allow species to move in response to changing conditions, or societal measures, such as new operations or procedures for responding to extreme weather.
- *Resilience.* Resilience means the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.[7] In the context of metropolitan area climate change planning, resilience refers to the ability of the metropolitan area to adjust to changes in climate while minimizing stresses to the region's infrastructure, economy, residents, and ecosystems. Actions to increase an area's resilience can include infrastructure adaptation, land use and transportation planning to reduce asset and system vulnerability to extreme weather or other climate change impacts, and social resilience measures, such as communications and

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

[4] IPCC, 2007. *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**.

[5] 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/**.

[6] 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**.

[7] Executive Order–Preparing the United States for the Impacts of Climate Change. November 1, 2013. **https://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change**.

community coordination. Adaptation measures may include management and maintenance of infrastructure, increasing the redundancy in system networks, protection of key assets, accommodation of climate impacts through design, and relocation of assets.

- *Vulnerability*. Vulnerability is a key concept in climate change adaptation and risk analysis, particular for understanding the vulnerability of particular assets or systems. In this framework, vulnerability is a product of the following:
    - *Exposure*. What climate stressors may an asset be exposed to under future climate conditions?
    - *Sensitivity*. How sensitive is an asset to future climate stressors? If it is exposed to higher temperatures or flooding in the future, how would it be affected?
    - *Adaptive Capacity*. What is the ability of an asset or system to adapt to potential damage from a climate stressor? 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?

These concepts informed the CCSP in developing analyses of potential mitigation and adaptation strategies for the Albuquerque region and helped MRCOG evaluate the resilience of its land use and transportation scenarios in their MTP.

1.4 Scenario Planning

The conventional approach to planning often uses one set of assumptions about the future based on projections of historical trends. Scenario planning is a technique that allows organizations to anticipate and prepare for multiple potential future conditions that may diverge significantly from past trends. Scenarios are used as a tool to test policy decisions against externally uncontrollable and uncertain environmental, social, political, economic, or technical factors.

Military strategists and corporate strategic planners originally developed scenario planning to help mitigate the risks of unforeseen futures, such as identifying threats ranging from national security vulnerabilities to fluctuations in oil prices. The practice was later adapted and applied to the metropolitan transportation planning process to inform strategic visioning processes at the regional level and to help regional stakeholders become more aware of the factors that may influence growth and development trends.

There are two basic types of scenario planning: normative and exploratory.[8] Normative scenario planning is designed to reveal and hone in on the values and goals of a set of stakeholders. A range of scenarios is typically arrayed from least to most aggressive with respect to its effect on a given parameter or set of parameters and tested against a set of metrics. For example, MPOs traditionally employ this approach to evaluate how different transportation and land use decisions will affect congestion, air quality, affordable housing, etc.

[8] **http://opengov.newschallenge.org/open/open-government/inspiration/city-builders-wanted/gallery/2027_1352_opening-access-to-scenario-planning-tools.pdf/**

FHWA released a **Scenario Planning Guidebook**[9] in 2011. The purpose of this guidebook is to assist regional transportation agencies with carrying out a normative scenario planning process from start to finish. Transportation agencies can use the guidebook as a framework to develop a scenario planning approach tailored to their needs. The guidebook provides detailed information on the six key phases that agencies are likely to encounter when implementing a scenario planning process. For each phase, the guidebook provides considerations, steps, examples, and strategies to help guide agencies in managing and implementing a comprehensive scenario planning effort.

Exploratory scenario planning, on the other hand, deals more directly with uncertainty. Scenarios are typically based on interacting demographic, economic, or environmental changes beyond local control. For example, the NPS uses this approach to develop robust and contingent management decisions that anticipate impacts from climate change.[10] Park managers are challenged to move beyond paralysis over the uncertainty of, for example, sea level rise and precipitation and begin to develop plans for asset management and visitor access that are robust under multiple scenarios.

The NPS released a **guide**[11] for exploratory scenario planning to consider climate change. Developed under the NPS Climate Change Response Strategy, this guide is part of an interdisciplinary, cross-cutting approach to addressing climate change. The overall program supports NPS efforts to understand climate change in national parks and surrounding areas and to adapt to climate change impacts on natural and cultural resources, facilities and infrastructure, park operations, and the visitor experience.

The CCSP employed aspects of both types of scenario planning. MRCOG conducted a normative exercise in scenario planning by testing different land use and transportation strategies vis-à-vis several important performance measures. This normative scenario planning benefited from the exploratory analysis of the effects of a variety of climate futures that may impact the region.

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[9] **http://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/**

[10] **http://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf.**

[11] Ibid.

2 Project Definition

The Central New Mexico CCSP included a wide variety of local and Federal agency partners. This section describes the partnerships that enabled this project and the roles and responsibilities of each in carrying it out. It also gives an overview of the project's scope from project inception to its conclusion in late 2014.

2.1 Project Area

The Central New Mexico CCSP focused on the four-county region that comprises the MRCOG jurisdiction (Figure 6). This region includes Bernalillo County, Valencia County, and portions of Sandoval County and Santa Fe County. The center of the region is the city of Albuquerque. MRCOG's jurisdiction includes the Albuquerque urbanized area and the organization functions as the region's MPO, and is sometimes referred to as MRMPO. MRCOG's region had a total population in 2010 of 897,146 and a population growth rate of over 2 percent per year.

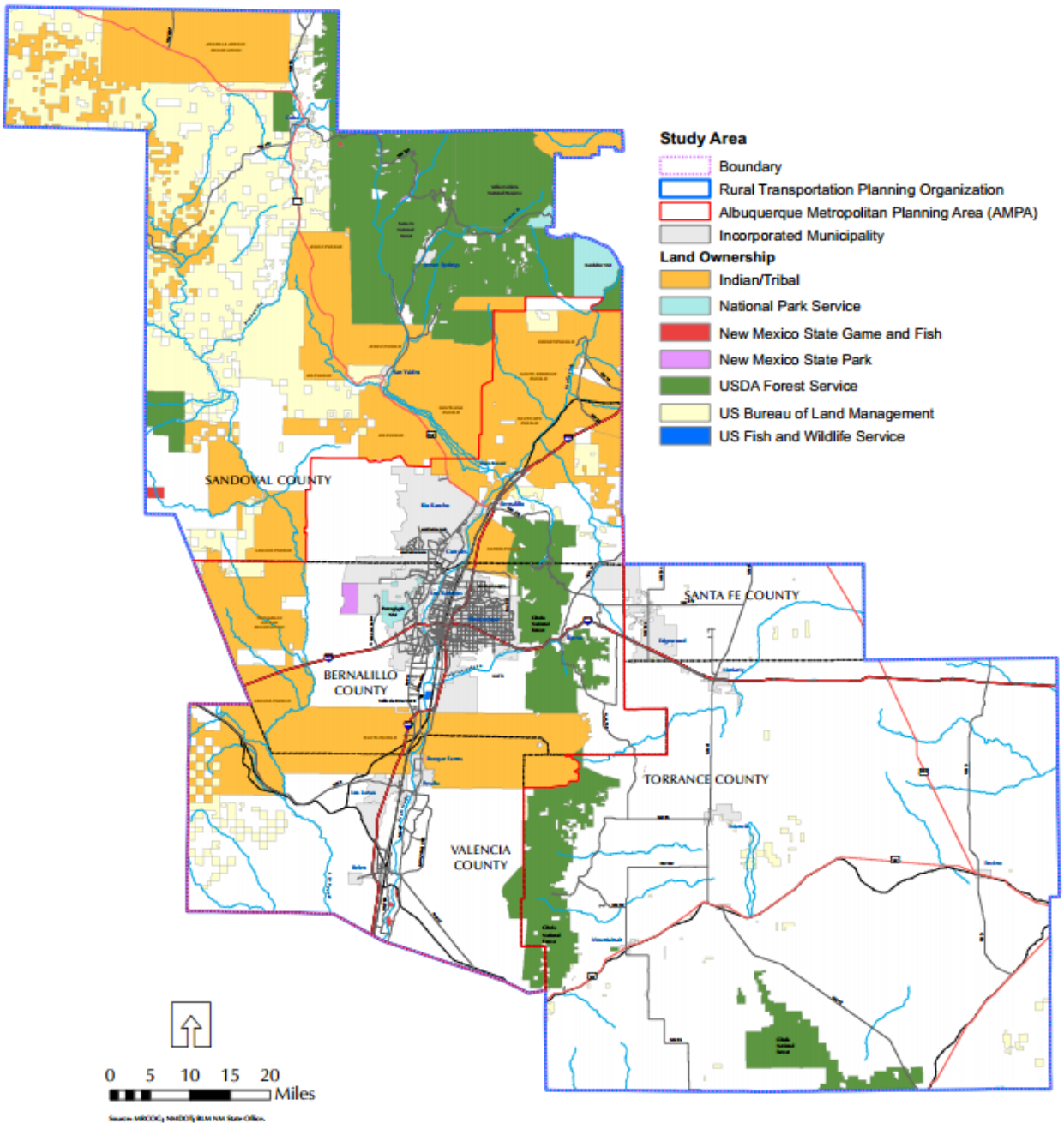

Figure 6: The CCSP Study Area. Source: MRCOG.

In addition to the urbanized areas for which MRCOG coordinates transportation planning, the area of study for the CCSP includes large swaths of land owned and operated by Federal land management agencies such as the BLM, NPS, FWS, and USFS. Other influential Federal agencies in the area include the United States Army Corps of Engineers (USACE) and the Bureau of Reclamation, which manages water resources throughout the arid Southwest.

2.2 Goals and Objectives

Volpe Center staff developed goals and objectives to guide the multiagency project team in its stewardship of the project and provided a framework for evaluating the successes and limitations of this effort. The project goals were developed by the Federal interagency working group that organized the scenario planning pilot project in Cape Cod, Massachusetts. The objectives were refined based on discussions with stakeholders and MRCOG staff during initial project development. Because the project will guide long-range planning, the goals and objectives are both specific to the project and long-term since planning processes take many years to implement.

Goal 1: Advance the role of climate change analysis in scenario planning.

This project will improve the state of the practice for integrating climate change adaptation and mitigation into regional transportation and land use planning using scenario planning processes.

- Objective 1a: Contribute to the state of the practice by identifying and testing new technical approaches to model and analyze climate change effects and impacts and GHG-emissions reduction strategies in a transportation and land use scenario planning process.
- Objective 1b: Apply novel approaches to scenario development that account for a range of uncertainty given locally controllable policy options and externally uncontrollable forces.

Goal 2: Influence decision-making in Central New Mexico.

This project will inform MRCOG's 2040 MTP, municipal hazard mitigation plans, local and county land use and transportation plans, and Federal land management agency plans.

- Objective 2a: As part of the scenario planning process, challenge existing assumptions and help participants identify difficult trade-offs.
- Objective 2b: Tailor climate change adaptation and mitigation analysis to the local context, making products relevant to a range of stakeholders.
- Objective 2c: Identify ways in which local decision-makers can prepare for a range of futures and build flexibility into land use and transportation plans and policies to best address uncertainties.
- Objective 2d: Incorporate GHG-emissions reduction strategies and targets into regional planning efforts.
- Objective 2e: Incorporate climate change futures, and an evaluation of the impact of these futures on proposed land use and transportation strategies, into regional planning efforts.

Goal 3: Develop a transferable process.

The process and analytical methods developed for this project will be transferable to other regions.

- Objective 3a: Generalize and disseminate project information and lessons learned.
- Objective 3b: Develop an analytical and process framework that ties into other existing frameworks that can be relevant and practical to other regions.
- Objective 3c: Foster relationships between Federal agencies that can contribute to other regional and local projects.

Goal 4: Build partnerships.

The project will build and strengthen relationships between Federal, State, regional, municipal, and tribal governments.

- Objective 4a: Develop and strengthen relationships between (and among) Federal, State, regional, and local agencies throughout the process.
- Objective 4b: Create a structure by which local and Federal agencies involved in the climate change scenario planning process can continue to collaborate beyond the end of the project.

This project report concludes with an evaluation of the project against these goals and objectives with recommendations for other organizations that wish to engage in a similar effort. Other organizations may incorporate climate change into metropolitan transportation planning and/or engage Federal land management agencies in making preparations for policy actions related to climate change mitigation or adaptation.

2.3 Study Partners

MRCOG partnered with three Federal transportation agencies (FHWA, Volpe Center, and the Federal Transit Administration [FTA]), four Federal land management agencies (BLM, NPS, USFWS, USFS), and a variety of other Federal agencies and partners (Bureau of Reclamation, Department of Homeland Security [DHS], Environmental Protection Agency [EPA], Federal Emergency Management Agency [FEMA], Sandia National Laboratories, USACE, National Oceanographic and Atmospheric Administration [NOAA], and the U.S. Geological Survey [USGS]) to carry out the project. Below is a description of the responsibilities of the project partners, their roles in the project, and the resources they provided.

2.3.1 The Mid-Region Council of Governments

MRCOG is an association of governments in Central New Mexico. MRCOG is the MPO for the Albuquerque metropolitan area and is responsible for developing the region's MTP and four-year transportation improvement program (TIP). MRCOG's member governments include:

- Sandoval County
- Village of Los Ranchos de Albuquerque
- City of Albuquerque (Administration)
- City of Albuquerque (City Council)
- Albuquerque Metropolitan Arroyo Flood Control Authority
- Albuquerque Public Schools
- City of Belen
- Town of Bernalillo
- Bernalillo County
- Village of Bosque Farms
- Village of Corrales
- Village of Cuba
- Town of Edgewood
- Village of Encino
- Town of Estancia
- Village of Jemez Springs
- Pueblo of Laguna
- Village of Los Lunas
- Los Lunas Public Schools
- Middle Rio Grande Conservancy District
- City of Moriarty
- Town of Mountainair
- Town of Peralta
- City of Rio Rancho
- Rio Rancho Public Schools
- Southern Sandoval County Arroyo Flood Control
- Village of Tijeras
- Torrance County
- University of New Mexico
- Valencia County
- Village of Willard

As the MPO that received the Federal assistance grant to conduct the CCSP, MRCOG led the development of the scenario planning process for the region as it prepared its update to the MTP. In this way, it was the primary project partner for the Central New Mexico Climate Change Scenario Planning Project.

2.3.2 The Volpe Center

The Volpe Center served as the coordinator, facilitator, and manager of the tasks and partnerships that comprised the CCSP. The Volpe Center also developed technical tools and provided analysis that informed several components of the project. The Volpe Center is a fee-for-service research agency under the U.S. DOT's Office of the Assistant Secretary for Research and Technology.

2.3.3 The Federal Highway Administration

The FHWA was the primary sponsor for the CCSP and oversaw all stages of its development related to the scenario planning and climate change work. FHWA is committed to improving transportation mobility and safety while protecting the environment, reducing GHG emissions, and preparing for climate change effects on the transportation system. FHWA is actively involved in efforts to initiate, collect, and disseminate climate change-related research and to provide technical assistance to stakeholders. In addition to this project, FHWA sponsors several **climate resilience pilot projects**[12] and **GHG mitigation assistance projects**.[13]

2.3.4 Federal Land Management Agencies

NPS, FWS, and BLM each provided funding for this project and were active participants.

2.3.4.1 National Park Service

The NPS provided funding to develop the climate futures used to integrate climate change considerations into regional transportation and land use scenario planning. NPS staff collaborated with Volpe Center and Bureau of Reclamation staff to develop analytical tools and review the research methodology used to develop the climate futures. This work complements NPS's work in responding to climate change, including development of a handbook, ***Using Scenarios to Explore Climate Change***.

2.3.4.2 U.S. Fish and Wildlife Service

The FWS supported the climate futures development through its involvement in the regional transportation planning process. The FWS dedicated Valle de Oro National Wildlife Refuge in 2012, the Southwest's first urban refuge, 7 miles south of downtown Albuquerque. Refuge staff have worked closely with local governments in the region to acquire land for the refuge, design natural drainage features to contribute to local flood management, and develop transportation options to make the refuge accessible to area residents. As a local stakeholder, FWS participated in MTP workshops and CCSP project development. The FWS also worked with the Volpe Center to produce two case studies as part of the CCSP to provide information to other

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[12] **http://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/vulnerability_assessment_pilots/index.cfm**
[13] **http://www.fhwa.dot.gov/environment/climate_change/mitigation/**

refuges and the general public on how refuges can develop regional partnerships and contribute to a region's climate change preparedness.[14,15]

2.3.4.3 Bureau of Land Management

The BLM also supported the climate futures development and participated in the MTP planning process. The BLM's **Rio Puerco Field Office**, which manages land in the northwestern part of the CCSP project area, was also in the process of developing a Travel and Transportation Management Plan (TTMP), for which BLM staff collaborated with MRCOG. The Volpe Center is applying the climate futures analysis to the Rio Puerco to inform its TTMP.

2.3.5 Other Participating Entities

Regional and headquarter representatives from a number of other Federal agencies and research centers, including NOAA, DHS, EPA, FEMA, FTA, Sandia National Laboratories, USACE, Bureau of Reclamation, and USGS, participated in the Federal Interagency Planning Group for the pilot project; shared resources and data; provided technical support; and participated in Planning Group and Technical Committee meetings for the CCSP. For example, Bureau of Reclamation, Sandia National Laboratory, and USACE's prior research,[16] data aggregation, and technical support were critical to the project's understanding of climate change impacts in the region and the development of the climate futures tool discussed later in this report. See Appendix C for more details on what each agency is doing related to adaptation and mitigation both nationally and in the southwest region of the U.S.

2.3.5.1 Climate Assessment for the Southwest

NOAA asked the Climate Assessment for the Southwest (CLIMAS) to assist the project by conducting an analysis of the Central New Mexico region's climate futures. CLIMAS, a University of Arizona-based climate research center, is part of NOAA's Regional Integrated Sciences and Assessments (RISA) program. CLIMAS's work for the Project was greatly informed by the Upper Rio Grande Impact Assessment by the Bureau of Reclamation. CLIMAS developed a report to guide the climate futures analysis for the project.[17]

2.3.5.2 Consultant Services

To obtain expertise on integrating climate change impacts and GHG emission reduction strategies into a scenario planning methodology using MRCOG's transportation and land use modeling tools, the Planning Group developed a Request for Qualifications (RFQ), which the Volpe Center used to procure a scenario planning consultant. The Volpe Center contracted with Ecosystem Management Incorporated of Albuquerque, New Mexico and the University of New

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

[15] USFWS, 2014, *Preparing for a Changing Climate: Valle de Oro National Wildlife Refuge*, **http://www.volpe.dot.gov/sites/volpe.dot.gov/files/docs/ClimateChange_CS_09052014_FINAL.pdf**

[16] Bureau of Reclamation, 2013, *Upper Rio Grande Impact Assessment,* **http://www.climas.arizona.edu/research/central-new-mexico-climate-change-scenario-planning**

[17] CLIMAS, 2014, Potential Changes in Future Regional Climate and Related Impacts: A Brief Report for the Central New Mexico Climate Change Scenario Planning Project, **http://www.climas.arizona.edu/research/central-new-mexico-climate-change-scenario-planning**

Mexico's Laboratory for Transportation Systems Analysis and Sustainability. The consultant team developed:

- An analysis of climate change impacts on the region's land use and transportation system and key natural resources.
- An analysis of the impact of land use and transportation decisions on climate change resiliency.
- Climate change adaptation and mitigation integration methodologies and scenario evaluation criteria.
- Regional GHG emission reduction strategies.
- Documentation of the scenarios and evaluation criteria.
- Interim and final reports discussing scenario development and analyzing their resiliency to climate change impacts. These final reports are available on the Central New Mexico Climate Change Scenario Planning **project website**.[18]

2.4 Overview of Project Scope

The study partners conducted work on the Central New Mexico CCSP between summer 2013 and December 2014. The sequence of the project is described below.

2.4.1 Planning Group Development and Stakeholder Coordination

Once Central New Mexico was selected as the project area, the Volpe Center formed a Planning Group to guide the project throughout its development. The Planning Group was composed of a diverse group of local stakeholders including MRCOG, key local government agency representatives, and several Federal Land Management Agencies(FLMAs) and Federal resource agencies mentioned earlier (refer to Appendix E). MRCOG also formally welcomed the participation of tribal governments located in the study region. Though some members were involved in MRCOG committees that informed the work of the project, tribal governments did not participate directly in the project. The Planning Group met monthly to provide input on the project and to serve as a technical resource for questions that arose. The Planning Group also identified stakeholders to take part in two technical committees, which are described below.

2.4.2 Regional Assessment

The first step of the project work was to conduct an assessment of relevant completed work and studies in the Central New Mexico region as well as on the subject of climate change adaptation and mitigation in transportation and land use planning. The regional assessment (Appendix B) provided project partners with a baseline understanding from which to engage in climate change scenario planning in Central New Mexico.

2.4.3 Goals and Objectives

Based on input from the Planning Group, FHWA, and MRCOG, the study's project team developed goals and objectives to guide the project and provide a baseline from which to evaluate its success and limitations. The final chapter of this project report discusses this evaluation.

2.4.4 Scenario Development and Analysis

Informed by the research contained within the regional assessment, the Volpe Center was charged with guiding the development and evaluation of possible GHG emission reduction

[18] **www.volpe.dot.gov/NMScenarioPlanning**

strategies as well as future climate change impacts in the region. Volpe Center staff worked with MRCOG to gather two technical committees to provide expert knowledge on the mitigation of GHG emissions and on climate futures and climate change adaptation.

The **Mitigation Technical Committee** was composed of local stakeholders and Federal and local resource agencies. This committee provided knowledge of the local transportation planning and policy environment and the efficacy and appropriateness of GHG emission reduction strategies for the region. The Volpe Center synthesized possible land use and transportation strategies that could be undertaken in the region and refined them into a report based on feedback from the Mitigation Technical Committee (Appendix F).

The **Adaptation Technical Committee** was also composed of local stakeholders and agencies such as flood control authorities, the Bureau of Reclamation, and the Department of Energy. It provided expert feedback and technical resources for the climate futures analysis and expected impacts from climate change effects. For this task, the Volpe Center worked with CLIMAS and benefited extensively from Bureau of Reclamation's ***Upper Rio Grande Impact Assessment***[19] report in identifying regional climate change impacts. The Volpe Center also gained insights into the analysis of likely climate futures and their effects on precipitation and temperature in the region. The project team then developed a new tool for estimating possible precipitation and temperature-based climate futures for the local area based on 112 model runs of downscaled bias-corrected daily timestep Coupled Model Intercomparison Project Phase 3 (CMIP3) climate projections provided to the Volpe Center by the Bureau of Reclamation. The CMIP provides the most robust climate modeling through participating climate scientists worldwide. The methodology for this tool is described later in this guide.

Early on in this project, and as part of the development of the MTP, MRCOG conducted several months of public outreach activities early in the project, including focus groups and public meetings to develop conceptual scenarios for future land use in the region. The scenario planning consultant, with input from the Volpe Center and Planning Group, developed methodologies to evaluate and predict how these land use scenarios would influence future GHG emissions and compared how resilient the region would be to potential climate change impacts under each scenario.

MRCOG held one workshop on July 10, 2014 to present these scenarios to a group of regional stakeholders. The workshop participants considered the climate change factors along with other regional issues and selected a preferred land use scenario. After this workshop, the project team refined the preferred land use scenario based on comments from workshop attendees, coupled with additional transportation strategies, and subjected to the same analysis as the conceptual scenarios. MRCOG presented this new scenario and compared it to the land use and transportation trend for the region. This information was used to inform discussion in a second workshop on August 27 where participants provided feedback and discussed possible strategies for climate change mitigation and adaptation.

Upon completion of the scenario planning workshops, MRCOG refined its land use and transportation model runs with assistance from the scenario planning consultants and developed a final Preferred Scenario for recommendation as a guide for the region.

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[19] **http://www.usbr.gov/WaterSMART/wcra/reports/urgia.html**

2.4.5 Identification of Next Steps

MRCOG then identified several policy strategies related to climate change mitigation and adaptation that it needed assistance implementing. These strategies included:

- Transportation asset vulnerability data collection plan
- Mitigation of GHG emissions from electricity generation
- Incentivizing transit-oriented activity centers
- Regional support for travel demand management
- Open space preservation programs and policies
- Green infrastructure investments

In response, the Volpe Center completed an integration plan that identified possible strategies for implementing these policy recommendations with identified roles and responsibilities for MRCOG and its partners in the region (see **www.volpe.dot.gov/NMScenarioPlanning**).

2.4.6 Coordination with MRCOG's 2040 Metropolitan Transportation Plan

The FHWA and the interagency working group designed the CCSP project to be closely aligned with an ongoing metropolitan LRTP process. MRCOG conducted a scenario planning process to inform its MTP, which is due for adoption in 2015. The MTP is a requirement of MPOs to conduct an LRTP every 5 years. These plans are multimodal and guide the use of Federal transportation funds in the region.

MRCOG sought the assistance of the Federal partnership to conduct the CCSP project as a way to generate local awareness and knowledge of possible climate change impacts to the region. MRCOG was also interested in exploring strategies the region could employ to reduce its contribution to GHG emissions. MRCOG structured the climate change work to be wholly integrated with the development of the MTP. However, MRCOG's MTP must adopt a land use future that aligns with the cities' and counties' current land use plans. MRCOG therefore treats the Preferred Scenario that resulted from this work as more of an aspirational guide in the MTP than as the future 2040 transportation network and land use prediction.

Many of the GHG emission reduction and climate change adaptation strategies that emerged from the project are included in the MTP. Additionally, the integration plan describes a few implementation strategies that MRCOG and its partners can initiate to align land use policies and transportation projects with its Preferred Scenario. As has been done successfully in other regions in the country, MRCOG plans on working with its member jurisdictions over the next 5 years to align their land use plans with the Preferred Scenario so that it ultimately guides growth in the region.

3 Regional Climate Change Assessment and Planning for Growth

The Central New Mexico CCSP project contextualized regional land use and transportation planning within a framework of uncertain climate futures and population and employment growth. This section of the project report first describes the method used to estimate possible climate futures for the region and the potential impacts of those futures on the local community. This description is followed by a discussion of the region's population, transportation, and land use trends that affect how growth will be accommodated in an uncertain climate future.

3.1 Climate Change Impacts for Central New Mexico

The CCSP project benefited from a significant amount of previous research that developed global climate models (called General Circulation Models or GCMs) and applied those models to conditions in the Southwestern United States. This research included work conducted by CLIMAS as well as the Bureau of Reclamation, USACE, and Sandia National Laboratories. The Volpe Center built upon this work by developing and applying a modeling tool to analyze and automate downscaled climate futures for the Central New Mexico region for MRCOG's MTP planning horizon of 2040 based on downscaled, daily-timestep projections for the region provided by the Bureau of Reclamation. The research context and the Volpe Center's methodology and climate futures results for the region are presented here.

3.1.1 Global Climate Models and Sources of Uncertainty

Most climate change projections of potential temperature and precipitation changes over the next century have been made by analyzing the outputs of GCMs run through a range of GHG emissions scenarios. These models generally agree on the direction of future global change, but the projected size of those changes cannot be precisely predicted. This range of uncertainty is due to three primary sources:[20]

1. **Natural variability**: Natural, year-to-year variability in climate conditions produces a modest level of uncertainty about climate change projections for a particular time period. Natural variability has a greater impact on uncertainty at the local or regional scale than at a global scale. Over a multi-decadal time scale, the effect of natural variability on projection uncertainty is less compared to a smaller timeframe.
2. **Emissions uncertainty**: Future GHG emissions rates may follow many possible trajectories, based on global economies, technologies, and policies. Climate projections rely on assumptions about future GHG emissions, which may be higher or lower than the actual emissions path that the world will experience over the next century. The Intergovernmental Panel on Climate Change (IPCC) has developed a range of alternative future emissions scenarios (termed A2, B1, etc. in their 2001 report and RCP2.6, RCP4.5, etc. in their 2014 report) to estimate future climate change projections under each scenario. These scenarios do not have probabilities assigned to them. Advances in climate science will not reduce the uncertainties associated with emissions paths. Over

[20] Cubasch, et. al., 2013: Introduction. In: 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.

longer timescales, emissions uncertainty becomes the predominant source of uncertainty in climate projections.

3. **Climate response uncertainty (or model uncertainty)**: GCMs estimate how the global climate will respond to changes in GHG emissions over time. A few dozen GCMs have been developed by scientists around the world, which vary in how they model climate responses based on the approximations they make in modeling complex global processes and feedbacks.

Figure 7 illustrates the relative importance of these three sources of uncertainty over different timescales.

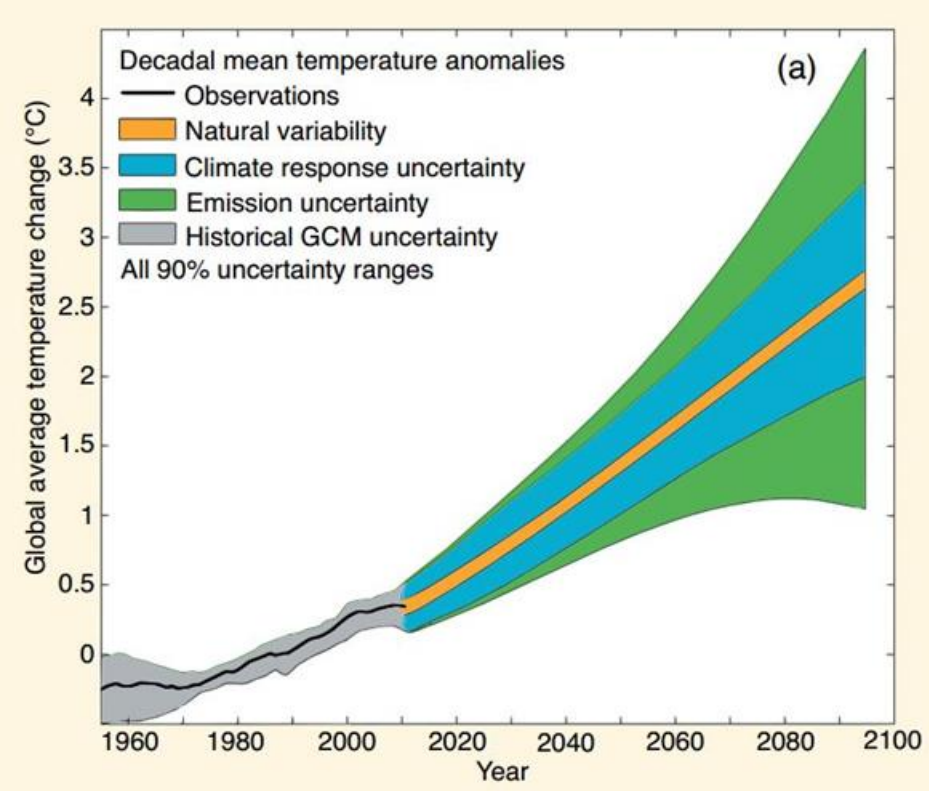

Figure 7: Schematic Diagram Showing the Relative Importance of Different Uncertainties and their Evolution in Time. Source: IPCC Fifth Assessment, Cubasch, et. al.

3.1.2 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, and New Mexico). For the Southwest region, the Third National Climate Assessment projected that regional average temperatures will rise 2.5°F to 5.5°F by the time period of 2041-2070, and 5.5°F to 9.5°F by the time period of 2070-2099, if GHG emissions continue to grow (A2 emissions scenario). If the world is able to reduce global GHG emissions substantially from what they are today (B1 scenario), then the region would see a projected 2.5°F to 4.5°F increase by the time period of 2041-2070 and a 3.5°F to 5.5°F

increase by the time period of 2070-2099. In both cases, summertime heat waves are expected to be longer and hotter, and wintertime cold weather is expected to decrease.[21]

CLIMAS prepared a report for the CCSP summarizing current research on potential climate change in the Southwest.[22] 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 the time period of 2021-2050, 1.8°F to 6.0°F for the time period of 2041-2070, and 2.7°F to 10.1°F for the time period of 2070-2099. This shift in annual mean temperatures is expected to impact extreme temperatures, leading to fewer cold spells and hotter, longer, and more frequent heat waves.

Figure 8: Settlement along the Rio Grande River in Albuquerque, NM. Source: FHWA.

The Bureau of Reclamation, USACE, and Sandia National Laboratories' *Upper Rio Grande Impact Assessment* analyzes the potential hydrological impacts of climate change on the Upper Rio Grande Basin and includes a literature review of observed and projected climate changes in the Upper Rio Grande area of New Mexico (Figure 9 in light grey).[23] This report provides more locally downscaled projections than the Third National Climate Assessment or CLIMAS, so the findings are more directly applicable to Central New Mexico. According to this report, mean annual temperatures in the Upper Rio Grande Basin are projected to rise by 5.4°F to 9°F by

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[21] 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.

[22] Climate Assessment for the Southwest (CLIMAS), 2014, Potential Changes in Future Regional Climate and Related Impacts–A Brief Report for the Central New Mexico Climate Change Scenario Planning Project, prepared for the Central New Mexico Climate Change Scenario Project.

[23] Llewelyn, et. al., 2013, Appendix B: Literature Review of Observed and Projected Climate Changes, *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**.

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.

Figure 9: Upper Rio Grande Basin. Source: New Mexico State University.[24]

3.1.3 Projected Precipitation Changes

The Third National Climate Assessment for the U.S. Southwest states that projections of precipitation changes are less certain and vary throughout the region. 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 the Southwest region, projections for precipitation changes are uncertain. The Third National Climate Assessment also states; however, that

[24] **http://aces.nmsu.edu/pubs/research/economics/TR45/images/Figure1.jpg**

droughts will be hotter and more intense in this region. Precipitation in higher elevations also is projected to fall less as snow and more as rain.[25]

CLIMAS reports similar projections, noting that the southern part of the Southwest may see precipitation decreases, while the northern area may see little or no change in precipitation relative to historical variation. According to CLIMAS, the region's total annual precipitation may change between -10 and +7 percent during 2021-2050, -17 and 7 percent during 2041-2070, and -20 and +10 percent during 2070-2099, relative to a 1971-1999 baseline.[26] CLIMAS does not have high confidence in projections of flooding due to heavy precipitation, but notes that even in a lower precipitation future, heavy storm events may still occur since a warmer atmosphere can hold more water vapor. The reason for inconsistent projections is the difficulty of projecting the main drivers of heavy precipitation in the region – The El Niño-Southern Oscillation and the North American Monsoon.[27]

The *Upper Rio Grande Impact Assessment* 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, the region will receive less precipitation, while southward movement of this boundary will result in more precipitation for the region. 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 existence of ocean-driven anomalies such as El Niño, La Niña, and the North American Monsoon. Overall, this report states that models project precipitation in the Upper Rio Grande will remain unchanged or will decline slightly over the 21st century, and projects a maximum reduction of approximately 13 percent, which is slightly less than the CLIMAS projection. However, the report projects that native supplies to the Rio Grande River will decrease on average by one third by the end of this century, and supplies to the San Juan Chama Project, which transfers some water from the Colorado River basin to the Rio Grande, will decrease by one quarter. These declines in the flow of water in the basin are due to higher evaporation and water use by plants associated with higher temperatures. This report projects that the frequency of extreme precipitation events is likely to be unchanged, although precipitation may become more concentrated in larger precipitation events followed by long periods of dry conditions. The report does not quantify the risk or magnitude of potential extreme precipitation events. Even if average precipitation does not decrease substantially, the assessment predicts decreases in overall water availability due to the higher temperatures.[28]

3.2 CCSP Climate Futures

The CCSP project team built upon these 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 and quantified scenarios of potential future climate conditions. Accordingly, the CCSP team developed "climate futures" for the plan year 2040, which are plausible scenarios based on global climate models that provide a quantitative basis to plan for the range of potential

[25] 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.
[26] CLIMAS, 2014.
[27] CLIMAS, 2014. 12-13.
[28] Llewelyn, et. al., 2013. 118.

changes in future climate in Central New Mexico. These climate futures are not forecasts but rather are alternative model-based visions of how the climate may change in the study area.

3.2.1 CCSP Climate Futures Methodology

In accordance with the NPS Climate Change Response Program guidance for scenario-based planning,[29] the project team began its work by following the first three steps of a five-step process to develop the climate futures (Figure 10).[30]

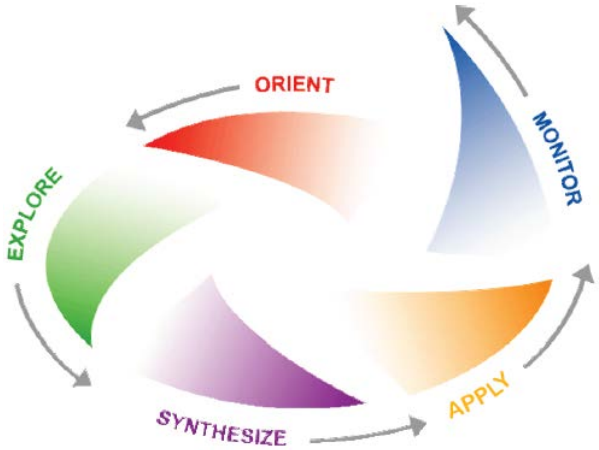

Figure 10: The Five-Step NPS Scenario Planning Process Developed by Global Business Network.

- Step 1 (Orient): Stakeholders, including Federal and regional agencies, assembled a Planning Group and two Technical Committees to identify the strategic climate-related challenges of the Central New Mexico region to be explored using scenarios.
- Step 2 (Explore): Taking an "outside-in" approach, the project team, MRCOG, the Committees, and partners determined the external forces/climate variables that would have the most impact on the region, namely high temperatures and precipitation extremes.
- Step 3 (Synthesis): The project team determined the endpoints for critical uncertainties related to temperature and precipitation, defining a continuum of possibilities for these climate variables through the year 2040, consistent with the MRCOG planning horizon. Based on this work, the project team then built plausible, relevant, and divergent climate scenarios, referred to as Climate Futures.

The project team developed a Climate Futures Exploration and Synthesis Tool (CFEST) to build on the qualitative NPS framework. This tool enables downscaled climate projections to be quantitatively produced in any future time period through the year 2099 and in any location within the study area, and anywhere in the western United States. Figure 11 summarizes the results of this tool for the southeast area of the city of Albuquerque.

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[29]Using Scenarios to Explore Climate Change: A Handbook for Practitioners (July 2013) http://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf Developed under the National Park Service Climate Change Response Program, this guide is part of an interdisciplinary, cross-cutting approach to addressing climate change.

[30]Using Scenarios to Explore Climate Change: A Handbook for Practitioners (July 2013) http://www.nps.gov/subjects/climatechange/upload/CCScenariosHandbookJuly2013.pdf

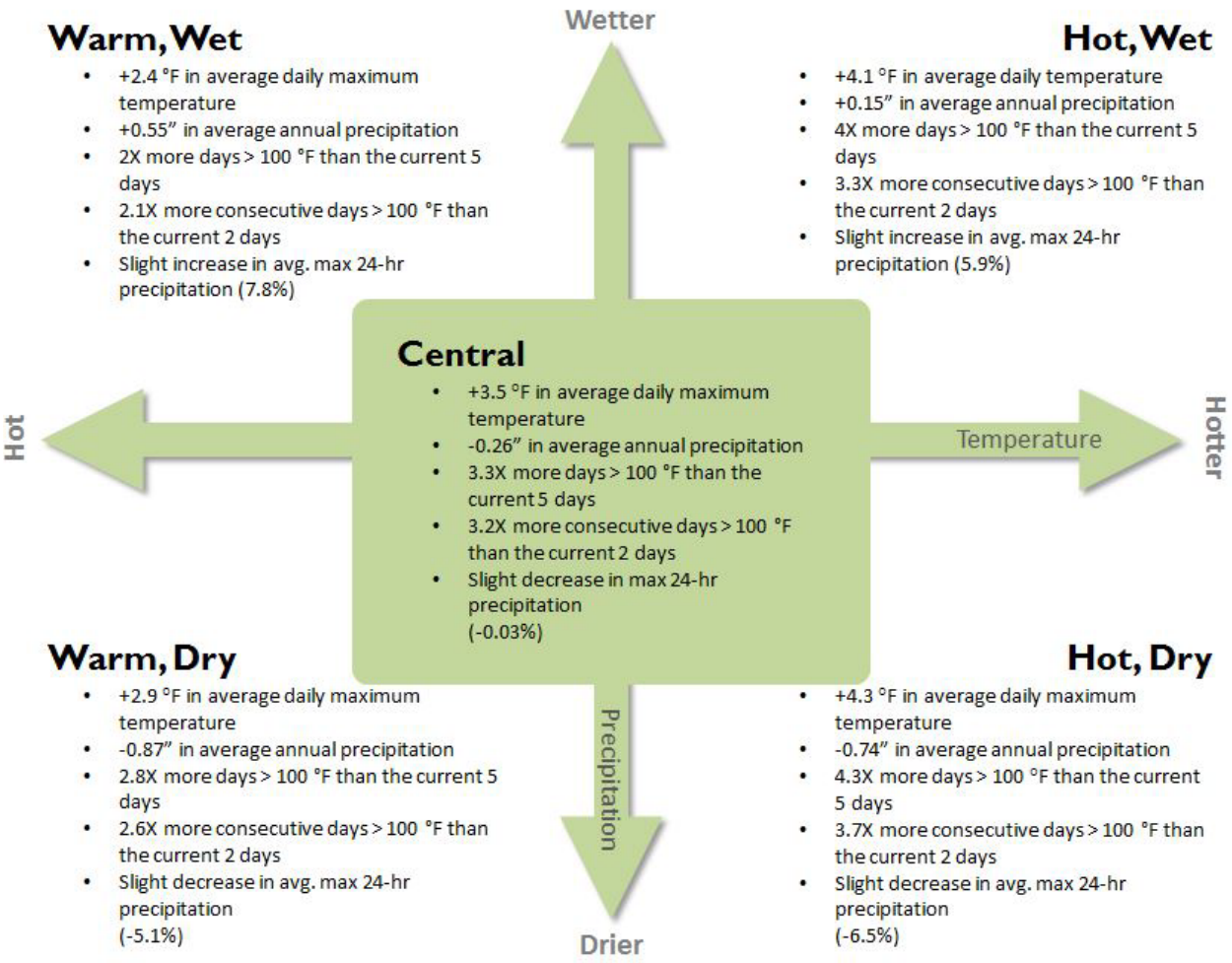

Figure 11: Summary of Climate Change Futures for the Year 2040 for Central New Mexico. Source: Volpe Center.

The CCSP Climate Futures are based on IPCC's CMIP Phase 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.[31] The dataset contains a total of 112 GCM runs, consisting of 9 different climate models and 3 emissions scenarios: A1B (high/current path), A2 (medium), B1 (low). The project team calculated model outputs for the following time periods:

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

[31] Reclamation, 2011. 'West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections,' Technical Memorandum No. 86-68210-2011-01, prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 138pp **http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf**

The project team also performed a calibration of the models' forecasts based on agreement between historic meteorological data and the models' backcasts.

To classify the 112 GCM runs into potential climate futures, the project team divided the model runs into 4 quadrants based on their changes in a) annual mean **temperature** and b) annual mean **precipitation** (Figure 12). In addition, the project team created a fifth Central Tendency future, which was defined by the 25th and 75th percentile values of the average changes in temperature and precipitation[32].

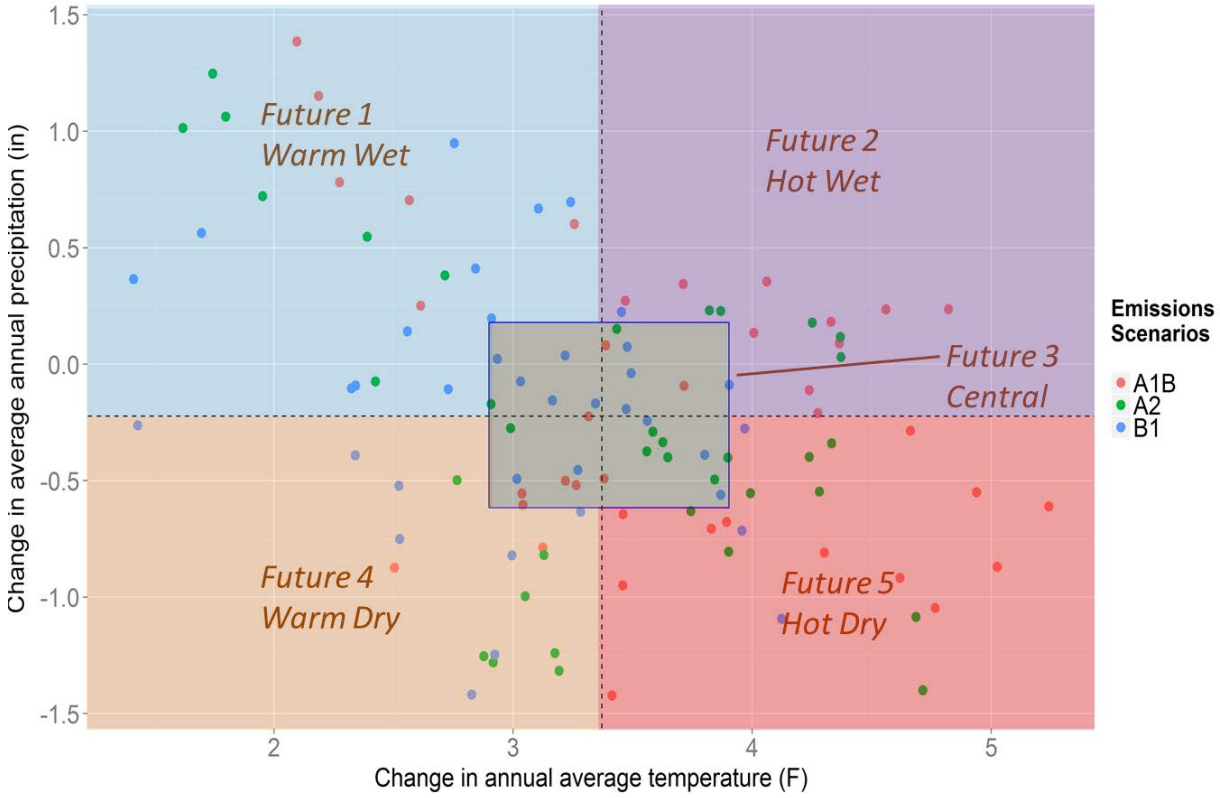

Figure 12: Changes in Annual Climate Averages for all GCMs in Albuquerque in 2040 (averaged over 2025-2055) versus the Late 20th Century Baseline (1950-1999). Source: Volpe Center.

While the temperatures range along the temperature axis, it is important to note that none of the possibilities for the region indicate 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 to a small decrease in precipitation. This is consistent with the findings in the literature cited above, particularly the *Upper Rio Grande Impact Assessment*.[33]

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[32] This approach to divide the model runs into four quadrants based on their changes in temperature and precipitation with a Central Tendency future was inspired by the methodology provided by Jesse Roach of Sandia National Laboratories that was done for a different time period. The Volpe Center developed a program that automates the downscaled projections from the global climate models. The work completed by the Volpe Center is consistent with analysis of different timescales completed by Sandia Labs and the Bureau of Reclamation in their analysis of hydrologic flows.

[33] Llewelyn, et al., 2013.

In addition to annual mean temperature and precipitation, the project team calculated the following statistics from the 112 bias-corrected and spatially downscaled projections provided by the Bureau of Reclamation for 6 1/8th degree grid cells in the Albuquerque region:

- Monthly average temperatures
- 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)

While the project team calculated these measures for several grid cells, for the sake of brevity, all of the graphs below are for a grid cell centered on the southeast part of the city of Albuquerque.

3.2.2 Temperature Findings

While each climate future has different annual average temperatures, they all have a similar seasonal variation. The plot in Figure 13 illustrates the change in maximum daily temperature for each month in the future time period versus the baseline period. Three conclusions are seen from the plot:

- The temperature change is strongly seasonal, with larger temperature increases expected during the summer months than during the winter months.
- The seasonal dependence is approximately the same under each of the climate futures.
- There is a significant range of 2-3° F between the Warm Wet future and the Hot Dry future. For example the increase in temperature in June is expected to be between 2.7° F and 5.2° F, respectively.

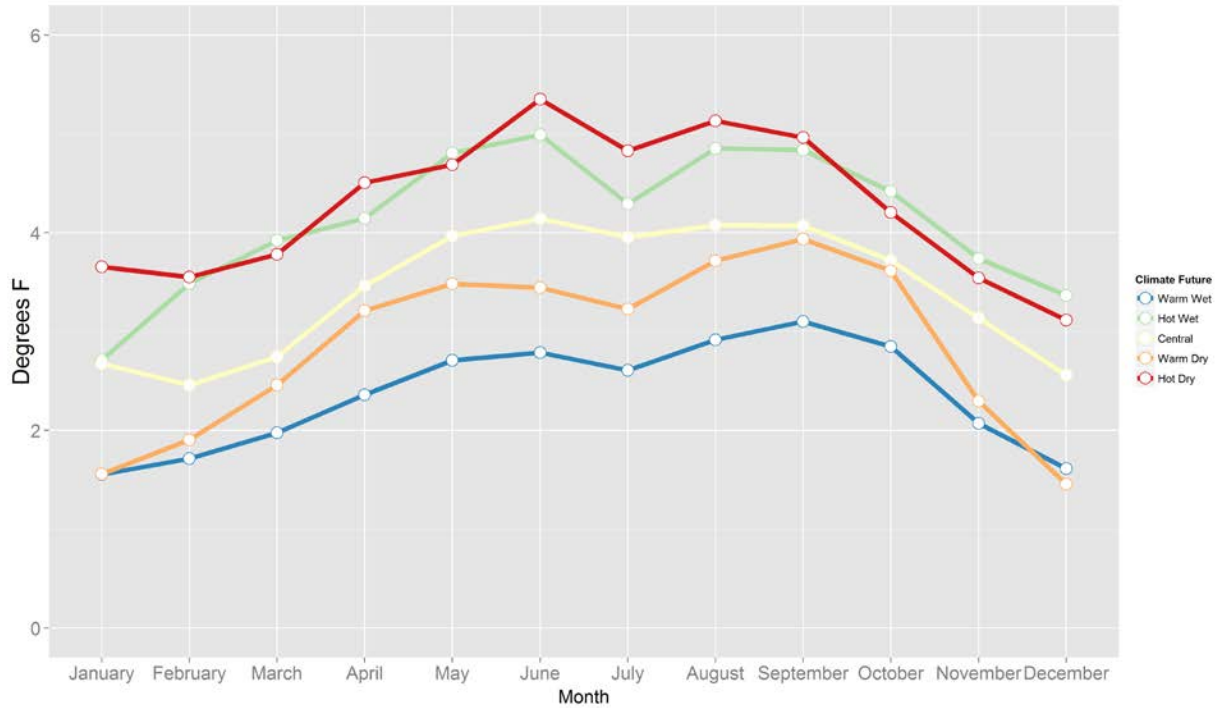

Figure 13. Monthly Temperature Change in 2040 (2025-2055) versus 1950-1999. Source: Volpe Center.

An important potential impact of temperature change is an increased frequency of extremely hot days that require air conditioning. Known as cooling degree days, these may lead to electrical brownouts or blackouts since the increase in electrical load may stress the utility and power system of the region, and requiring upgrades in generation and transmission capacity. The plot in Figure 14 uses boxplots to illustrate the model outputs for the number of annual cooling degree days for each climate future. Each box shows the 25th, 50th, and 75th percentile values based on the models in each climate future; the vertical "whiskers" and dots denote the extent of outlier values. The plot compares the backcast or baseline number of days per year with a maximum temperature exceeding 100° F under each climate future in the baseline period with the forecast number of such days in the future period. Since the models are calibrated to historical data, the backcast frequency of five days per year is the same across all climate futures. The future values, however, vary widely and paint a picture of many more cooling degree days in the year 2040. At the low end under the Wet Warm future, 10 days are expected on average to have a maximum temperature exceeding 100° F (roughly double the baseline value of 5 days/year); on the high end under the Hot Dry future, 22 such days are expected on average. In fact, as shown by the "whisker" extending from the top of the boxplot representing the Hot Dry future, over 30 days per year is plausible and should be considered as the worst-case scenario for future planning.

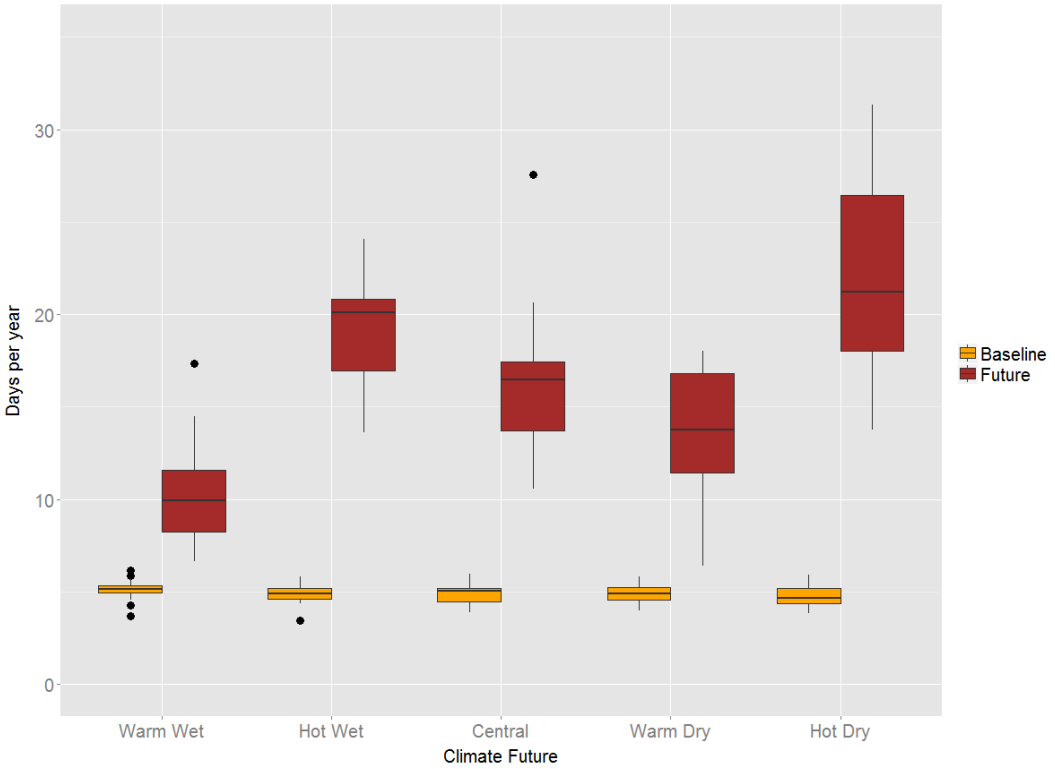

Figure 14. Annual Cooling Degree Days (>100° F) in Baseline (1950-1999) and 2040 (2025-2055). Source: Volpe Center.

Heat waves occur when extremely hot days occur consecutively. The impacts of heat waves include public health emergencies, especially affecting vulnerable populations, as well as damage to roads, railroads, and certain other infrastructure. The boxplot in Figure 15 compares the baseline and future maximum consecutive days of 100° F or more. As for the previous output for the total number of cooling degree days, this threshold temperature can be set to

any value by the user. Compared to a maximum two-day event in the baseline period, the climate futures indicate maximum annual heat wave durations between an average of four and seven days, with outlier values exceeding 11 days.

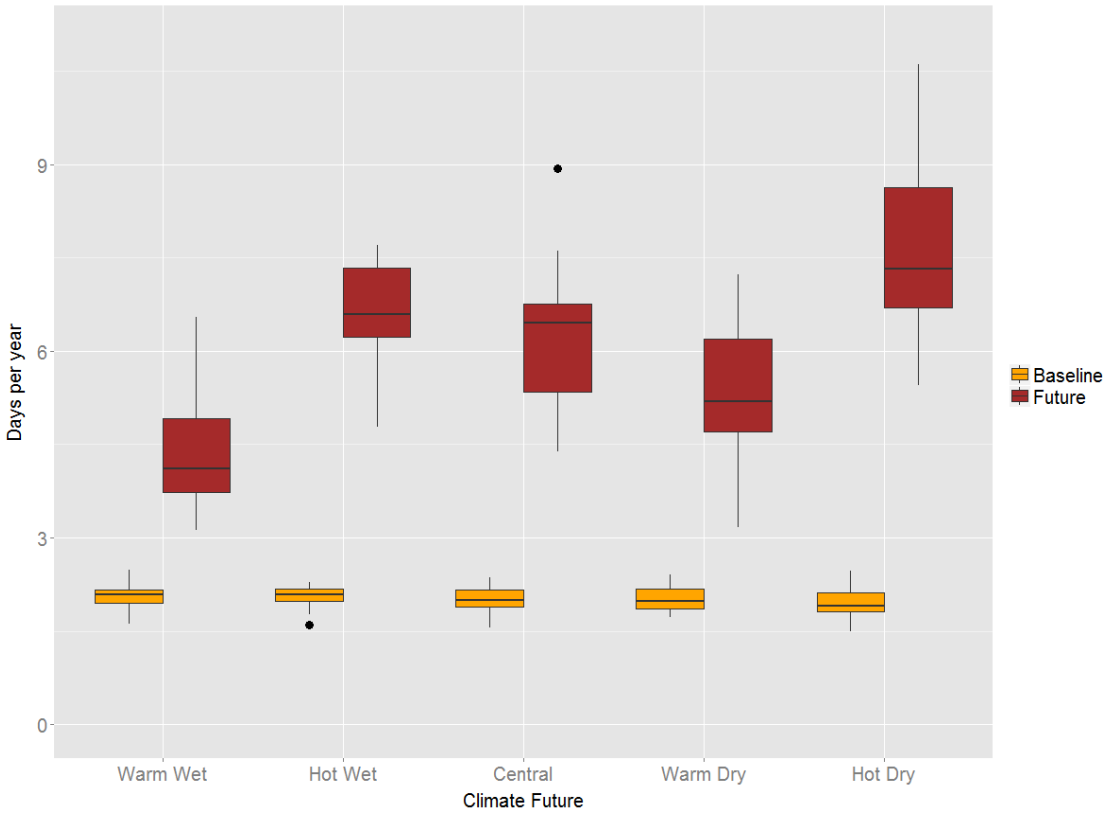

Figure 15. Maximum Consecutive Days over 100° F in baseline (1950-1999) and 2040 (2025-2055). Source: Volpe Center.

3.2.3 Precipitation Findings

Precipitation is a critical uncertainty for this region for two reasons. One reason for uncertainty is the region's location near the boundary of the tropical and temperate climate zones and the resulting lack of consistency between the models about the future of the North American Monsoon. Projections for short-term, extreme precipitation events also have high uncertainty because downscaled global climate models do not provide sufficient temporal resolution to project when and how intensely rain falls in the region. These details are important because arid regions like Central New Mexico can experience drought interspersed with heavy rainfall that is not easily absorbed by the drought-stressed soil.

Although based on GCMs, which are less certain about future precipitation trends in the region, the CFEST tool does show variation among the four climate futures in the pattern of seasonal precipitation change. Changes in average monthly precipitation in the future period versus the baseline period under each of the five climate futures are shown in Figure 16 as colored bars. At least three conclusions and their potential impacts can be seen:

- The climate futures consistently project reduced precipitation in the spring months of March, April, and May. With these months being drier, changes in spring snowmelt runoff are expected.

- The models diverge during the winter, summer, and fall seasons, indicating that those months are more uncertain and that planning should account for either decreases or small increases in precipitation.
- The magnitudes of the projected changes in precipitation are small, not exceeding 1/6th inch per month.

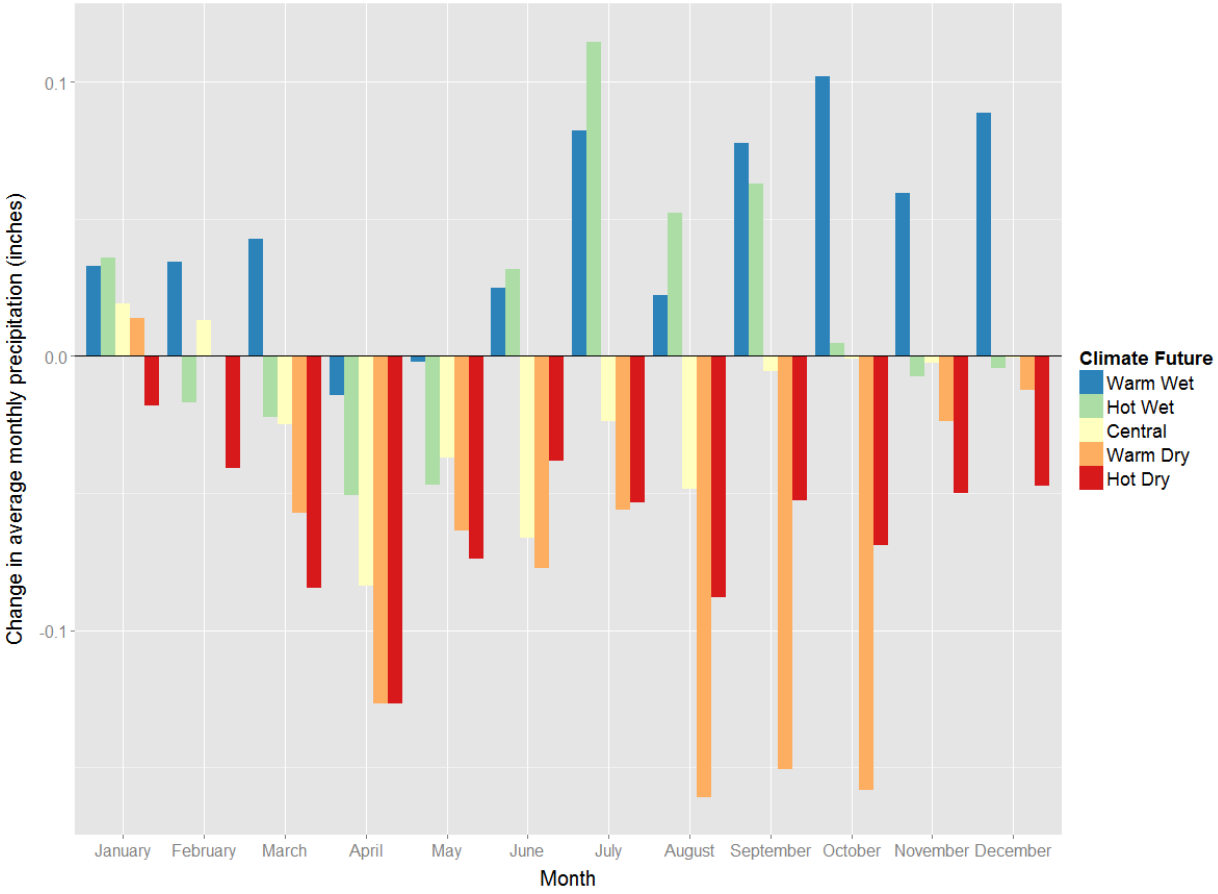

Figure 16. Monthly Average Precipitation Change in 2040 (2025-2055) versus 1950-1999. Source: Volpe Center.

The risk of flash flooding, due to extreme events such as heavy short periods of precipitation, may increase in the region because the atmosphere will be warmer, which increases its capacity to hold water vapor. However, such short-duration events are more difficult to project. Figure 17 compares the maximum 24-hour precipitation event during an "average" year in the late 20th century versus forecasted future periods. With the relatively modest increases and decreases in precipitation shown in this figure, the climate futures do not provide clear projections of major precipitation events. This result, however, may be the limitation of the downscaling process used by the Bureau of Reclamation and may not indicate there will be little effect on flash flood risk in the region.[34]

[34] According to a BoR Technical Services Center Technical Memorandum, a byproduct of the downscaling process used to produce the 1/8th degree dataset is the removal of extreme precipitation value outliers. Possible future approaches to better analyze potential extreme events include projecting them by

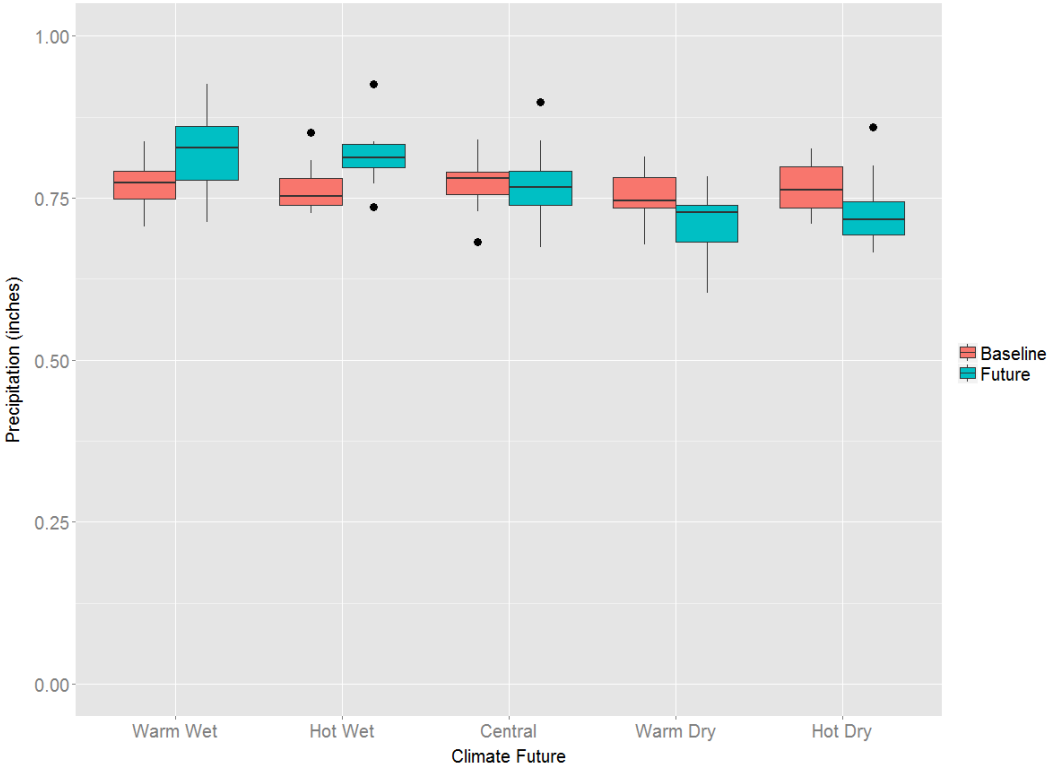

Figure 17. Maximum 24-hour Precipitation Amount in Baseline (1950-1999 average) and 2040 (2025-2055 average).[35] Source: Volpe Center.

Temperature and precipitation trends together affect water resources in the region. Drought is caused by a combination of a lack of rainfall and higher heat-driven evaporation of water stored in the soil, as well as higher transpiration by plants. Expected higher temperatures in the region will likely dry the soil out more quickly through the year, thereby reducing its infiltration capacity and limiting its ability to absorb and store stormwater during events. Furthermore, the higher temperatures expected in the future will increase the temperature of the ground and lead to higher rates of evapotranspiration of rainfall.

At the request of MRCOG, the project team analyzed five additional locations to produce a regional picture of the climate futures (Figure 18). Using the same time intervals as the original locations, the effects of elevation and location in the region became apparent in outputs such as the heat wave analysis. The heat wave analysis showed that mountainous areas that historically saw zero days per year exceeding 100° F are projected to see none in 2040 in all but the Hot Dry future. In contrast, low-elevation locations such as Los Lunas are projected to see increases in heat wave duration as large or even larger than downtown Albuquerque.

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correlating the curve of the distribution of known events in the recent past with the model's version of the present and extrapolating this correlation to the future projections; or downscaling the coarse GCMs using a different methodology.

[35] Note: climate futures do not provide clear projections of major precipitation events because high precipitation outliers were removed from the dataset

This analysis of several locations shows that different parts of mountainous areas will experience varying climate change impacts. For this reason, it is valuable to use downscaled projections to differentiate the plausible climate change impacts in different parts of the study area, and test growth scenarios accordingly. As discussed further in the next section, the Climate Futures informed the identification of where existing development is at risk, where future development should be minimal, the energy consumption increase for cooling, and impacts for natural and cultural resources.

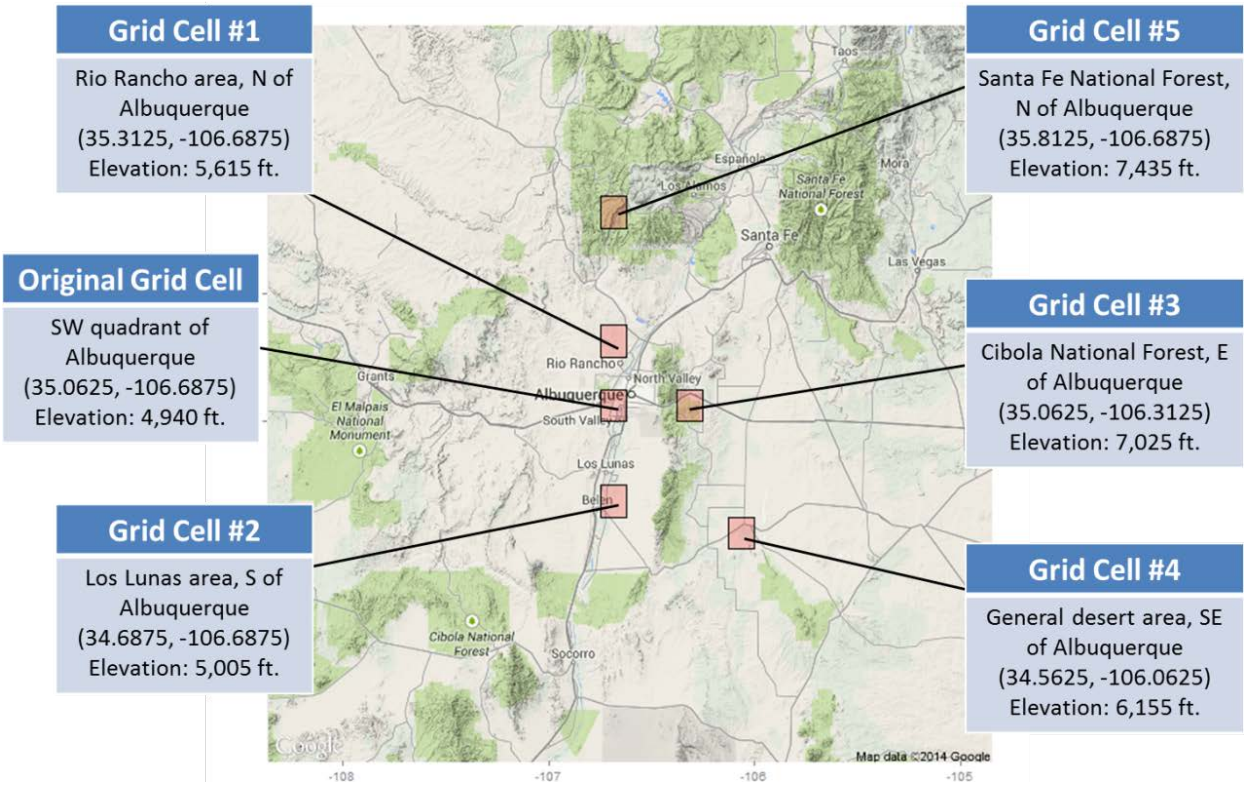


Figure 18. Five Additional MRCOG-Identified Grid Cells of Interest were Analyzed to Develop Climate Futures for Different Elevations and Areas of the Five-County Study Area. Source: Volpe Center.

3.3 Population, Employment, and Land Use Trends for Central New Mexico

As a component of the MTP, MRCOG develops population and employment forecasts for the region in order to help guide transportation investment decisions and land use planning by its member governments. These forecasts do not consider how different climate futures might influence growth and development. Such an analysis would be exceedingly complex and largely speculative. Instead, the MPO develops forecasts based on demographic and economic trends, and migration patterns from the recent past. These forecasts determine the number of new residents and employers that must be accommodated in planning future land use and transportation scenarios.

The region has seen steady growth over the last 60 years. Since 1950, the population of the MRCOG region has increased five-fold (Figure 19).

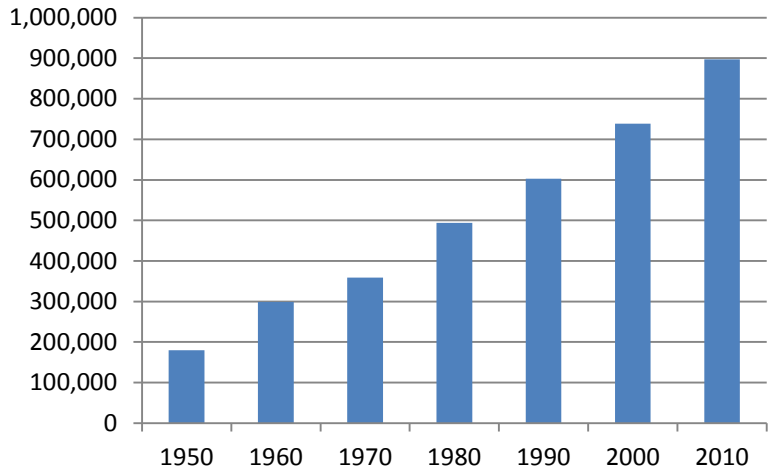


Figure 19: MRCOG Area Population 1950-2010. Source: MRCOG.

Since almost all of the population growth in the region occurred after World War II, there are few areas that were not designed primarily for car access and no large mass transit system was ever constructed. As a result, urban development in the region has consumed a lot of land (Figure 20).

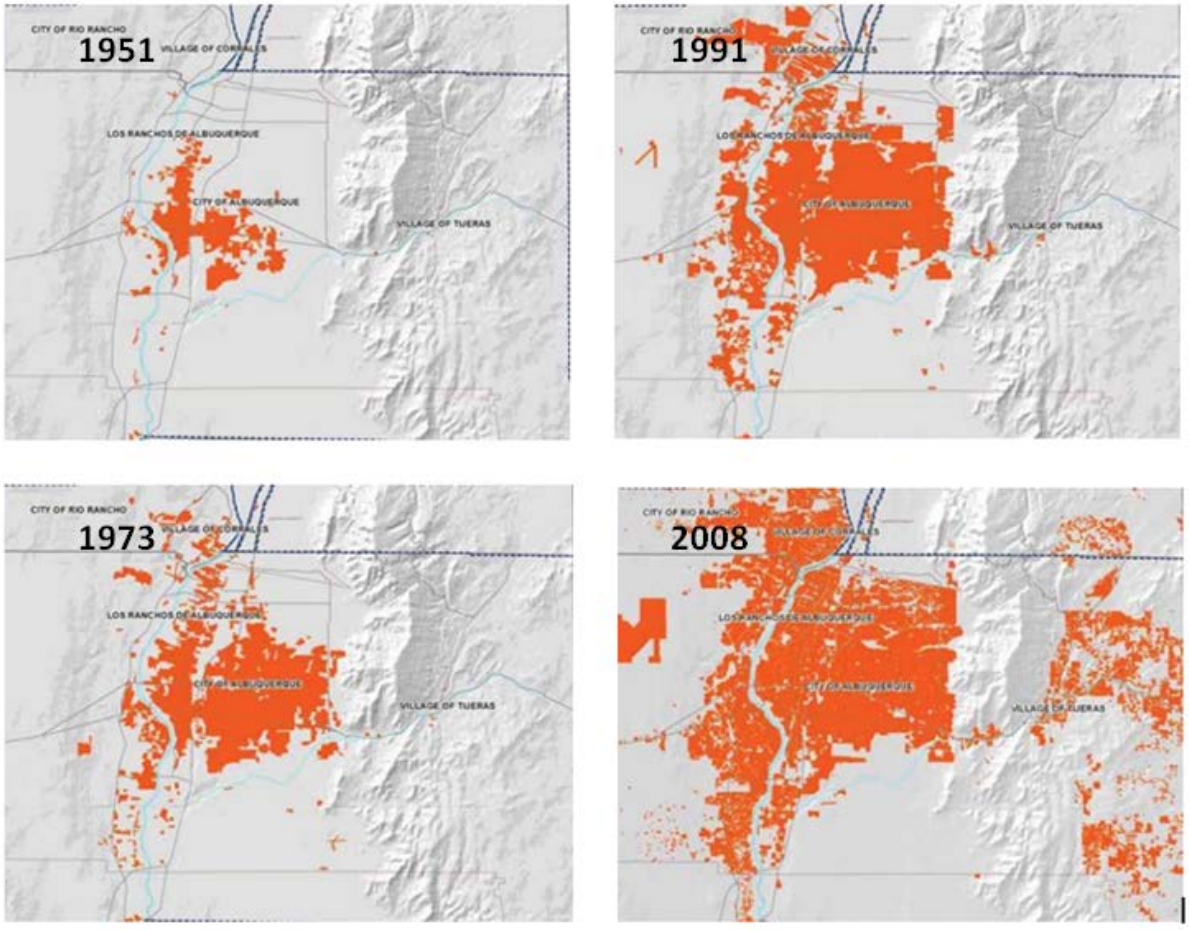


Figure 20: Development Footprint of the Albuquerque Region 1951–2008. Source: MRCOG.

MRCOG projects the population of the region will continue to increase from 890,000 today to around 1,360,000 by 2040 (Figure 21). This is an increase of roughly 50 percent. This growth is due to the large population increase that is expected across the Southwest, particularly in urban areas like Albuquerque, despite a small decrease in growth during the recession. At the same time, employment is projected to grow from 388,981 jobs today to close to 582,000 jobs by 2040 (Figure 22). This is a projected increase of roughly 46 percent.

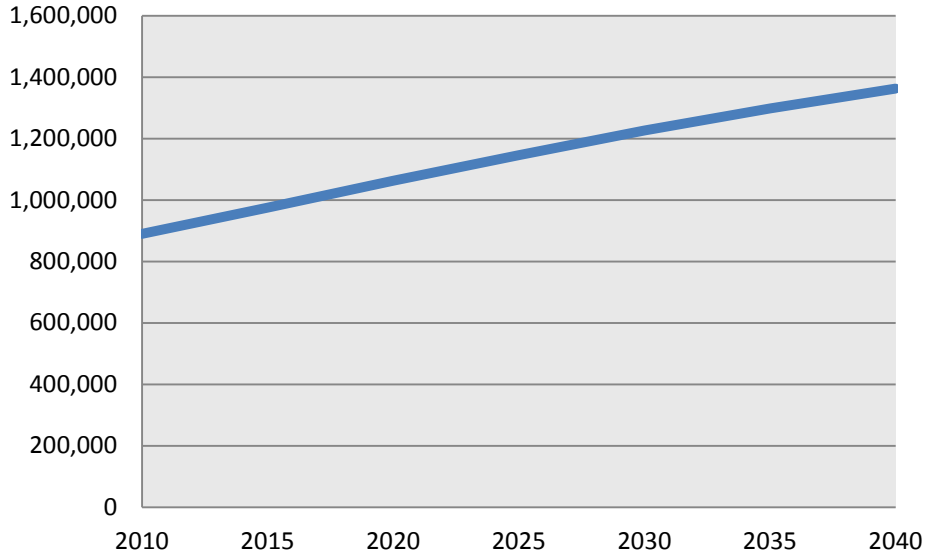


Figure 21: MRCOG Region Population Projection 2010–2040. Source: MRCOG.

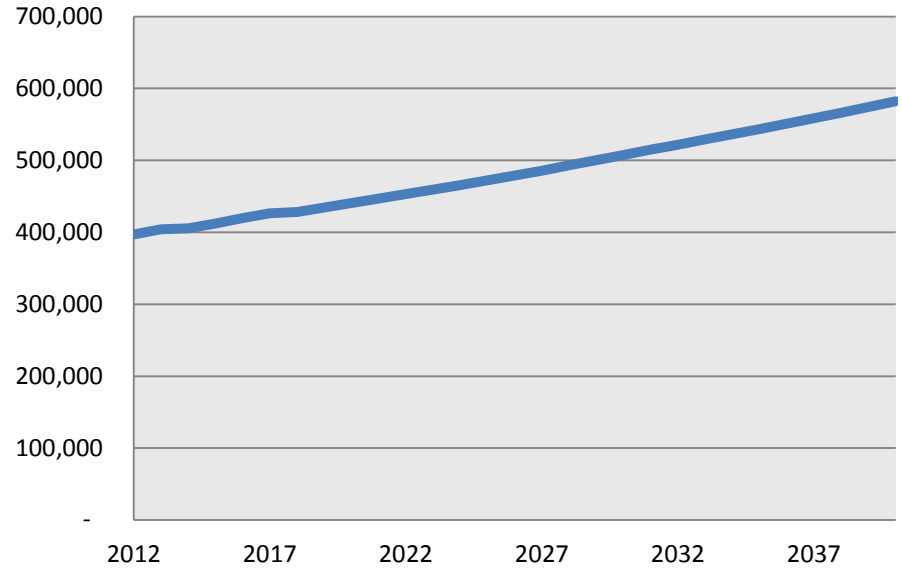


Figure 22: MRCOG Region Employment Projection 2012–2040. Source: MRCOG.

As is the case throughout the United States, the future age distribution of the population in Central New Mexico is projected to be different from today. The most dramatic aspect of this difference will be a much larger population of older adults.

3.4 Accommodating Growth in a Changing Climate

As the region grows, leaders in Central New Mexico have expressed an interest in steering the character of growth more carefully and intentionally than has been done in the past. Using scenario planning as the method, MRCOG used its MTP as an opportunity to incorporate concerns about climate change into the conversation about growth.

As explained in the next chapter, the local effects of climate change may increase the risk of flooding in some neighborhoods and to infrastructure due to the possibility of more concentrated precipitation events (Figure 23); which the region already experiences periodically. There may also be an increased risk of wildfire from projected higher temperatures and the likelihood of drought. Higher temperatures may also cause greater stress on infrastructure, leading to higher costs for maintenance. Climate change may also increase ecosystem fragmentation, such as the conversion of low-lying forest ecosystems to scrub. This fragmentation could have negative consequences for the persistence of native species that depend on these habitats.

Figure 23: A Sign in Downtown Albuquerque. The region is already subject to periodic flooding, which may increase in intensity due to a warming atmosphere. Source: FHWA.

At the same time, leaders in Central New Mexico are interested in reducing the region's contribution to the cause of climate change. Development patterns and transportation may influence the region's dependence on the burning of fossil fuels to sustain the economy and life of the community. If certain transportation investments and land use development policies and strategies can reduce that dependence, the region will contribute fewer GHG emissions than if it follows the same path as it has in the past. A great amount of research exists on the mitigation of climate change through reducing GHG emissions. The project team developed a detailed synthesis of mitigation methods and potential applications within the region, which is included as Appendix F. The project consultants conducted additional analysis, which is available on the **CCSP project website**.[36]

These intertwining goals to **adapt** the region to climate change impacts and **mitigate** climate change by lowering GHG emissions shaped the scenario development and analysis for this project.

[36] **www.volpe.dot.gov/NMScenarioPlanning**

4 Scenario Development and Analysis

The focus of this project was to incorporate climate change mitigation and adaptation into a scenario-driven planning process. MRCOG used scenario planning techniques to generate discussions among stakeholders about the various issues facing the region and how to guide future growth. This section includes a discussion of how MRCOG and the interagency project team developed, analyzed, and refined the scenarios for the 2040 MTP.

4.1 The Development of Land Use Scenarios

For several months prior to the development of the scenario planning workshops, MRCOG conducted an extensive public outreach program. One component of this outreach included regular discussions with MRCOG's Land Use and Transportation Integration (LUTI) Committee, which is made up of staff from local agencies in charge of transportation and land use planning. MRCOG also held some public meetings and conducted focus groups with different types of stakeholders in the region that have a particular interest in or influence over land use development. MRCOG supplemented these outreach activities with regional surveys aimed at understanding residents' concerns and interests.

During public outreach, MRCOG staff listened to the public and local agency staff to identify six key challenges and needs that were of interest to Central New Mexico residents:

1. **Water sustainability and environment**: Look at ways to improve water conservation through reuse, delivery, and development patterns. Better understand the current water resources and future availability and how transportation decisions affect our environment.
2. **Economic development**: Identify the best ways to achieve economic vitality that also enhances human health and quality of life. Develop a sustainable, diversified, attractive, and resilient local economy. Work to retain families and the younger generation.
3. **Diverse housing and transportation options**: Improve roadway and trail connectivity and design. Create a transportation network that allows safe and convenient options to walk, bicycle, take transit, and drive. Support a variety of housing options for people of all ages and incomes.
4. **Balance of jobs and housing**: Effectively use compact development and infill to balance housing and jobs and decrease travel distances to services and transit stations. Reduce pressure on the transportation system by limiting sprawl.
5. **Focus on unique activity centers**: Support public spaces that foster social life with a mix of housing, retail, and workspace. Improve existing centers and strategically locate new activity centers. Provide a unique variety of great places accessible by transit for entertainment and arts, to gather, or to run errands.
6. **Historic and rural preservation**: Preserve cultural heritage, balance rural character with urban growth, and respect and acknowledge the difference between our local neighborhoods and regional identities. Ensure historic preservation in main streets and original town sites.

MRCOG also accounted for the interests of the CCSP Planning Group and technical committees by examining aspects of transportation and development related to climate change such as emissions levels, development in areas at risk of flooding and forest fires, as well as impacts to crucial habitat areas. From these themes, MRCOG staff adapted the performance measures

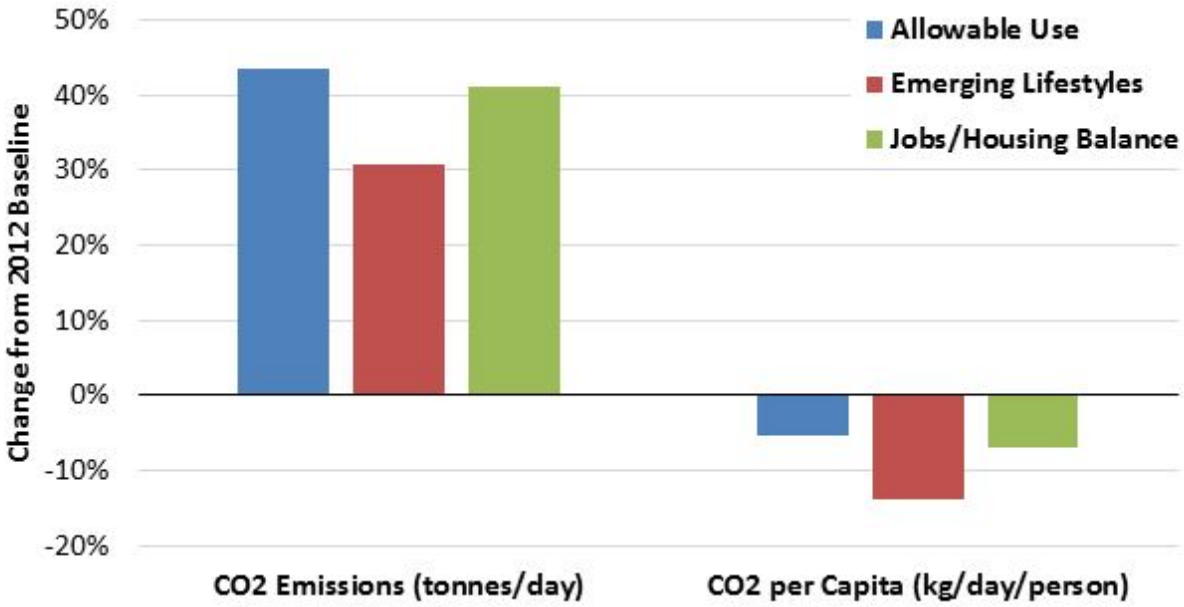
from the previous iteration of the MTP and developed several new performance measures to indicate the effects of different land use and transportation scenarios.

Based on this work and input, MRCOG staff developed three preliminary or conceptual land use scenarios. MRCOG developed these land use scenarios by altering the allowable zoning in each and did not alter the roadway network, which was the same used in the 2035 plan, or land use beyond zoning. The scenarios included 1) an **allowable uses** scenario that forecasted land use patterns that would likely emerge with existing zoning, 2) a **jobs-housing balance** scenario that changed zoning to allow for more jobs on the west side and more residents on the job-rich east side, and 3) a **Preferred Scenario** that reflected new trends in living and commuting among young adults and new retirees, which allowed for higher density land use in activity centers and along the existing high frequency bus network. Local stakeholders in transportation, land use planning, and land management considered these scenarios at two workshops.

Figure 24: New High-Density Development in Downtown Albuquerque, NM. Source: FHWA.

4.2 Scenario Planning Workshops

MRCOG presented these three scenarios and the performance measures used to evaluate them to participants at the first scenario planning workshop held in July 2014. Workshop participants also heard a presentation from the Volpe Center about the climate futures analysis described in Chapter 3. During the second half of the workshop, participants reacted to the climate futures analysis and the performance of each scenario and provided feedback for MRCOG staff to consider before it worked on refining the scenarios. In general, the participants overwhelmingly supported the Preferred Scenario as it seemed to perform best on most of the performance criteria. However, several participants expressed disappointment that the benefits were too small, particularly as they related to GHG emission mitigation (Figure 25).



Scenario	CO2 Emission Rate (g/mi)	CO2 Emissions (tonnes/day)	CO2 per Capita (kg/day/person)
Allowable Use	509	16,200	12.0
Emerging Lifestyles	487	14,752	10.9
Jobs/Housing Balance	497	15,906	11.8
2012 Baseline	555	11,282	12.7

Figure 25: GHG Emissions Change from 2012 Emissions Levels Based on Changes to Zoning. Source: MRCOG.

At the conclusion of the first workshop, the participants settled on the Preferred Scenario (originally called "Emerging Lifestyles") out of the three preliminary ones developed by MRCOG staff, but they also requested that aspects of the "jobs-housing balance" scenario be incorporated into a Preferred Scenario. The interagency and consultant team then worked together to add land use development incentives or "shifters" that would further support the objectives of the Preferred Scenario. MRCOG and the consultant team again ran the land use and transportation models against the performance measures important to the region. For the incentives that were not able to be modeled using existing travel demand modeling technology, the consultant team applied several off-model analyses to arrive at an estimate of their various effects. The refined Preferred Scenario and a Trend Scenario were then compared to one another based on these measures.

At the August 2014 workshop, participants were presented with two new Preferred Scenarios. One of these scenarios included a "2040 network" composed of new links in the transportation network proposed by local governments as well as an expanded Bus Rapid Transit (BRT) system on three corridors that were the subject of preliminary transit planning activities. This scenario also included general bus transit frequency improvements. The second of these scenarios included a "2025 network" composed of a limited number of new network links and the expansion of a BRT system without increased transit frequencies. MRCOG chose to include this second scenario as a constrained scenario in case there is less funding available for the region than originally expected. Both of these Preferred Scenarios included three tiers of activity

centers (major, moderate, and minor) connected by transit lines (Figure 26). Some of these activity centers are areas identified for increased density. This chapter will explain how these levels of density were later determined. These two scenarios were compared to a "Trend" scenario that assumed development would continue in a similar fashion as it has over the last 20 years, not including the enhanced transit service of the Preferred Scenarios. As is shown in Table 1, MRCOG iterated the scenarios for the year 2025 when it conducted its modeling to ensure a better degree of accuracy in the model outcomes.

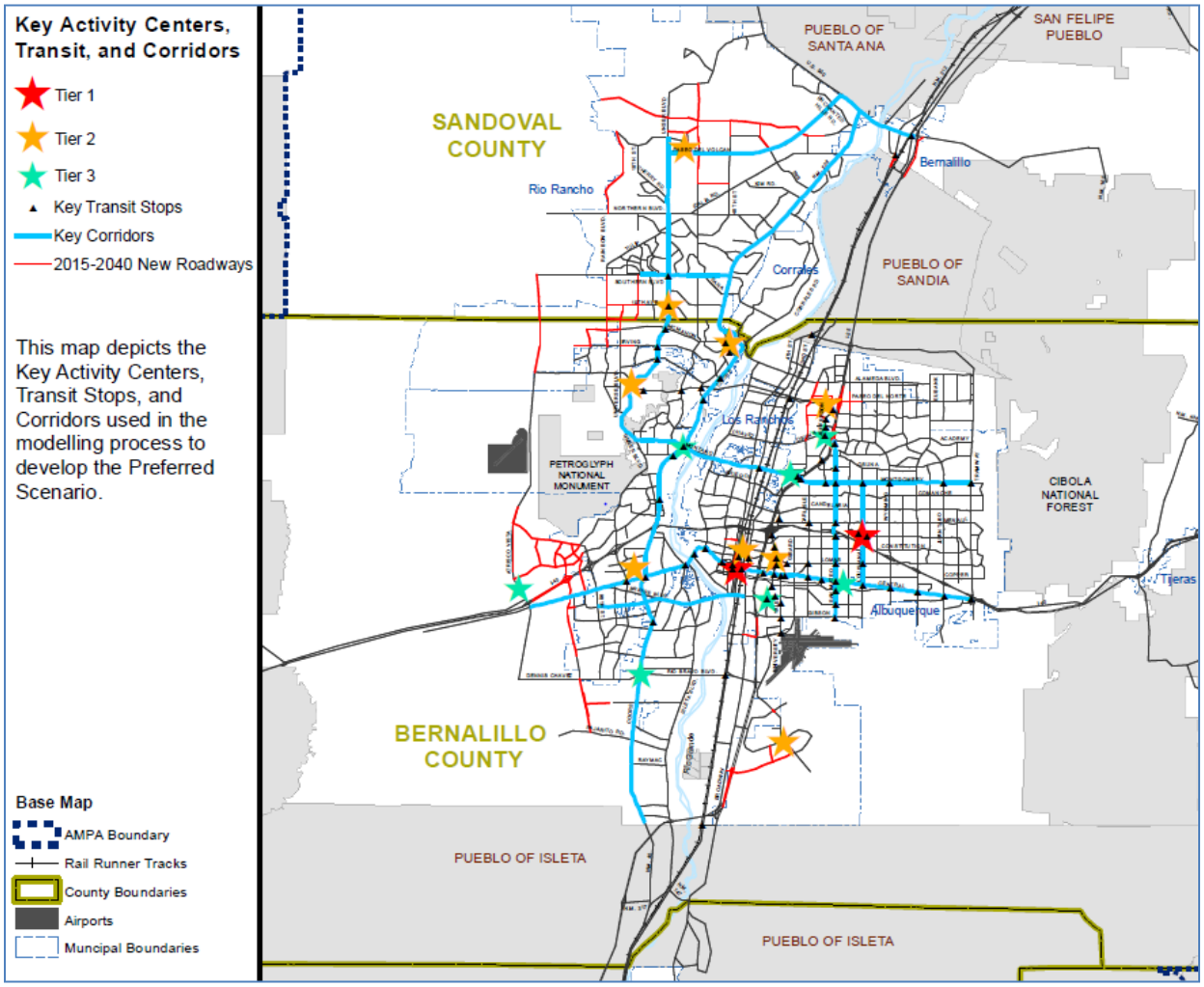


Figure 26: The Preferred Scenario Transportation Network. Source: MRCOG.

Table 1: Workshop #2 Scenarios.

	Trend Scenario	Preferred Scenario	Constrained Scenario
Year 2025			
Land Use	Existing Plans & Policies	Zoning Changes & Development Incentives	Zoning Changes & Development Incentives
Road Network	2025 Network	2025 Network	Existing
Transit System	Existing	2025 Network & Service Plan	Existing
Year 2040			
Land Use	Existing Plans & Policies	Zoning Changes & Development Incentives	Zoning Changes & Development Incentives
Road Network	2040 Network	2040 Network	2025 Network
Transit System	Existing + Central BRT	2040 Network & Service Plan	2025 Network & Service Plan

By applying the shifters, changing the transportation network, and iterating the model runs, the differences between the "trend" and Preferred Scenarios became clearer. The Preferred Scenario accommodated much more of the growth in households and jobs on the east side of Albuquerque near existing centers, whereas the Trend scenario resulted in more dispersed development on the periphery of the region (Figure 27 and Figure 28).

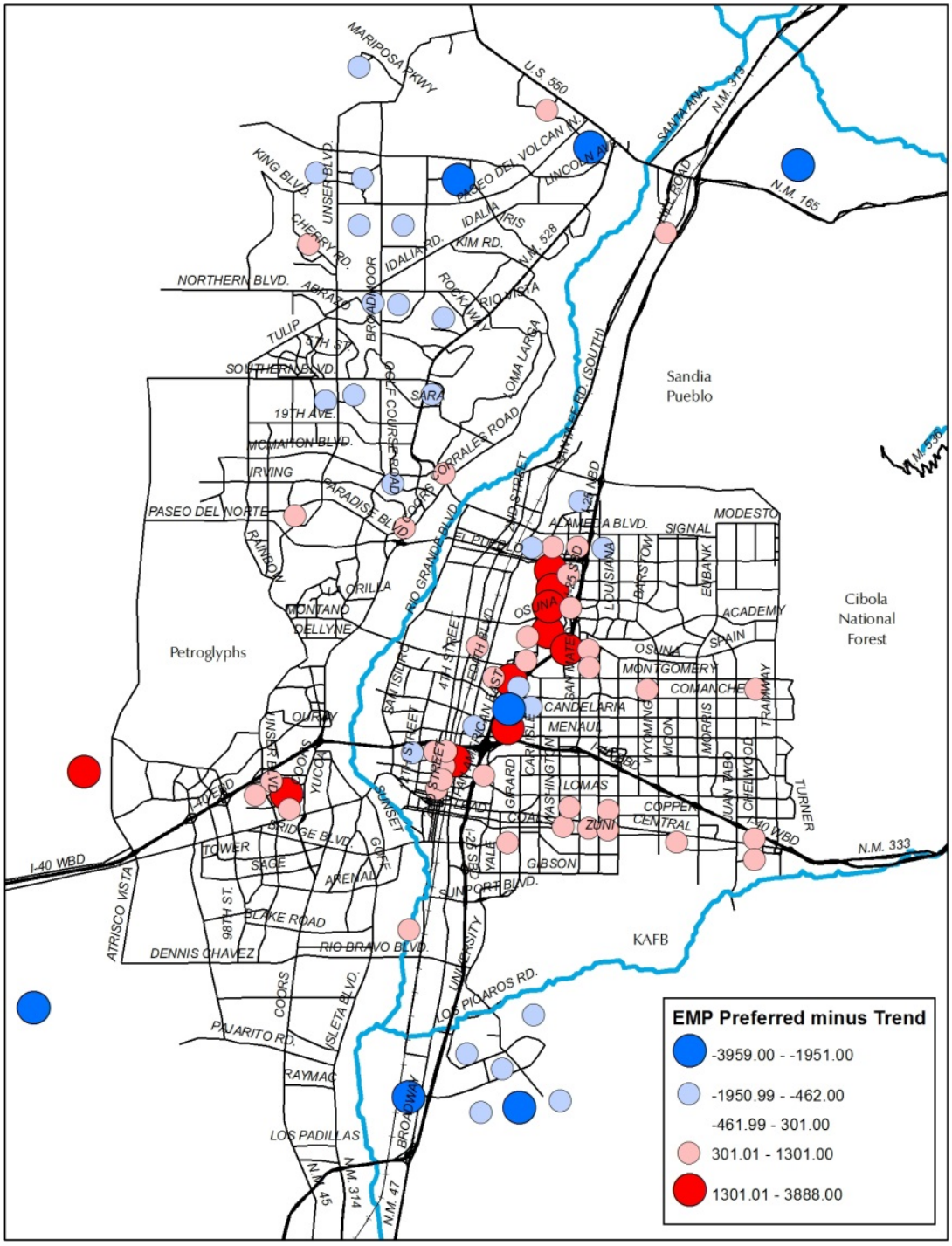


Figure 27: Change in Employment between the Preferred Scenario and the Trend Scenario Classified by Natural Breaks (Red indicates higher values in the Preferred Scenario; Blue equals more growth in the Trend Scenario). Source: MRCOG.

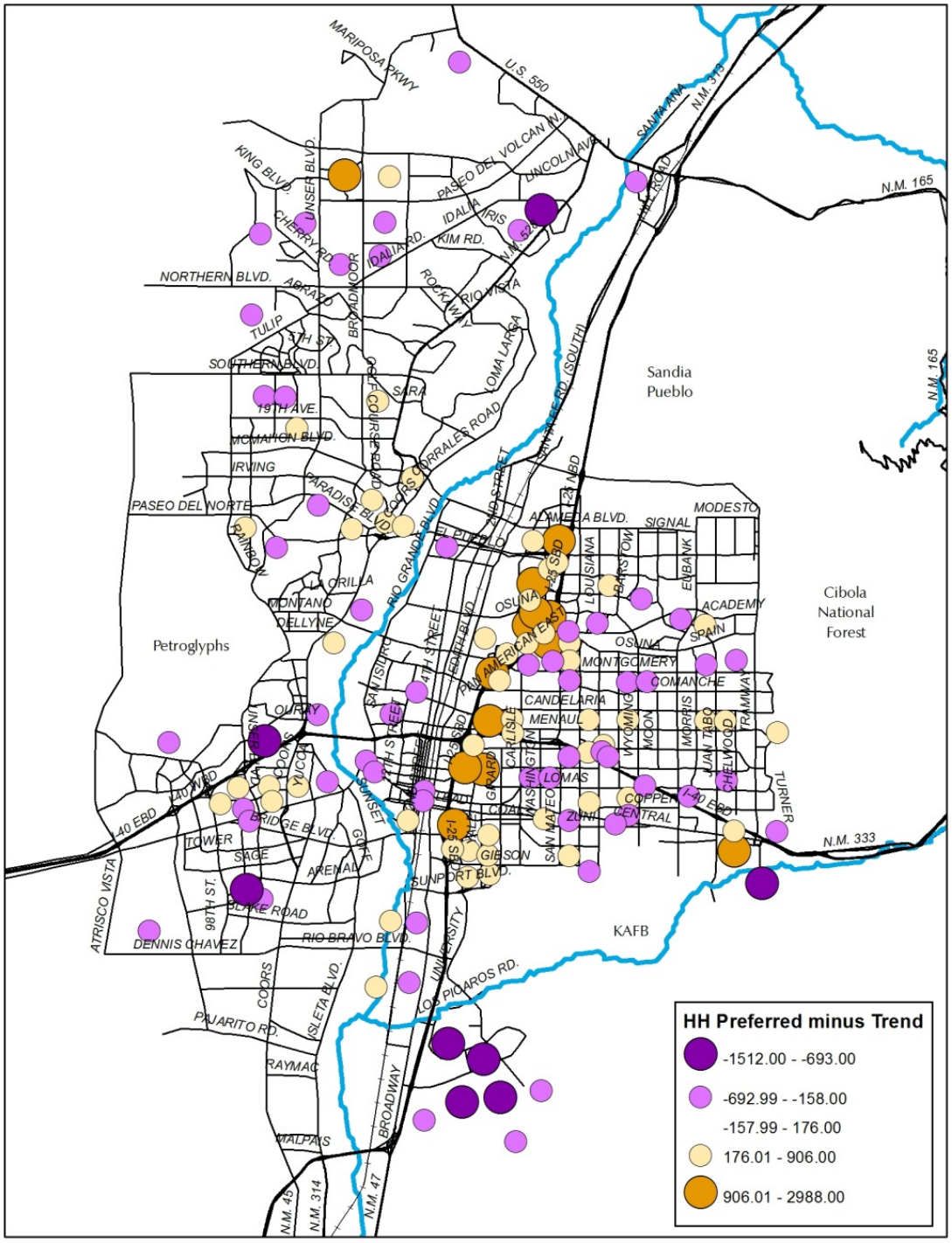


Figure 28: Changes in Households between the Preferred Scenario and the Trend Scenario Classified by Natural Breaks (Orange equals more households in the Preferred Scenario; Purple indicates more households in the Trend Scenario). Source: MRCOG.

MRCOG presented workshop participants with the new transportation and land use scenarios and the performance measures for GHG mitigation and resiliency (Figure 32), as well as traditional measures like congestion. The Preferred Scenario performed better than the Trend in almost all measures. However, there was a sense among many workshop participants that the

region needs to be more ambitious in changing its land use and transportation to make a substantial change in its contribution to GHG emissions and be more resilient to future impacts from climate change.

The workshop concluded with participants breaking into small groups to discuss the implementation of strategies implicit in the Preferred Scenario. Workshop participants developed a long list of specific strategies that MRCOG and its partners could explore to meet and exceed the performance objectives of the Preferred Scenario. These strategies included:

- Expanding transit service and increasing incentives for transit
    - Providing universal transit passes
    - Raising the sales tax and other revenue for transit
    - Establishing BRT and high-frequency transit corridors
    - Establishing mode-share goals along key transit corridors and identifying levels of service required to achieve them
- Developing a more balanced transportation network
    - Building a more complete and safe bicycle network
    - Developing and implementing Complete Streets policies that mandate the consideration of pedestrian, bicycle, and transit needs in all roadway construction projects
    - Improving subdivision connectivity through new standards and retrofits
    - Reducing or eliminating parking requirements for developments and creating parking management plans
- Improving transportation network efficiency
    - Developing a more coordinated official freight network
    - Creating a regional Intelligent Transportation Systems (ITS) Plan
    - Prioritizing signal timing enhancements and other measures on arterial roadways
- Investing in green infrastructure through careful street design
- Growing activity centers and transit-oriented development districts
    - Implementing form-based codes for mixed-use and transit-oriented development districts
    - Streamlining the development review process for projects that furthers the goals for activity centers and transit-oriented development districts
    - Exploring new financing mechanisms to incentivize development in activity centers and transit-oriented development districts
    - Encouraging master planning in growth areas on the periphery of the region
    - Considering density bonuses in key activity centers
    - Allowing accessory dwelling units
- Conserving natural resources by:
    - Reducing water consumption through conservation programs by the water authority
    - Increasing the use of grey water
    - Setting caps or a target for water use
    - Investing in the ecosystem services of land management agencies
- Managing regional growth to contain development in areas best suited for it
    - Developing policies and programs to reduce development in crucial habitat areas, as well as areas vulnerable to wildfire
    - Connecting open space with trails and green corridors
    - Exploring an urban service boundary, particularly for water service

    - Calibrating impact fees for development to be commensurate with the cost of providing services to that development
    - Creating opportunities for transfer of development rights or land purchases to conserve open space
    - Providing conservation easements along with cluster subdivisions
- Using technology to reduce energy dependence
    - Using public assets for renewable energy generation
    - Improving internet speeds through investment in fiber-optic technology and incentivizing telework

This iterative process utilized by MRCOG and the CCSP project partners ultimately resulted in a Preferred Scenario in the MTP. A final refined scenario was agreed upon after identifying regional challenges, soliciting feedback from stakeholders, and developing strategies in the scenario planning workshops. This process provided the staff at the MPO with a defensible rationale for introducing the recommended development strategy in the region's transportation plan.

4.3 Transportation Greenhouse Gas Mitigation Strategies

The Technical Advisory Committee for Greenhouse Gas Mitigation met several times throughout the project and discussed existing and potential activities to reduce the transportation sector's contribution to GHG emissions in the Albuquerque region. The Volpe Center worked with MRCOG to develop a synthesis of possible strategies that agencies in the region could undertake. This document, *Transportation-Related Greenhouse Gas Mitigation Strategies and Potential Applications in Central New Mexico* is included as Appendix F. The committee developed a universe of strategies (listed below), which were screened by the consultant team to identify strategies with the greatest likelihood for being effective and implemented. The document describes and analyzes these strategies in more detail.

Land Use Strategies:

- Zoning changes
- Encouragement of infill development
- Transit-oriented development
- Building design standards
- Urban growth boundaries or infrastructure dependent growth policies

Transportation Investments to Support Land Use:

- Bicycle and pedestrian infrastructure
- Improving public transportation including BRT

Figure 29: A Bicycle Trail in Albuquerque, NM. Source: FHWA.

- Complete Streets policy

Transportation Demand Management:

- Road pricing (high-occupant toll [HOT] lanes)
- High-occupant vehicle (HOV) facilities
- Parking management and demand-responsive parking pricing
- Car-sharing
- Bike-sharing
- Ride-sharing
- Employer commuter programs and transportation management associations/organizations
- Providing transit incentives
- Statewide mileage-based user fee or "wheels" tax

Transportation System Management:

- Traffic signal enhancement
- Incident management
- Intersection improvements
- Establishing roadway connectivity standards

Vehicle Improvement:

- Electric vehicle infrastructure support
- Heavy-duty vehicle retrofit to low emission engines and more efficient equipment
- Truck-stop electrification (TSE) technologies

MRCOG and the technical committee provided feedback on how some of these strategies could manifest in the region. Some strategies with the greatest potential were incorporated into the analysis to develop transportation and land use scenarios for the MTP.

4.4 Methodology for Scenario Evaluation

The consultant team worked with MRCOG to evaluate the scenarios using a combination of the integrated land use model UrbanSim with the travel demand model CUBE Voyager. The preliminary scenarios only adjusted zoning to show how much this policy lever would affect the performance measures and land consumed by 2040. The refined scenarios varied by both zoning and transportation network changes, as well as targeted development strategies. The consultant team then used the EPA's MOVES 2010b[37] model to calculate emissions results from different land use scenarios. The consultant team also used off-model analysis to evaluate several GHG emission reduction strategies for which the modeling system was unable to account. The detailed methodology used for scenario evaluation is included in the task memos and final report available on the **CCSP project website**.[38]

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[37] EPA has since released MOVES 2014, which has been updated to reflect the latest light vehicles CAFE standards. This version was not available at the time of this analysis and likely would have shown greater decreases in per-capita GHG emissions than what is presented in this analysis.

[38] **www.volpe.dot.gov/NMScenarioPlanning**

4.4.1 Land Use and Transportation Demand Modeling

MRCOG has two components in its modeling system: CUBE Voyager software for its travel demand model and UrbanSim for its integrated land use model. These models are tools to help understand anticipated results of different land use and transportation strategies. UrbanSim is a relatively new tool that is different from traditional land use models because it simulates the likely real estate market response to changes in land use policy and transportation investments. UrbanSim does this by forecasting the attractiveness of real estate, given various market assumptions and estimates, and then assigns land uses based on expected decisions by households and employers that are influenced by the price and appeal of different parcels of real estate (Figure 30).

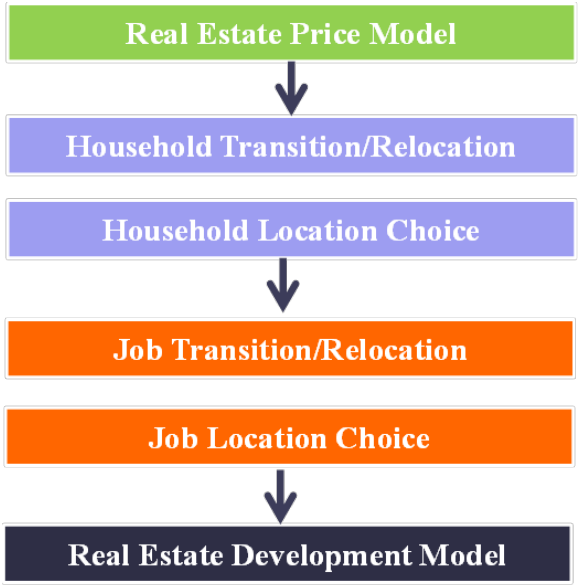

Figure 30: UrbanSim Modeling Process.[39] Source: MRCOG.

Using UrbanSim to inform scenario planning provided a different kind of analysis of land use and transportation than most planning exercises. Instead of the common approach of inventing hypothetical land uses to test transportation performance, UrbanSim projects the likely effect of policy incentives, zoning, and transportation investments on future land use. This method may lead to less dramatic differences between scenarios than growth management scenario planning often reveals. MRCOG believes this method is more useful for its purposes because it is better at recognizing and accounting for existing constraints within the market for land development. Integrated land use and transportation models can help the region evaluate 1) zoning strategies, 2) transportation network investments (both roads and transit), and 3) development incentives.

4.4.1.1 Zoning

Zoning sets the parameters for development related to the land uses and densities allowed on a particular parcel. The development of alternative zoning required the spatial selection of targeted areas in the region and a redefinition of the growth potential in terms of allowable

[39] Real estate prices influence household and employer location decisions, which is fed into the real estate development model that takes into account constraints and opportunities in the land market

uses, maximum units per acre, and maximum floor-to-area ratio (FAR). Changes to the allowable use will affect what type of development may be pursued. Changes to units per acre and FAR affects the remaining developable capacity for an area. While zoning determines what types of development projects and intensities are allowed in a specific area; it is the attractiveness of the site and market demand that influences whether a parcel is actually developed and at what intensity. Zoning was the only strategy that MRCOG altered in the development of the preliminary scenarios for the first scenario planning workshop. UrbanSim projected the market response to this alteration by distributing population and employment differently based on a different zoning paradigm.

4.4.1.2 Transportation Networks

Roadway projects identified by cities, counties and NMDOT form the basis for future-year transportation networks. Alternative road and transit networks require coding new networks within CUBE Voyager. After the networks are developed, they are introduced into a travel model simulation. Alternative networks, such as the provision of new transit service (Figure 31), will have an impact on mode split, travel times, VMT, and land development patterns. The travel demand model assigns trips and modes based on existing knowledge about how travelers choose routes and modes. This knowledge is derived from surveys of residents.

Figure 31: An ABQ Ride Bus in Downtown Albuquerque. Source: FHWA.

CUBE Voyager is a traditional four-step travel demand model. This model is based on geographic information about the region divided into traffic analysis zones (TAZs). The model's four-step process includes:

1. The frequency of trips coming and going from each zone.
2. The distribution of these trips between zones.

3. The choice of mode by individuals making trips.
4. The assignment of the particular route of each trip based on the quickest possible path.

Changes to the transportation network or to the availability of alternatives to car travel have a direct effect on the third and fourth steps in the model. They may also have an indirect effect on the second step in the model as transportation strategies that change the network may increase or decrease the attractiveness of land development in a TAZ.

4.4.1.3 Policy Incentives

MRCOG simulated policy incentives to development within the UrbanSim model by manually adjusting the levers (or shifters) that increase or decrease the development probability of an area targeted for additional or reduced investment. These incentives may be related to:

- The development process, such as expedited approvals and waived or reduced permitting fees.
- Regulatory mechanisms, such as density bonuses, parking reductions, or relaxed design criteria.
- Financial incentives, such as tax increment financing districts, impact fee reductions, or shared infrastructure costs.

The policy levers implemented in UrbanSim do not represent a specific type of incentive. Rather, they simulate a relative magnitude of any of these types of incentives. The levers are essentially assigned a value (e.g., 1, 2, or 3) that can be attached to a point (e.g., a transit node) or a zone (e.g., an activity center) that increases the probability there will be new development. MRCOG assigns the values based on an idea of an expected or desired impact from the incentive. For example, if a value of 3 is necessary to arrive at a desired objective (e.g., 2,000 more jobs in downtown), it will not be possible to say exactly which specific policies need to be enacted to realize that objective. Rather, it indicates the relative level of investment that may be necessary in order to achieve the level of development desired.

Areas that are incentivized in this way using UrbanSim are still subject to all of the other modeling inputs and influences. For example, if a parcel has no remaining capacity, or if it is not zoned for certain types of development, adding a policy lever will have no effect. The policy lever increases likelihood, but does not ensure future development. It is also important to note that locations for which no policy lever has been applied may still experience considerable development. If the model indicates that an area is likely to develop to desired higher densities, then perhaps policy incentives are not necessary in that area.

MRCOG created the three final scenarios (“Preferred”, “Preferred constrained”, and “Trend”) within this modeling environment and MRCOG evaluated these scenarios based on several outputs from the models.

4.4.1.4 Motor Vehicle Emission Simulator

To calculate the emissions impacts from different strategies, the consultant team worked with MRCOG to apply the EPA’s **Motor Vehicle Emission Simulator (MOVES).**[40] MOVES takes the output from the travel demand model and estimates emissions from the VMT and traffic operations that result from the model output. It uses factors such as vehicle type, speed, miles

[40] http://www.epa.gov/otaq/models/moves/index.htm

traveled, and traffic volume to estimate total emissions. MOVES is typically used for air quality conformity purposes, but it can be useful for estimating GHG emissions as well.

4.4.2 Qualitative, Off-Model, and Post-Processing Analysis

The transportation and land use models cannot model many of the GHG mitigation strategies considered for this project. The project team considered a) ease of analysis and b) potential for GHG mitigation when picking which strategies to evaluate using off-model analysis (Table 2). There were not enough resources within the scope of this project to conduct a sophisticated evaluation of all mitigation strategies discussed in the *Transportation-Related Greenhouse Gas Mitigation Strategies and Potential Applications in Central New Mexico* report developed for this project.

Table 2: Matrix of Mitigation Strategies and the Magnitude of Their Potential to Mitigate Climate Change and Their Analysis Capability. Source: UNM.

Strategy	GHG Mitigation Potential	Analysis Capability
Analysis Completed During the Scenario Planning Phase		
Zoning changes	●●●●● L	●●●●● U
Infill development	●●●●○ L	●●●●○ U
Transit oriented development	●●●●○ L	●●●●○ U,C
Improving public transportation	●●●○○ S	●●●○○ C
High Priority or Potential GHG Mitigation Effectiveness (Post-workshop Analysis)		
Urban growth boundaries	●●●●● M	●●●●● U
"Wheels" tax (VMT charging) & Gas Tax	●●●●● S	●●●●○ C
Bicycle infrastructure improvements	●●●○○ S	●●○○○ O,P,Q
Incident management	●●○○○ S	●○○○○ Q
Traffic signal enhancement	●●●○○ S	●●●○○ C,P
Establishing roadway connectivity standards	●●●○○ L	●●●●○ C
Lower Priority or Lower Potential GHG Mitigation Effectiveness		
Bike sharing	●○○○○ S	●○○○○ Q
HOV facilities	●○○○○ M	●○○○○ Q,P
Building design standards	●●○○○ L	●○○○○ Q
Establishing a complete streets policy	●●○○○ L	●○○○○ Q
Road pricing (HOT lanes/congestion	●●●○○ S	●●○○○ C,P
Parking management	●●●○○ S	●●●○○ C
Car sharing	●○○○○ S	●○○○○ Q
Ride sharing	●○○○○ S	●●●○○ Q,C
Travel demand management-educational	●○○○○ S	●○○○○ Q
Travel demand management-transit	●●●○○ S	●●○○○ Q,P
Intersection improvement	●○○○○ S	●●●●○ P,C
Electric vehicle infrastructure support	●●○○○ M	●○○○○ Q,M
Heavy-duty vehicle retrofit	●○○○○ M	●●●●○ Q,M
Truck-stop electrification technologies	●○○○○ S	●●○○○ M

●○○○○ → ●●●●● (Low → High)

L = long term
M = medium term
S = short term

U = UrbanSim, C = CUBE,
M = MOVES, O = Off Model,
P = Post Process, Q = Qualitative

The technical reports developed for this project discussed all of the above strategies in detail. The consultant team analyzed all but two of the Higher Priority/High Potential strategies for their GHG mitigation potential using a combination of methods other than CUBE and UrbanSim. These included qualitative analysis based on existing literature on the subject, off-model analysis that applied quantitative factors developed from separate studies in other regions to the local context, and post-processing analysis whereby the consultant team adjusted the model using calculations developed outside of the model that were then fed back into the model. A detailed discussion of this process is available in the technical reports available on the **CCSP project website**.[41]

4.4.3 Evaluation of Climate Change-Related Performance Measures

The project team used these models and other methodologies to evaluate the scenarios on several climate change adaptation and mitigation measures in preparation for and following the workshops. Figure 32 presents the results of the analysis for the final scenarios. A detailed explanation of the methodologies and results are included in the consultant final report and task memos available on the **CCSP project website**.[42]

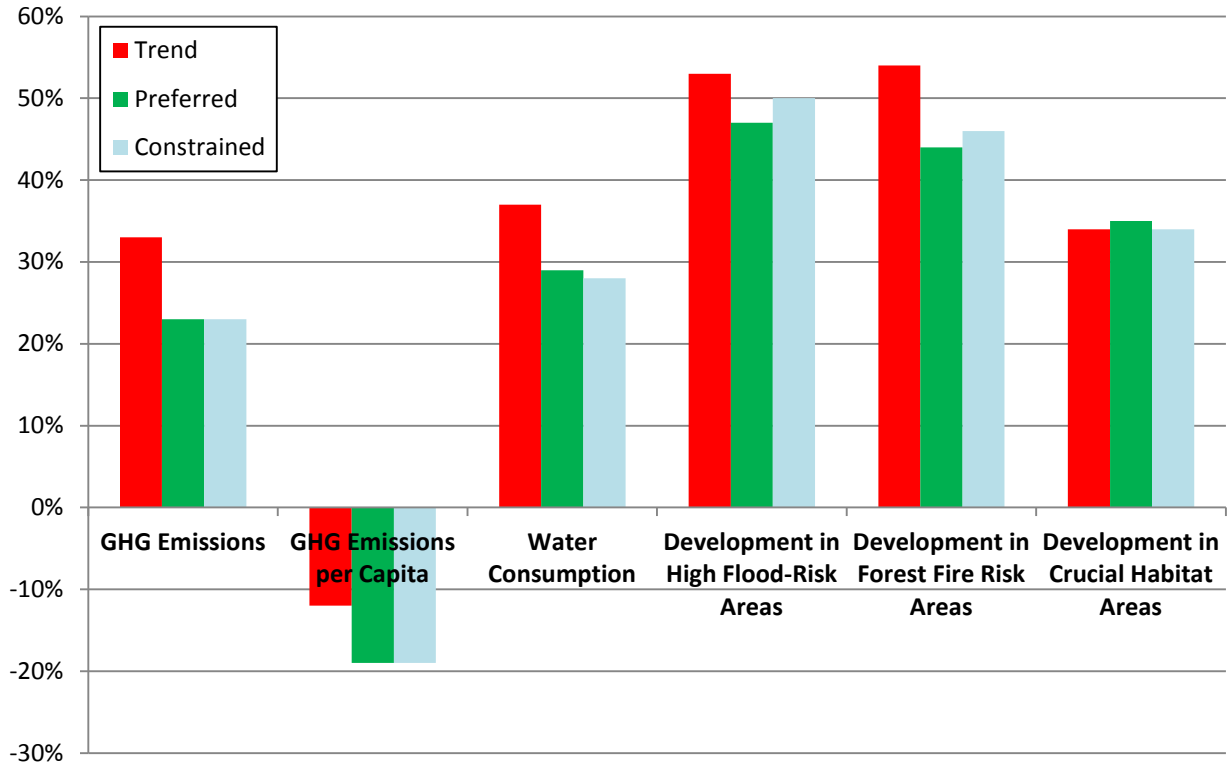

Figure 32: Percent Change in Climate Change-Related Performance Measures between the Present and 2040. Source: EMI and UNM.

4.4.4 Possible Impacts of Climate Futures in Central New Mexico

Because the Upper Rio Grande Impact Assessment analysis indicated that water availability is likely to decrease by as much as one third due to the effects of climate change,[43] the consultant

[41] **www.volpe.dot.gov/NMScenarioPlanning**
[42] Ibid.
[43] Llewelyn, et. al., 2013. 118.

team analyzed **water consumption** by collecting the median per-acre consumption rates for agriculture, industrial, institutional, residential, and commercial land use. Extrapolated consumption rates were based on 2013 water uses account data provided by the Albuquerque Bernalillo County Water Utility Authority. The project team evaluated this database of water use by linking it to MRCOG's parcel level data. Among the findings from this analysis is that residential land uses much more water on average than other land uses. A large range of water consumption rates exist among residential uses, with multifamily residential developments generally using less water per household than single-family residential developments. The Preferred and Preferred-Constrained Scenario resulted in less water consumed (Figure 33).

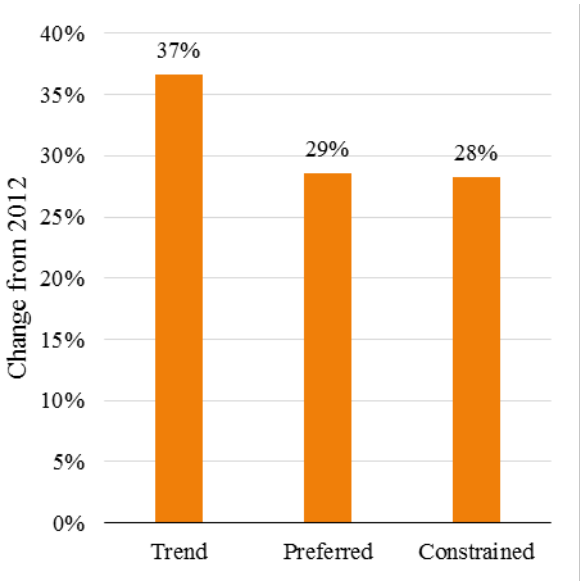

Figure 33: Growth in Water Consumption between Scenarios. Source: UNM.

The climate model results for precipitation are less certain than they are with regard to temperature. The wet scenarios; however, will likely result in a higher incidence of extreme precipitation because the higher temperatures will allow the atmosphere to hold more water vapor.[44] This warming atmosphere tendency may result in an increase in the frequency of 100-year storm events. The consultant team evaluated **development in High Flood Risk Areas** by mapping the FEMA 100-year floodplains along with areas where development could occur within these floodplains under each scenario. The largest changes expected for development in flood zones are for multifamily residential areas. The Preferred and Preferred-Constrained Scenarios resulted in fewer square feet of development in floodplains than the Trend Scenario (Figure 34).

[44]CLIMAS. 8.

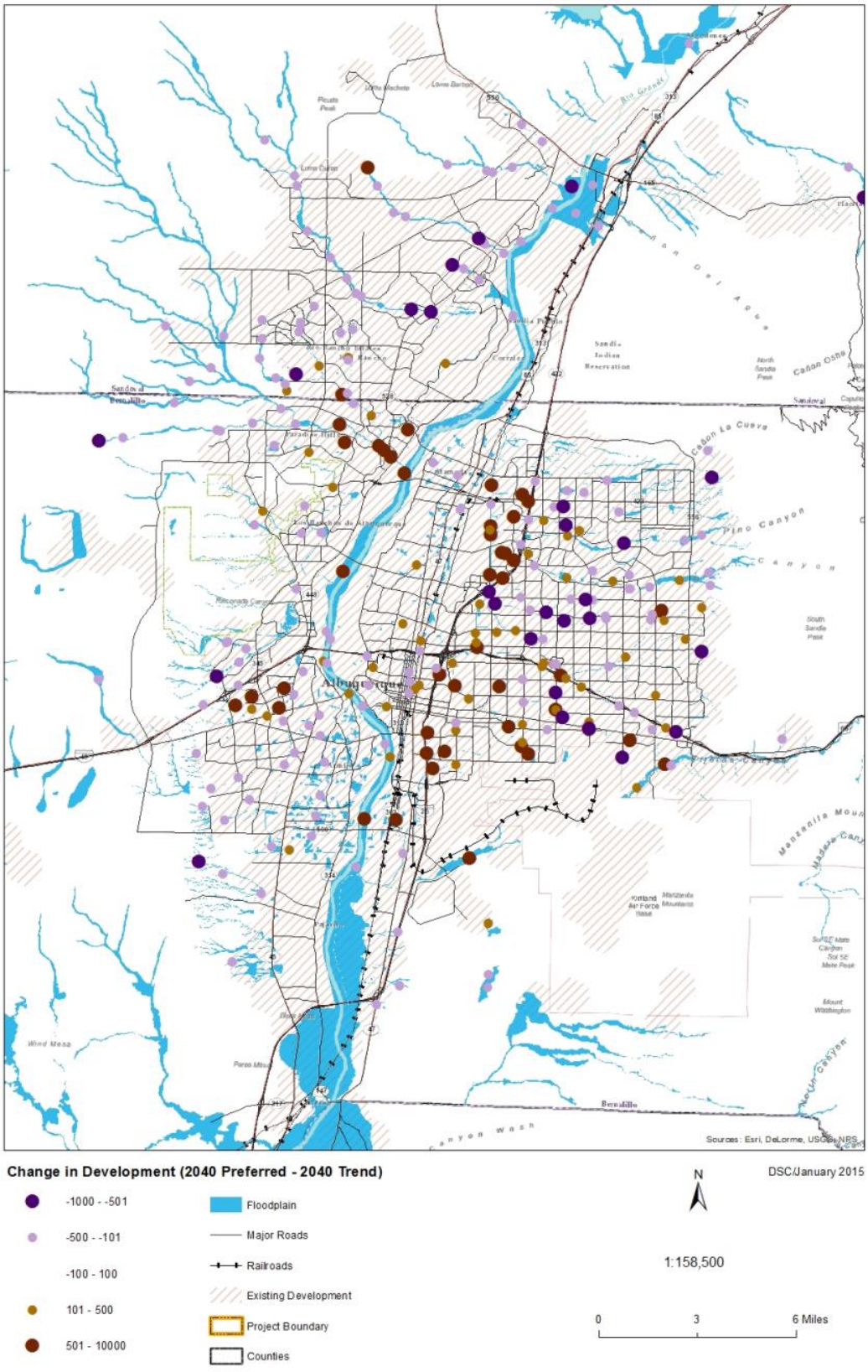

Figure 34: Change in Development in Floodplains between Trend and Preferred Scenario. Source: EMI.

In addition to this limited analysis of the region's floodplains, the Southern Sandoval County Arroyo and Flood Control Authority (SSCAFCA) used the climate futures projections from this project to conduct a limited modeling of future flood risk at one location to determine if future storms are higher intensity. SSCAFCA modeled the change in the peak flows and inundation that would occur along the upper Calabacillas Arroyo if rainfall for the 24-hour 100-year design storm increased by 10 percent and 25 percent. These increases are hypothetical, since SSCAFCA, like the project team, did not have the resources to complete a robust analysis of how global climate change may affect incidences of extreme precipitation. Using these assumptions, SSCAFCA modeled the change in peak flows and inundation using a hydrologic model recently developed by SSCAFCA and the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA). The results indicated that a 10 percent increase in precipitation from the 24-hour 100-year design storm results in a 25 percent increase in peak flows in the arroyo, while a 25 percent increase in precipitation from the 24-hour 100-year design storm results in a 75 percent increase in peak flows. This analysis shows that if climate change produces higher intensity storms (and this project did not do this with any certainty), flood risk may expand to locations outside of the 100-year flood zones.

The consultant team identified major roads and bridges in the flood plain by performing a GIS analysis of major transportation facilities in the current 100-year flood plains. Most of these facilities are located near streams and arroyos, which can be unpredictable areas of flash flooding particularly during the summer monsoon season (Figure 35).

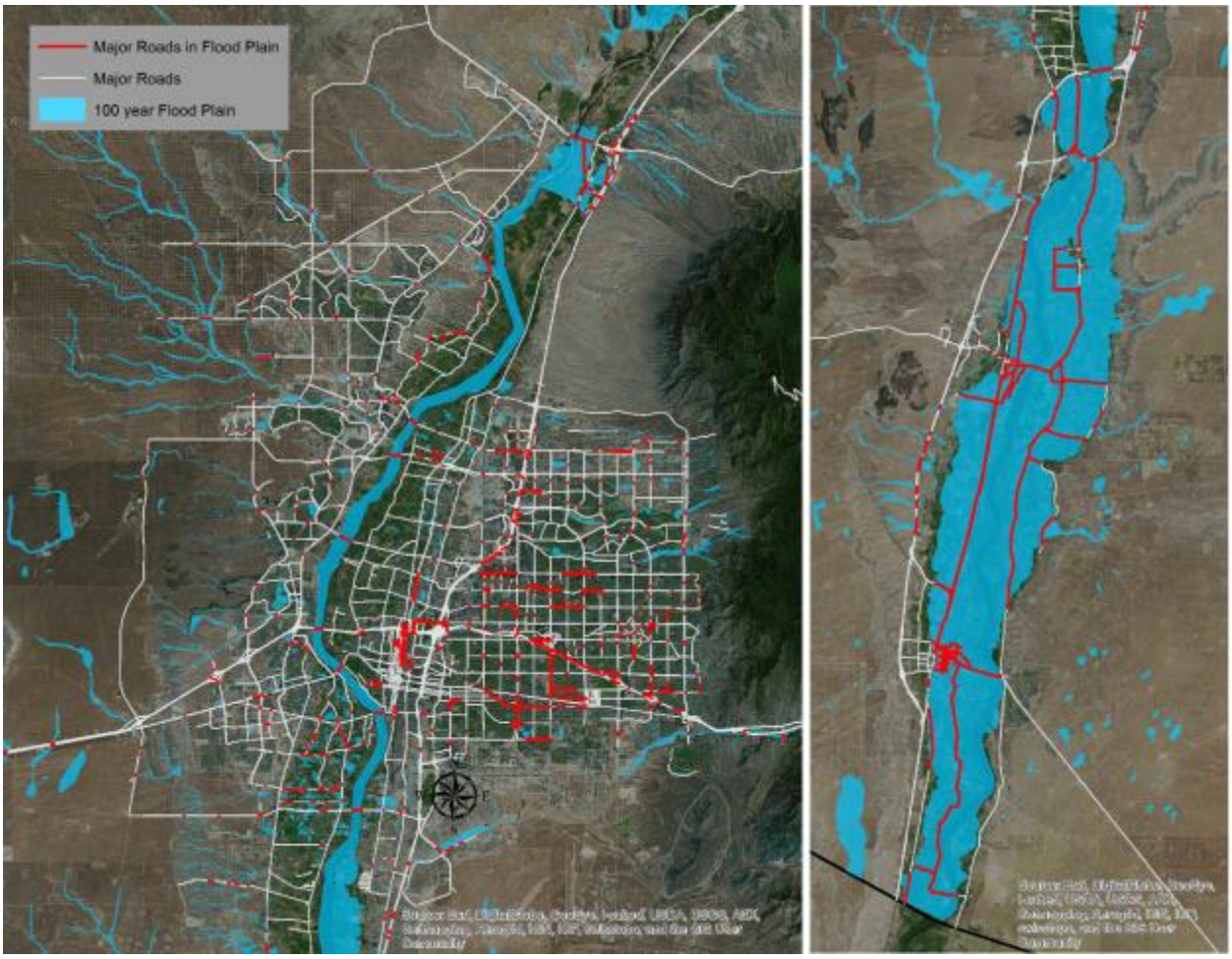

Figure 35: Major Roads (in Red) in 100-Year Floodplains (in Blue). Source: EMI.

The consultant team analyzed **development in Forest Fire Risk Areas** by developing a GIS layer demarcating wildfire risk areas within wildland urban intermix (WUI) areas where housing is within wildfire reach. Wildland urban interface areas with mixed housing and low-density vegetation within fire's reach were also mapped (Figure 36).

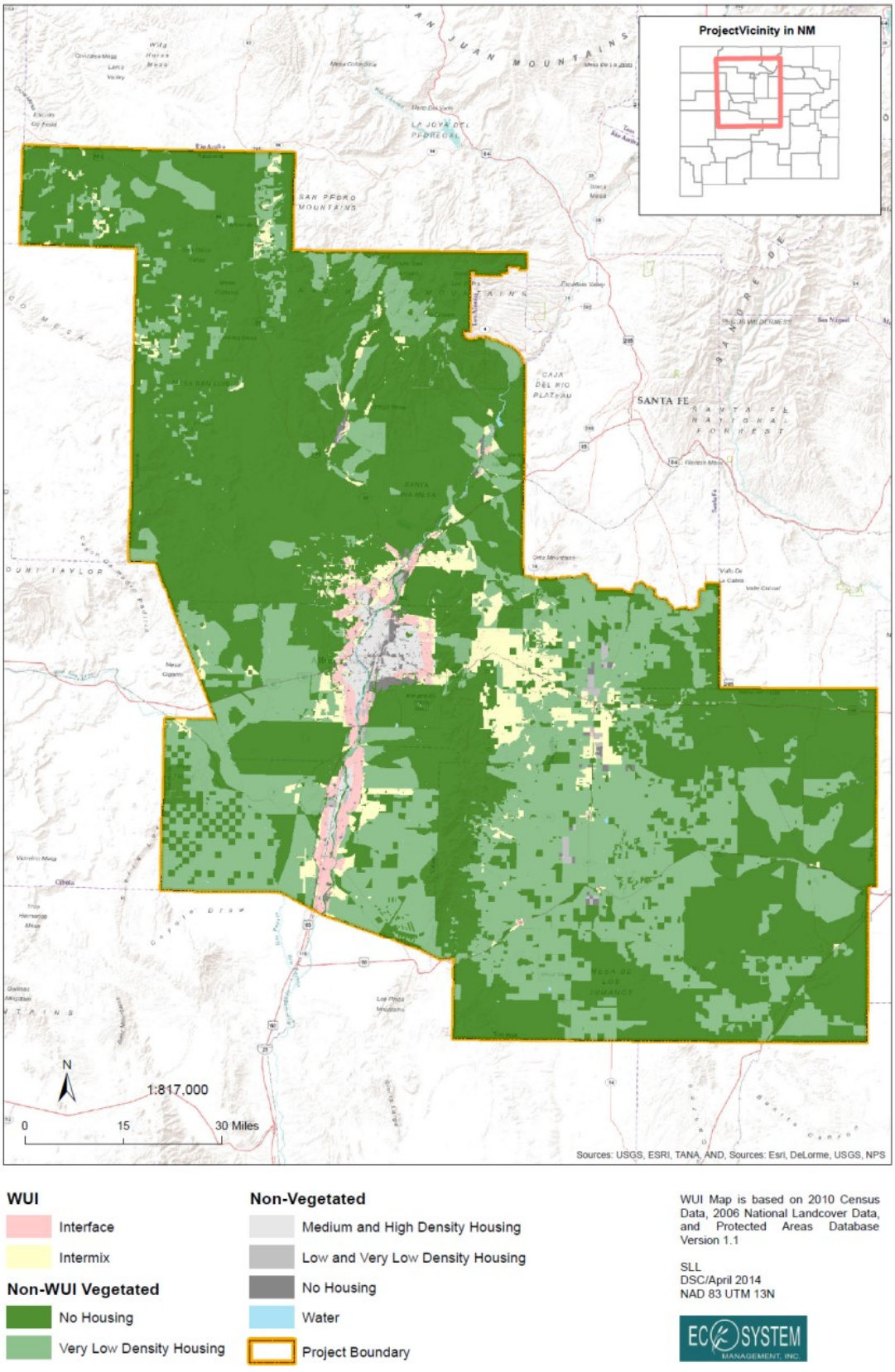

Figure 36: Wildland Urban Interface/Intermix (WUI). Source: EMI.

The consultant team demarcated the wildfire risk areas using modeled fire behavior parameters (rate of spread, flame length, crown fire potential) and ecological conditions to calculate fire risk. The consultant team then compared the scenarios based on the amount of new household and employment growth in the wildland urban intermix and interface areas. The Preferred Scenario showed slightly less development in these areas than the Trend and Preferred-constrained scenarios (Figure 37). It is important to consider fire risk in planning for future growth, particularly in the West, because rising temperatures will increase the likelihood and severity of forest fires (e.g., one study estimates that a 1.8-degree Fahrenheit increase in average temperatures in the project area is expected to result in close to six times the acreage burned).[45] Climate change may also result in a higher incidence of lightning strikes, which is a common igniter of forest fires.

[45] Funk, J., S. Saunders, T. Sanford, T. Easley, A. Markham. 2014. Rocky Mountain Forests at Risk: Confronting Climate-driven Impacts from Insects, Wildfires, Heat, and Drought. Union of Concerned Scientists and the Rocky Mountain Climate Organization, Cambridge, MA.

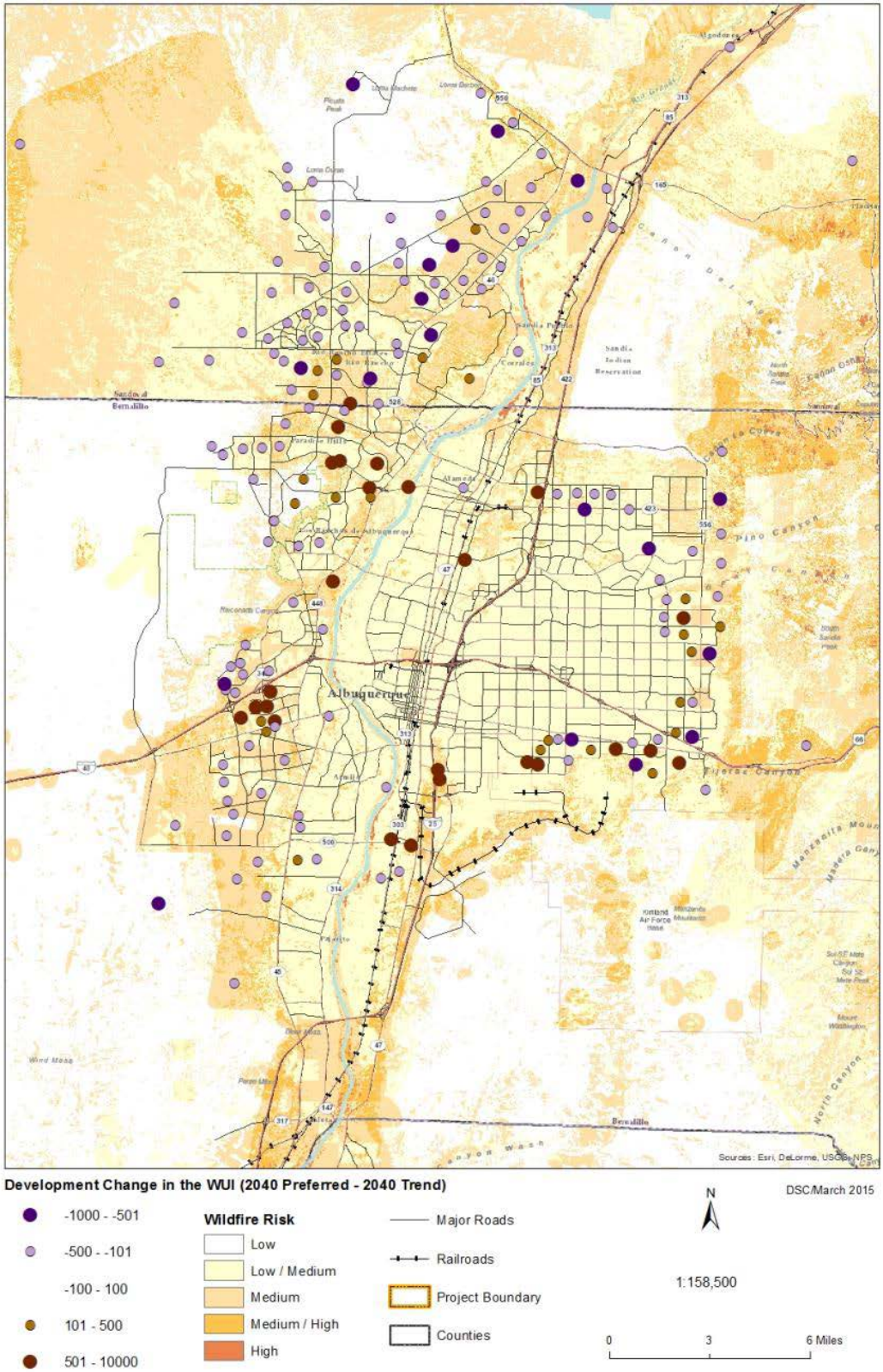

Figure 37: Change in Development in WUI between Preferred Scenario and Trend Scenario. Purple indicates less development in wildfire risk areas in the Preferred Scenario. Source: EMI.

The consultant team analyzed **development in Crucial Habitat Areas** by using the Western Governor's Association's Crucial Habitat Assessment Tool (CHAT) ratings throughout New Mexico. Each square mile of the State is given a score from 1 to 6 on the likelihood it contains natural resources that contribute to crucial habitat with six representing areas having the most crucial habitat based on:

- Species of concern (animals and plants),
- Wildlife corridors,
- Terrestrial species of economic and recreational importance,
- Aquatic species of economic and recreational importance,
- Freshwater integrity (watershed status),
- Large natural areas, and natural vegetation communities of concern.

Figure 38: A Crossing of the Rio Grande River. Source: FHWA.

These data were overlaid with the change in development for each scenario giving each area of analysis a development impact score. Adding these development impact scores indicated different levels of impact for each land use scenario. The Preferred Scenario had slightly more development in areas of crucial habitat than the Trend scenario. The reason for this difference is likely because the Preferred Scenario includes more development in the urban core near the Rio Grande River (Figure 38), which is an area of critical importance for species survival and migration. This result prove what may be advantageous for many objectives, is maladapted to another. The region may wish to view this finding as an opportunity to more carefully manage and protect crucial habitat in urban areas.

4.4.5 Greenhouse Gas Emissions Strategy Evaluation

The consultant team evaluated **GHG emissions levels** using the integrated transportation and land use model with MOVES. Each scenario produced different amounts of VMT because of network differences, land use differences, and differences in the modes of transportation available for travelers in the region. The Preferred and Preferred-Constrained Scenarios performed significantly better than the Trend in GHG emissions, but still resulted in higher emissions than today because population and employment growth will increase overall trips in the region. The MOVES model indicates that GHG emissions per capita will decrease under all scenarios due to better fuel economy for cars from light-duty and heavy-duty vehicle CAFE standards (Figure 39).

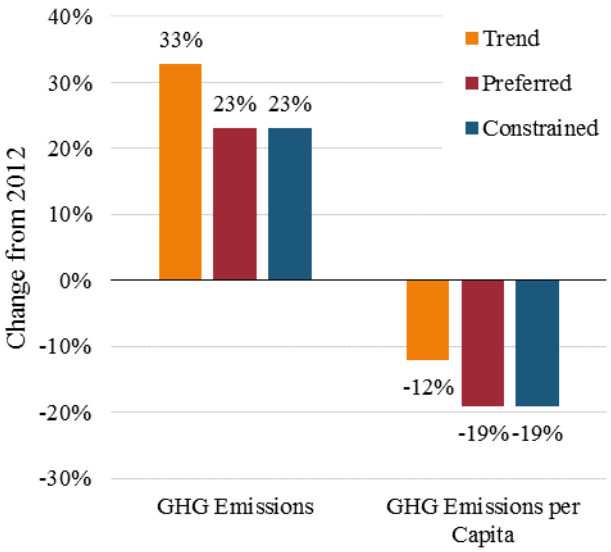

Figure 39: GHG Emissions for Three Final Scenarios from Model Results. Source: UNM.

The consultant team also evaluated several GHG emissions reduction strategies using post-processing or off-model analysis. The analysis showed statistically significant results for four strategies (Table 3). These strategies included a) restricting future development within a boundary, b) applying a mileage tax at a rate higher than the average current fuel tax, c) building the bicycle network in the MRCOG bicycle plan, and d) completing traffic signal timing along major roadway corridors in the Albuquerque area. The detailed methodology for this work is presented in the technical report on the **CCSP project website**.[46]

Table 3: Estimated CO2 Reduction from Four Additional Strategies Using Off-Model and Post-Processing Analysis. Source: UNM.

Strategy	CO2-eq Reduction
Growth Boundary	512 tonnes/3.8%
VMT Tax 0.005 per mile[a]	107 tonnes/0.8%
VMT Tax 0.03 per mile	780 tonnes/5.8%
VMT Tax 0.12 per mile	2,384 tonnes/17.9%
Bicycle Infrastructure	49.1 tonnes/0.4%
Traffic Signal Enhancement	27.6 tonnes/0.2%

4.5 MRCOG's Metropolitan Transportation Plan

MRCOG adopted two scenarios to inform the update to the 2040 MTP in 2015. It must adopt the Trend Scenario because it is the likely pattern of development based on current local zoning, plans, and transportation investments included within the MTP. It also adopted a scenario similar to the Preferred Scenario from the CCSP as an aspirational scenario to reflect the region's desire for future development. The transportation project list used in the initial scenarios for the CCSP was also reduced by the policy board as member governments came to

[46] **www.volpe.dot.gov/NMScenarioPlanning**

appreciate the need to maintain existing infrastructure before building new roads. The MTP discusses the climate change analysis presented here and offers implementation strategies with general steps that MRCOG and its partners are to take to move the region toward its preferred vision. It is MRCOG's intent to continue to work with its partners to refine these strategies into specific action steps over the five-year life of the plan.

The MTP recognizes that more compact and managed development will make the region more resilient to the effects of climate change, reduce emissions, and result in benefits to travelers. The MTP specifically discusses flood mitigation and the location of vulnerable areas as well as the importance of considering wildfire risk in setting up regions for targeted growth. The inclusion of these discussions into the LRTP is one of the first steps in making Central New Mexico more resilient to the effects of climate change, yet there is much work to be done. This work includes more detailed analysis of climate change impacts on infrastructure and development and greater coordination of regional partners in changing policies, resulting in a new direction for growth to which the region aspires.

The final task of the CCSP was developing an Integration Plan that describes ways the MPO, working with its regional partners, can move toward implementing several promising strategies discussed during the scenario planning process. MRCOG chose the strategies that were selected for inclusion in the Integration Plan.

5 Conclusions

Four goals and 12 related objectives guided the Central New Mexico CCSP. This conclusion section presents an evaluation of the success of this project in fulfilling its goals and objectives and provides recommendations for other regions interested in pursuing a similar project. This evaluation was informed with input from members of the project team and workshop participants who provided feedback on their experience in the scenario planning workshops as detailed in Appendix K.

In general, the project was able to meet its goals and objectives and workshop participants thought both workshops were successful in generating meaningful discussion of climate change in the region. Most of the project limitations explained below arose as project partners and stakeholders began engaging in the details of the project and gained an understanding of the extent of analysis necessary to make effective policy recommendations. A project with a large budget could allow for more face-to-face communication and give project partners and stakeholders more time and resources to fully engage with the topic. Such an expanded project could build on the following recommendations to create a transportation plan that includes specific implementation steps based on second-level impact analysis, such as flooding and drought.

5.1 Goals and Objectives

The Federal interagency working group that organized the scenario planning pilot project in Cape Cod, Massachusetts, developed the four project goals. Volpe Center staff developed the objectives under each goal based on discussions with stakeholders and MRCOG staff during initial project development.

5.1.1 Goal 1: Advance the role of climate change analysis in scenario planning.

This project will improve the state of the practice for integrating climate change adaptation and mitigation into regional transportation and land use planning using scenario planning processes.

The project advanced nascent scenario planning efforts in the Albuquerque area and allowed MRCOG to introduce the idea to stakeholders that some growth patterns are more robust to climate change impacts than others. This project also brought the relationship between regional growth and water availability to the forefront of discussions about managing the region's future development.

Objective 1a: Contribute to the state of the practice by identifying and testing new technical approaches to model and analyze climate change effects and impacts and GHG-emissions reduction strategies in a transportation and land use scenario planning process.

Successes:

- Using UrbanSim to provide a more realistic and quantitatively defensible prediction of future land use.
- Following an innovative approach to climate change mitigation analysis in scenario planning by using a state-of-the-art land use model integrated with a regional travel demand model to analyze GHG emission changes due to zoning changes, development location incentives, and transit and road investments.
- Developing methodologies for the off-model analysis of strategies like bicycle investments and signal timing.
- Integrating a wildfire risk analysis into the scenario planning effort and providing a methodology to be used in other regions of the country where wildfire risk is an issue that will likely increase in prominence with climate change.
- Identifying areas where development should ideally be limited such as existing floodplains, wildfire risk areas, and crucial habitat areas.

Limitations:

- Many of the adaptation strategies related to land use planning are outside the defined purview of an MPO, which is focused on transportation planning and programming Federal transportation funds. MPOs can suggest, recommend, and coordinate land use planning jurisdictions, but their authority to require certain actions in this field is limited.
- It would be helpful if UrbanSim were more transparent about what policy actions result when different shifters are applied to parcels in the model (e.g., expedited development review, tax incentives).
- Some climate impacts identified for the region, such as water scarcity and extreme precipitation, need more analysis in order to make informed data-driven decisions about land use and transportation.
- Identifying changes to existing floodplains in the region from increased precipitation was not possible within the scope of the project. Doing so would require data collection and analysis that exceeded the resources of this project due to the complexity of precipitation and drainage patterns in this region.
- MRCOG chose to include the planned roadway projects of its member governments in each of the transportation and land use scenarios because they felt that doing so would generate more buy-in to the process among elected officials. While this approach made the most sense for MRCOG at this stage of its planning process, this decision limited the ability to test how different bundles of individual transportation investments would affect land use patterns and measures related to GHG emission mitigation and climate change

adaptation. Without evaluating different sets of individual transportation investments from the outset, it was difficult to determine what kinds of transportation policies might reduce emissions the most and be the most robust under a range of climate futures. It also likely underestimated the impact of land use strategies that are meant to work in concert with transportation investments.

Considerations/recommendations:

- Analyze scenarios that have different bundles of individual transportation investments. Scenario planning is most valuable in the exploratory phase of planning and can help stakeholders understand the effects and trade-offs of differing policy directions so they can make decisions about transportation investments based on that understanding. MRCOG was able to do this to a limited degree through developing a constrained scenario that delayed transportation projects due to possible lower funding levels in the future. MRCOG also modeled different land use policies and incentives, but the MPO has less influence on land use than on decisions around transportation investments.
- Develop quantitative factors that identify the financial and infrastructure impacts associated with different types of climate change impacts to help policymakers apply climate analysis into decision-making about infrastructure and land use. FHWA now has several **tools**[47] available to assist in this kind of effort.
- Many regions in the country will face increased water scarcity due to climate change. It would be beneficial to develop a comprehensive study that examines the effect of different land use patterns on water consumption, as well as regional strategies to manage where growth occurs in order to preserve water resources.
- Further investigate projections for extreme precipitation based on existing knowledge about precipitation in the recent past applied to models that project precipitation in the future.

Objective 1b: Apply novel approaches to scenario development that account for a range of uncertainty given locally controllable policy options and externally uncontrollable forces.

Successes:

- The climate futures analysis accounted for a range of uncertainty by considering five plausible climate futures based on the analysis of downscaled climate projections data.
- The use of a constrained funding scenario was a novel way to approach uncertainty in future funding levels.

Limitations:

- The climate futures and other externally uncontrollable factors were not thoroughly or quantitatively integrated with the growth and investment scenarios.

[47] **www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/**

Considerations/recommendations:

- While this project analyzed climate futures for the MTP horizon year of 2040, planning for climate change requires thinking beyond the traditional planning horizon year even when the MTP only influences planning up to that year. Decisions about infrastructure investments should be informed by knowledge of the impacts a changing climate will have on a piece of infrastructure over the entirety of its useful life. Bridges, roadways, and other infrastructure built near the end of the long range plan will have lifetimes that extend well past 2100. In addition, land uses are essentially locked in for many decades after infrastructure is built, when impacts may be more serious than in 2040.
- A future project may wish to adjust the number and purposes of the public workshops. The first workshop could be devoted to summarizing literature findings on regional climate change impacts to transportation and land use, analyzing the likely future local conditions from different climate futures and, by drawing on research on the topic, identifying, in a general sense, what kinds of strategies might need to be taken in order to respond to the levels of risk inherent in these climate futures. The second workshop would be devoted to identifying transportation and land use policies and strategies that are either 1) robust under all climate scenarios, 2) reduce risk or serve as insurance against the worst case scenario, 3) can be adjusted over time as more information is available, or 4) prevent incidents for which the region has low-risk tolerance. Dividing the scenario planning project in this way (determining what is likely to happen and then focusing on what to do about it) would allow more time for regional decision-makers to use this analysis to determine the best policies and strategies to adopt in their long range plan and programming efforts.
- FHWA now has several **tools**[48] available to assist in climate impacts analysis. A future project should use these tools as well as methodologies from the FHWA pilot projects (Appendix J) to do some limited hydrologic modeling to estimate the increase in flood risk areas likely to develop because of climate change. The pilot project in New Jersey used regression analysis to model the expansion of existing floodplains. The Iowa DOT pilot project inputted climate data into the State hydrologic model to project future flood frequencies and identify bridge and roadway vulnerabilities in two river basins. These methodologies would not be perfect in the Central New Mexico context due to the complexity of the terrain and the relative uncertainty about precipitation; however they may provide a rough sense of the kinds of impacts that might be seen in specific areas of the region. After a first workshop that could focus on identifying what kinds of strategies might need to be taken in order to respond to risk implied by the climate futures, the second workshop could be an opportunity to engage the region's owners of transportation assets (the State DOT, cities, counties, transit agencies) in a focused discussion about vulnerabilities from potential climate change impacts.

5.1.2 Goal 2: Influence decision-making in Central New Mexico.

This project will inform MRCOG's 2040 MTP, municipal hazard mitigation plans, local and county land use plans, and Federal land management agency plans.

This project was strongly linked to MRCOG's 2040 MTP. The project and its results are discussed throughout the plan and several of the documents from the CCSP have been included

[48] **www.fhwa.dot.gov/environment/climate_change/adaptation/publications_and_tools/**

as appendices in the MTP or referenced in the document. The conversations the project generated between different groups in the region, such as the flood control authorities, FWS, BLM, the municipalities, and the MPO will be valuable to the region as it works to implement its strategies.

Objective 2a: As part of the scenario planning process, challenge existing assumptions and help participants identify difficult trade-offs.

Successes:

- The project helped to quantify the benefits of an alternative approach to growth and development. There is now a growing sense among stakeholders in the region that urban growth must take on a new form.
- One particularly valuable result from the analysis in the CCSP was identifying critical habitat areas and areas prone to wildfire. These kinds of geographically specific analyses can help the region better understand the risks associated with different development patterns and plan accordingly.

Limitations:

- The project did not force regional stakeholders to identify or make difficult trade-offs between different individual and sets of transportation investments vis-à-vis their resulting impact on GHG emissions, resilience, and other performance measures. MRCOG did not feel the scenarios would be accepted by policymakers if they began from a blank slate to identify individual transportation investments that had not been vetted by local governments first. It did; however, make stakeholders aware of areas of the region that may be risky for future development due to climate change impacts.
- Because the performance of the different scenarios developed for this project did not show exceedingly large differences between the scenarios, the benefits of new approaches to growth management seemed too modest, according to workshop participants.

Considerations/recommendations:

- Rather than beginning with hypothetical land use and transportation scenarios, begin by identifying performance measurement targets and build transportation and land use strategies that meet those targets under most or all climate scenarios. Approaching scenario planning this way would allow stakeholders to recognize the degree to which various measures need to be taken in order to meet performance objectives. A target-based approach like this may not result in “realistic” policy prescriptions but would give decision-makers a framework to address as many policy areas as they are able to influence. This approach would offer a different starting point for a planning process than is what is typical for a metropolitan transportation plan, but it could work in tandem with such a process.

Objective 2b: Tailor climate change adaptation and mitigation analysis to the local context, making products relevant to a range of stakeholders.

Successes:

- Synthesizing regional climate change research and developing climate futures data that will provide a basis for any future planning that considers climate change.

Limitations:

- MRCOG and its member governments do not that they have a clear sense of what to do with some of the new information. The project team developed an Integration Plan that dives into more details about several of the strategies of interest to MRCOG.

Considerations/recommendations:

- The analysis for the project did a good job of identifying climate change impacts for Central New Mexico, but more work needs to be done at the local level to identify risks to infrastructure and existing and future land use. Another project may wish to devote more time to second level analysis of climate impacts on transportation and land use (e.g., changes to flood risks, wildfire risks) under different climate scenarios rather than just temperature and precipitation. This kind of work would involve interviewing subject matter experts and devoting more time and resources to the analysis of geographic- and asset-specific sensitivities and impacts in the local area. This type of vulnerability assessment provides decision-makers more tools to put strategies in place that are specific to existing and future infrastructure and land use.

Objective 2c: Identify ways in which local decision-makers can prepare for a range of futures and build flexibility into land use and transportation plans and policies to best address uncertainties.

Successes:

- The project engaged the region in a conversation about alternative forms of development and climate change adaptation, rather than basing decisions on past trends alone. This analysis was at an appropriate scale for an MPO's LRTP.
- The Integration Plan for MRCOG provides some specificity about how MRCOG and its member governments can integrate the findings from this project into policy actions.

Considerations/recommendations:

- Focus more resources on developing policy actions required to address the risks presented by climate change in addition to or instead of the details of the risks themselves. If an area is flagged in the climate futures analysis as being particularly vulnerable to an adverse impact, then development should be minimized in that area. While the analysis completed for this project was appropriate for a typical LRTP, the region would benefit from more attention to, and articulation of, specific actions to minimize the risks from climate change scenarios.
- Other regions may be well-served to justify strategies primarily on their co-benefits. Because some people do not feel a strong sense of urgency over the issue of climate change, basing discussions on the many co-benefits of strategies can still result in better

climate preparedness or mitigation while still engaging decision-makers who are not singularly motivated by the climate change issue.

Objective 2d: Incorporate GHG-emissions reduction strategies and targets into regional planning efforts.

Successes:

- The work on GHG-emissions reduction strategies was robust and tailored to the local context.
- The MTP has incorporated the work from this project on GHG emissions reduction strategies.

Limitations:

- Reducing GHG emissions is not yet at the top of the region's current priorities in transportation planning; instead, mitigating GHG emissions is considered a co-benefit of other regional strategies.
- While GHG emission reduction strategies were analyzed as part of this project and will inform MRCOG's MTP, the scenario planning project did not incorporate target setting.

Considerations/recommendations:

- Set regional targets for GHG emission reductions and then work backwards from those targets to identify strategies that can help the region get on a course to meet these goals in a realistic fashion. Developing targets first and designing a transportation and land use pattern that results in that reduction gives stakeholders a better sense of what would be required to meet the targets, however ambitious they may be. If necessary, scenarios can then be refined to become more realistic and achievable.
- If reducing GHG emissions is not at the top of regional priorities, reframing the issue to support co-benefits of these strategies, such as energy efficiency, can help build support for strategies to reduce GHG emissions.

Objective 2e: Incorporate climate change futures, and an evaluation of the impact of these futures on proposed land use and transportation strategies, into regional planning efforts.

Successes:

- The climate futures are a useful framing mechanism for explaining potential impacts of climate change, and will continue to be useful to the region's planners in their efforts to guide policy on growth management.

Limitations:

- A need exists to provide a better understanding of the specific impacts from climate change, as well as finding more ways to utilize the information in daily decision-making.

Considerations/recommendations:

- Prior to developing conceptual land use and transportation scenarios, a future project may wish to first develop a complete picture of potential climate change impacts that is both applicable to the region as a whole (heat waves, drought risk), and geographically specific (flood risk, wildfire risk, sea level rise). Project planners may then use these futures as a base upon which to develop performance targets for growth management scenarios. This process would allow a region to develop its conceptual growth scenarios with an understanding of climate impacts. This approach would not have been feasible in the CCSP because it started at a later point in MRCOG's MTP development timeline, but a future project could offer a longer timeline to allow for a more full integration of climate impacts on decision-making.

5.1.3 Goal 3: Develop a transferable process.

The process and analytical methods developed for this project will be transferable to other regions.

The process and most analytical methods used for this project are transferable to any region that wishes to incorporate climate change in scenario planning. The project's reliance on modeling, however, means that this approach is most applicable to medium-sized and larger metropolitan areas that have some experience using travel demand and/or land use models. FHWA and other partners will disseminate the lessons learned from this project for the benefit of other regions interested in pursuing a similar approach to planning for climate change.

Objective 3a: Generalize and disseminate project information and lessons learned.

The project's methodology, lessons learned, and recommendations will be disseminated in formats such as webinars, peer exchanges, conference panels and presentations, and facilitation of conversations between MRCOG staff and staff of MPOs interested in pursuing a similar project.

Objective 3b: Develop an analytical and process framework that ties into other existing frameworks and is relevant and practical to other regions.

Successes:

- The CCSP was well-integrated within the 2040 MTP planning process as well as the BLM's Transportation Management Plan, which made the project immediately relevant as part of existing planning frameworks.
- The wildfire risk analysis is an approach that wildfire-susceptible regions of any size could use for LRTP and land use planning.
- While each MPO has a different modeling environment, the basic approach that MRCOG used in tying together economic, land use, and transportation models can be used by any MPO that uses models for transportation and air quality planning. This approach is going to be more applicable to medium- and large-sized MPOs who have more sophisticated modeling resources at their disposal. Smaller regions may need to find an approach that is less technically rigorous.

Objective 3c: Foster relationships between Federal agencies that can contribute to other regional and local projects elsewhere.

Successes:

- The project successfully brought together agencies that had never previously worked closely together. In particular, MRCOG benefited from new relationships with the many Federal land management agencies operating in the region, in particular the Bureau of Reclamation and USACE. This project provides a model for metropolitan areas to incorporate the participation of Federal land management and resource agencies into their planning processes and to tap their expertise and programming in areas like natural resource management. These relationships will become increasingly important for metropolitan planning in a changing climate.

Limitations:

- Among Federal agencies, the project could have benefited from more in-person Planning Group meetings in Washington, DC or Albuquerque. With limited resources, it was difficult to have more than a few in-person meetings between agency partners who were located in various parts of the country.

5.1.4 Goal 4: Build partnerships

The project will build and strengthen relationships between Federal, State, regional, municipal, and tribal governments.

The CCSP was successful at convening a wide range of stakeholders and agencies from the Federal and State government, and municipalities. These relationships generated productive partnerships around issues of mutual concern like water supply planning, flood mitigation, and air quality. In many cases, these individuals and organizations had not previously collaborated on any project. In the process of coordinating the CCSP, MRCOG elevated its role and visibility within Central New Mexico in such a way that positioned it to continue to provide leadership on issues of importance like climate change preparedness and mitigation.

Objective 4a: Develop and strengthen relationships between (and among) Federal, State, regional, and local agencies throughout the process.

Successes:

- Several partnerships that were utilized during this project were in place at its onset. However, the project improved connections between environmental, water resource management agencies, and land use and transportation planners that were not as strong prior to the project.
- The project brought together a wide array of stakeholders including locally elected officials, local planning departments, New Mexico DOT, water authority, flood control authorities, Federal land management agencies, and other Federal agencies.
- Workshop participants had positive feelings about the project and were energized by their engagement in them, especially related to discussion of growth scenarios.
- The CCSP fostered new relationships between MRCOG and the Bureau of Reclamation and USACE. These relationships will be particularly beneficial to the region as transportation and land use planners anticipate possible climate change impacts like increased flood risk, drought risk, and further strains on the region's water supply.

- The BLM and FWS both project funding partners, received technical assistance and planning resources related to the analysis that was completed for the CCSP.

Limitations:

- MRCOG acknowledges that sustaining and focusing on these new relationships for future work may be difficult without the express direction from MRCOG's board, as they fall outside the typical planning responsibilities of the organization. The Integration Plan contains some recommendations for MRCOG to work with some of the various agencies involved in this project in the future.
- There was little to no participation in the project from tribal governments. These stakeholders were informed by MRCOG of the project and invited to participate early in the project's development but were largely absent from the process.

Considerations/recommendations:

- A lot of work went into the mitigation and adaptation technical committees. It would be advantageous to have these stakeholders continue to meet to discuss the implementation of strategies that were discussed in those committees. Maintaining an ad-hoc committee would continue the promising information-sharing that those meetings fostered as MRCOG works toward adopting a regional vision that is closer to the Preferred Scenario.

Objective 4b: Create a structure by which local and Federal agencies involved in the climate change scenario planning process can continue to collaborate beyond the end of the project.

Successes:

- MRCOG is optimistic the new and improved relationships developed during this project will continue to benefit them as they work toward a new transportation and land use planning vision.

Limitations:

- This project did not create a new formal structure to continue to collaborate beyond this project.

Considerations/recommendations:

- Establish an MPO-led ad-hoc committee of Federal land management agencies, as well as other Federal agencies that support climate change adaptation and mitigation efforts like FEMA, NOAA, DOE, and USDOT to focus on issues of mutual importance as they arise.

5.2 Summary of Key Lessons Learned and Recommendations for Future Research

The Central New Mexico CCSP included some successful methodologies that other regions interested in pursuing a climate change scenario planning process can apply. The project also revealed a few key areas that would benefit from more attention in a future project. Below is a summary of these findings for MPOs and State DOTs to consider in future projects.

1. **Quantify the benefits of an alternative approach to growth and development.** Instead of a continuance of the status quo, there is now a growing sense among stakeholders in the Central New Mexico region that urban growth must take on a new form that takes into consideration resiliency to climate change impacts.

2. **Invite Federal land management and resource agencies to participate in the planning processes** and tap into their expertise in areas like natural resource management. These relationships can be beneficial as they may reveal possibilities for these agencies to contribute toward finding solutions to the problems that planners anticipate from climate change impacts, such as increased flood and drought risk, impacts to the natural environment, and further strains on water supply.

3. **Prior to developing conceptual land use and transportation scenarios, first develop a complete picture of potential climate change impacts** that is both applicable to the region as a whole (heat waves, drought risk) and geographically specific (flood risk, wildfire risk, sea level rise). Ideally, this analysis would involve developing quantitative factors that identify the financial and infrastructure impacts that could be associated with various climate change effects. The region could then use these factors to develop performance targets for their growth management scenarios. A performance target-based approach like this would give decision-makers a framework to identify transportation and land use policies and strategies that are effective under all climate scenarios, reduce risk against the worst case scenario, and prevent incidents for which the region has low risk tolerance. By performing this analysis early on, regional decision-makers would have more time to use the results to determine the best policies and strategies to adopt in their long-range plan and programming efforts.

4. **Plan for climate change beyond traditional planning time frames.** While this project analyzed climate futures for the MTP horizon year of 2040, decisions about infrastructure investments should be informed by climate change impacts on infrastructure over its lifetime, which can extend well past 2100.

5. **Use a variety of robust methodologies for estimating GHG emissions from different land use and transportation scenarios as well as analyzing variations in resiliency to climate change impacts.** UrbanSim provided a state-of-the-art land use model that, when integrated with the transportation model, resulted in a more realistic and quantitatively defensible prediction of future land use than traditional scenario planning methods would yield. This type of approach could be followed by MPOs that have similar modeling capabilities, with or without UrbanSim. The project also included useful off-model and post-processing analysis of GHG emissions reduction strategies like signal timing and bicycle investments that could currently not be integrated in the transportation and land use models.

6. **Where appropriate, integrate wildfire and flooding risk analysis into metropolitan transportation planning.** This project provides a methodology that could be applied in other regions of the country where wildfire risk is an issue, which will likely increase in prominence with climate change. Wildfire and flood risk can be added to other risk factors, such as crucial habitat vulnerability to guide development away from vulnerable locations.

7. **Examine the effect of different land use patterns on water consumption** as well as regional strategies to manage where growth occurs in order to conserve water resources. Many regions in the country will face increased water scarcity due to future climate change. This project included an analysis of water availability, but more complete data and transferrable methods of estimating the effect of different patterns of urbanization on water consumption could have tremendous value in other parts of the country.

8. **Analyze scenarios that have different bundles of individual transportation investments** (e.g., different future road and transit networks). Much of the focus of this project was on land use, and while MPOs do and should consider land use planning, they have less influence on land use than on decisions around transportation investments. Scenario planning is most valuable in the exploratory phase of planning and can help stakeholders understand the effects and trade-offs of differing policy directions so that they can make decisions about transportation investments based on that understanding.

This project demonstrated that it is possible to consider both resilience to climate change impacts and mitigation within a single planning framework. The project's successes and limitations provide helpful lessons for any entity similarly embarking on a planning effort that wishes to address climate change adaptation and/or mitigation.