FAR WEST TEXAS CLIMATE CHANGE CONFERENCE

Study Findings and Conference Proceedings

Texas Water Development Board
December 2008

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Preface

Letter to Participants from the Conference Program

June 17, 2008

Dear Conference Participant:

On behalf of the Texas Water Development Board and the Far West Texas Regional Water Planning Group, we would like to thank you for participating today in the Far West Texas Climate Change Conference. As directed by Senate Bill 1762, authored by State Senator Eliot Shapleigh during the 80th Texas Legislative session, the purpose of this conference is to review potential impacts of climate change on surface water supplies from the portion of the Rio Grande subject to the Rio Grande Compact. As part of this review, today's speakers will present an overview of potential climate change impacts to the Far West Texas region, as well as research and ongoing initiatives in New Mexico, Arizona, and Colorado. We will also hear from preeminent water managers in the region. In the afternoon, we will have the opportunity to brainstorm strategies to offset the potential impacts of climate change. We will also explore additional research needs and options to fund strategies and research.

Because of the unique geography and scarcity of water resources in Far West Texas, planners and water resources managers in the region are already at the forefront of innovative water management. We are honored to have with us today Senator Eliot Shapleigh and experts in the fields of climatology, geology, economics, and water management, as well as a diverse array of participants working together to identify potential impacts of climate change on water resources and to explore adaptation strategies to address these impacts. Findings from the conference will be delivered to the Texas Legislature by December 31, 2008, and will help inform the Far West Texas Regional Water Planning Group and the other 15 regional water planning groups in Texas on both science and policy issues related to climate change.

Thank you again for your participation, and we are confident that this conference will be an exciting and influential event.

Sincerely,
J. Kevin Ward
Executive Administrator

Acknowledgments

Far West Texas has long been at the forefront of progressive water resources management. Located in the most arid region of the state, residents recognize water is a scarce resource that must be managed with great care to ensure the region's economic health and quality of life. The Far West Texas region already employs a host of integrated water management strategies, including conjunctive use of surface and groundwater, the highest percentage of conservation strategies of any region in the state, wastewater reuse, and one of the largest inland desalination facilities in the world.

The Texas Water Development Board (TWDB) was therefore honored when Senate Bill 1762, authored by State Senator Eliot Shapleigh, directed TWDB to conduct a study regarding the possible impact of climate change on surface water supplies from the Rio Grande. In conducting the study, TWDB was directed to convene a conference within the Far West Texas Regional Water Planning Area to review analyses of potential impacts of climate change on surface water resources and make recommendations for incorporating potential impacts of climate change into the Far West Texas Regional Water Plan. This volume is meant to be a stand-alone reference as well as proceedings of the Far West Texas Climate Change Conference held in El Paso June 17, 2008.

Orchestrating the conference required a great deal of effort, and we are thankful for the assistance of many people. First, we would like to thank Senator Shapleigh and his staff, Sushma Jasti, Legislative Analyst, and E. Anthony Martinez, Communications Director, for their leadership and guidance. We would like to thank the members of the Far West Texas Regional Water Planning Group for their assistance in planning the conference, and El Paso Water Utilities - Public Service Board for their assistance with sponsorship of the conference, in particular Ed Archuleta, General Manager; Dr. Bill Hutchison, Water Resources Manager; Anai Padilla; and the gracious staff of the Carlos M. Ramirez Water Resources Learning Center. We are thankful for the assistance of Barbara Kaufman, Deputy Executive Director of the Rio Grande Council of Governments and administrator of the regional water planning process in the Far West Texas, and Dr. Ari Michelsen, Resident Director of the Texas Agricultural Research & Extension Center in El Paso. We would also like to thank the presenters for sharing their time and knowledge with conference participants.

We are grateful to TWDB staff, including Connie Townsend, Laila Johnson, Sonia Uribe, Dr. Shirley Wade, Dr. Robert Mace, Dr. Barney Austin, and Carla Daws for their invaluable assistance in planning, publicizing, and executing the conference. And finally we would like to thank all who attended the conference for their enthusiastic participation. We hope they will continue to be committed to thoughtful and cooperative planning for the water resources of Texas.

J. Kevin Ward
Carolyn L. Brittin
Kathleen B. Ligon

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1.0 Introduction

Water managers in Texas and beyond are struggling with how to incorporate the consideration of potential impacts of climate change in short- and long-term water supply planning efforts. Traditionally, water planners have assumed that weather patterns documented in the historical record will persist into the future (Groves and others, 2008). Planners have relied on the concept of “stationarity,” which assumes that natural systems fluctuate within a relatively stable envelope of variability (Milly and others, 2008). However, the range of natural processes has recently been challenged by tree ring-based reconstructions of streamflow that show that the window of natural variability is actually much broader than documented by the historical record. In fact, far worse droughts have occurred in previous centuries than the mid-20th century drought upon which Texas water planning is based. The stationarity assumption has also been challenged by human disturbances in watersheds such as land cover and land use changes, drainage modifications, large-scale infrastructure, and other alterations in natural hydrology that aggravate flooding, water quality, and water supply problems (Milly and others, 2008). One of the most daunting challenges to the stationarity assumption is mounting evidence, most recently highlighted by the International Panel on Climate Change, that the world’s climate itself is changing enough that it could have profound impacts on water resources and their management around the world.

Because of these concerns, State Senator Eliot Shapleigh from El Paso, Texas, authored Senate Bill 1762 during the 80th Regular Texas Legislative Session. The bill directed the Texas Water Development Board (TWDB), in coordination with the Far West Texas Regional Water Planning Group (list of members is provided in Appendix A), to conduct a study regarding the possible impact of climate change on surface water supplies from the portion of the Rio Grande in Texas subject to the Rio Grande Compact.[1]

In conducting the study, TWDB was directed to convene a conference within the Far West Texas regional water planning area to review

- any analysis conducted by a state located west of Texas regarding the impact of climate change on surface water supplies in that state;
- any other current analysis of potential impacts of climate change on surface water resources; and
- recommendations for incorporating potential impacts of climate change into the Far West Texas Regional Water Plan, including potential impacts to the Rio Grande in Texas subject to the Rio Grande Compact, and identifying feasible water management strategies to offset any potential impacts.

[1] Note: The Rio Grande Compact is an agreement between Colorado, New Mexico, and Texas that apportions the waters of the Rio Grande above Fort Quitman, Texas. Fort Quitman, a frequently cited landmark on the Rio Grande, was located 80 miles below El Paso in far southern Hudspeth County. Abandoned in the late 1800s, only a cemetery remains near the site of the fort today (Texas State Historical Association, 2008).

The legislation required that the conference include, but not be limited to, the participation of the following representatives:

- the Far West Texas Regional Water Planning Group
- water authorities
- industrial customers
- agricultural interests
- municipalities
- fishing or recreational interests
- environmental advocacy organizations
- institutions of higher education

TWDB was required to submit to the Texas Legislature a written report regarding the study findings by December 31, 2008. This report is intended to meet this statutory requirement by summarizing the proceedings from the Far West Texas Climate Change Conference, including speaker presentations and findings from three facilitated discussion sessions. To provide a backdrop on the importance of this conference and why it was initiated, this report begins by giving background on the regional water planning process in Texas, with information on the Far West Texas Regional Water Planning Group and a summary of the latest Far West Texas Regional Water Plan. The report also provides a brief overview of climate change science and why the issue of climate change is important to the regional water planning process.

This report is intended to be a tool for the Far West Texas Regional Water Planning Group, other regional water planning groups in Texas, and TWDB to use in addressing the issue of climate change in water resources planning and management. This study involved no original research and is not intended to comprehensively address the potential impact of climate change on water resources in the state of Texas. Nor does the report address the potential causes of climate change or mitigation of any potential causes.

In order to prepare for the conference, TWDB staff conducted two planning meetings and consulted with members of the Far West Texas Regional Water Planning group. Senator Shapleigh and his staff provided guidance on topics, speakers, and the general concept for the conference. In addition to a press release and media advisory, invitations were extended to all voting and nonvoting members of the Far West Texas Regional Water Planning Group, all water utilities in the Far West Texas regional water planning area, all members of the Border Legislative Conference, chairs and designated political subdivisions of all other regional water planning groups in Texas, and many other groups and individuals who might have found the conference of interest or whose representation was required by statute.

The Far West Texas Climate Change Conference was held June 17, 2008, at the Carlos M. Ramirez Water Resources Learning Center in El Paso, Texas. Over 100 individuals attended, including members of the Far West Texas Regional Water Planning Group and representatives from state and federal agencies, environmental organizations, water providers, universities, and other entities (Appendix B). J. Kevin Ward, TWDB Executive Administrator, provided welcoming remarks and Senator Shapleigh gave an introduction.

Speakers included climate change scientists from Texas, New Mexico, Arizona, California, and Colorado and leading water managers from the Far West Texas region. Texas and the western United States are fortunate to have a large number of researchers committed to the topic of climate change. Unfortunately, the conference schedule allowed for only a handful of these researchers to participate.

Dr. Gerald North, Dr. Bruce McCarl, Dr. John Nielsen-Gammon, Dr. Charles Jackson, and Dr. Edwin Maurer provided an overview of potential climate change impacts to the Far West Texas region. Dr. Brian Hurd, Dr. Connie Woodhouse, and Nolan Doesken, Colorado State Climatologist, gave a perspective on climate change from other states. Rio Grande Compact Commissioner Patrick Gordon, Wayne Treers, Gary Esslinger, Dr. Bill Hutchison, and Jesus Reyes gave an overview of current and proposed water management strategies for Far West Texas.

The following concurrent facilitated discussion sessions were held after the conclusion of presentations:

- Potential Water Management Strategies to Address Climate Change in Far West Texas
- Research Needs to Address Climate Change in Regional Water Planning
- Potential Options to Fund Water Management Strategies and Research

An overview of conference proceedings is available in Chapter 4 of this report. The chapter includes presentation summaries, with the presenter's title and biography, abstract (if provided), and summaries of notes from the three discussion sessions. Complete conference presentations are available in Appendix C, in the compact disk at the back of the report. They are also available online at http://www.twdb.state.tx.us/wrpi/climate/climate_conference.htm.

2.0 Water Resources Planning and Management in Far West Texas

2.1 The Rio Grande

The Rio Grande is one of the most important water resources in the Far West Texas region and in the western United States. It originates in southwestern Colorado and northern New Mexico where it derives its headwaters from snow melt in the Rocky Mountains. The river flows southward through New Mexico and then forms the international boundary between Mexico and Texas. The Rio Grande's total length is almost 1,900 miles, with approximately 1,248 miles making up the international boundary.

The waters of the Rio Grande and its tributaries are used for recreational, agricultural, and municipal uses. With the exception of the Rio Grande, very little surface water is a reliable source of supply in Far West Texas, especially during drought conditions (FWTRWPG, 2006). In New Mexico, Elephant Butte Dam and Reservoir, approximately 125 miles north of El Paso, can store over 2,000,000 acre-feet of water from the Rio Grande to meet irrigation demands in the Rincon, Mesilla, El Paso, and Juarez valleys. Below Elephant Butte, flow in the river is largely controlled by releases from Caballo Reservoir in southern New Mexico. Most of the Rio Grande's flow above Fort Quitman, Texas, is diverted at the Mesilla Dam in New Mexico and at the American Dam in Texas. Water is also diverted at the International Dam to supply irrigation demand in Mexico as stipulated by treaty.

Downstream from El Paso to Fort Quitman, flow in the river consists mostly of treated municipal wastewater from El Paso, untreated municipal wastewater from Juarez, and irrigation return flow. Below the El Paso-Hudspeth county line, flow consists mostly of irrigation return flow and occasional floodwater and runoff from adjacent areas. The flow from Fort Quitman to Presidio is frequently intermittent and the section is often referred to as the "Forgotten River" reach of the Rio Grande. The river becomes a permanent stream when it is joined by the Mexican tributary, the Rio Conchos, just upstream of Presidio. From Presidio downstream until it reaches Amistad Reservoir near Del Rio, the Rio Grande often lacks sufficient flow to adequately support minimum recreational, environmental, or agricultural needs (FWTRWPG, 2006).

Because its waters are shared between three U.S. states and Mexico, a system of federal, state, and local programs has been developed to oversee the management of the Rio Grande. The following provide a legal framework for its management:

1906 International Treaty—The treaty between the United States and Mexico obligates the United States to deliver 60,000 acre-feet of water annually from the Rio Grande to Mexico at no cost and in accordance with a monthly distribution schedule from February through November. The International Boundary and Water Commission and the Comisión International de Límites y Aguas are the designated binational agencies that oversee the yearly delivery of international waters to Mexico. The U.S. Bureau of Reclamation calculates the allocations in coordination with the International Boundary and Water Commission.

Rio Grande Compact—Signed in 1938 between the states of Colorado, New Mexico, and Texas, the compact was ratified by the U.S. Congress and approved by the President of the United States. The purpose of the compact is to equitably apportion the waters of the Rio Grande Basin above Fort Quitman and to schedule regular deliveries of water. The Rio Grande Compact Commission administers the compact to ensure that Texas receives its equitable share of quality water from the Rio Grande as apportioned. The commission is composed of one representative from each state:

- the State Engineer of Colorado
- the State Engineer of New Mexico
- an appointee by the Governor of Texas

The current compact commissioners are Dick Wolfe for Colorado, John D'Antonio for New Mexico, and Patrick Gordon for Texas.

Rio Grande Project—The Rio Grande Project is a federal irrigation storage and flood control reclamation project administered by the U.S. Bureau of Reclamation. The project's primary facilities are Elephant Butte and Caballo reservoirs in New Mexico and diversion dams at the headings of main canals. The project delivers water to the Elephant Butte Irrigation District and the El Paso County Water Improvement District No. 1. The Elephant Butte Irrigation District encompasses project lands in New Mexico south of Caballo Reservoir, and the El Paso County Water Improvement District No. 1 encompasses project lands in El Paso County, Texas. Since 1941, the Water Improvement District has delivered water to the City of El Paso for municipal and industrial use through contracts between the district, the city, and the U.S. Bureau of Reclamation. The project also delivers water to Mexico in accordance with the 1906 Treaty.

1944 International Treaty—Outside the geographic scope of this conference and report, the 1944 treaty addresses the waters in the international segment of the Rio Grande from Fort Quitman, Texas, to the Gulf of Mexico. The treaty allocates water in the river based on percentage of flows from each country's tributaries. The 1944 Treaty also stipulates that one-third of the flow of the Rio Conchos in Mexico is allotted to the United States. Like the 1906 Treaty, the International Boundary and Water Commission is also responsible for implementing the 1944 Treaty.

2.2 Regional Water Planning in Texas

In response to the drought of the 1950s and in recognition of the need to plan for the future, the Texas Legislature created the Texas Water Development Board in 1957 to help communities develop adequate water supplies. The legislature also mandated that the TWDB begin a formal process for developing a plan to meet the state's future water needs. In 1997, the legislature established a new water planning process based on a consensus-driven approach at the regional level. As directed by Texas Water Code §16.053, TWDB promulgates administrative rules and provides technical and financial support of the regional water planning process. TWDB also designated the original regional water planning areas and is responsible for reviewing those designations every five years or when necessary.

The Region E, or the Far West Texas Regional Water Planning Group, was one of 16 regional water planning groups designated to coordinate the regional water planning process (Figure 1). Each planning group consists of about 20 members representing a variety of interests as defined by statute: agriculture, industry, environment, public, municipalities, business, water districts, river authorities, water utilities, counties, and steam-electric power generation. The Far West Texas Regional Water Planning Group and all other planning groups approved bylaws to govern their methods of conducting business and designated a political subdivision to administer the planning process and manage any contracts related to developing regional water plans. The Rio Grande Council of Governments administers the planning process for the Far West Texas region.

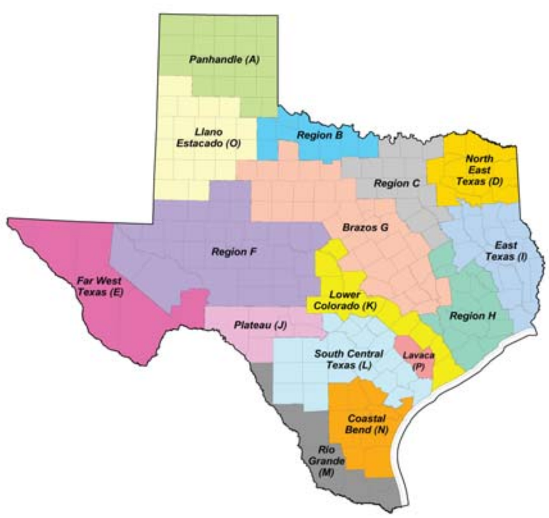

Figure 1. Location of the 16 regional water planning areas in Texas.

The ongoing work of the regional water planning process consists of seven tasks performed during each five-year planning period:

- Describing the regional water planning area

- Quantifying current and projected population and water demand
- Evaluating and quantifying water supplies
- Identifying surpluses and needs
- Evaluating water management strategies and preparing plans to meet the needs
- Recommending regulatory, administrative, and legislative changes
- Adopting the plan, including the required level of public participation

Once a planning group adopts its regional water plan, it is sent to TWDB for approval. TWDB then compiles information from all of the approved regional water plans and other sources to develop the state water plan. The Far West Texas Regional Water Planning Group adopted their first regional water plan in 2001 and their second plan in 2006. The Far West Texas plan, along with the 15 other regional water plans, was then compiled into the 2002 and 2007 state water plans. Development of the 2011 Far West Texas Regional Water Plan is now underway in the third round of regional water planning.

2.3 The Far West Texas Regional Water Plan

The 2006 Far West Texas Regional Water Plan follows the same general format as all of the 16 regional water plans. The plan provides a description of the planning area along with an evaluation of current and future water demands for all water use categories and an evaluation of water supplies available during drought conditions to meet those demands. Where future water demands exceed supply, water management strategies are considered and recommended to meet potential water shortages. The plan recognizes and protects existing water rights, water contracts, and option agreements, and no known conflicts exist between the Far West Texas plan and those prepared for other regions. The following information is summarized from the Far West Texas Water Plan (FWTRWPG, 2006) and the 2007 State Water Plan.

Planning Area Description

The Far West Texas planning area includes seven counties that lie within the Rio Grande basin (Figure 2). With some of the most impressive topography and scenic beauty in Texas, the region is home to the Guadalupe Mountains and Big Bend National Parks. El Paso, the largest city in the region, is also the nation’s largest city on the U.S.-Mexico border. Ciudad Juarez, with an estimated population of over 1.3 million, is located across the Rio Grande from El Paso and shares the same water resources. The largest economic sectors in the region are agriculture, agribusiness, manufacturing, tourism, wholesale and retail trade, government, and military.

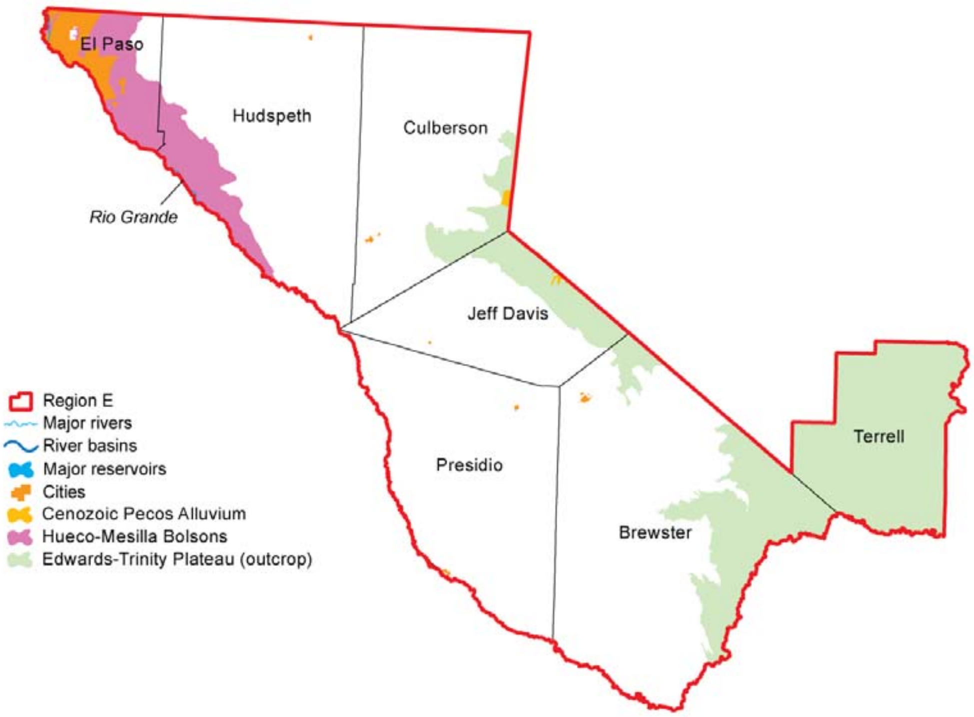

Figure 2. Far West Texas Region.

Population and Water Demands

With the exception of El Paso County, the counties of Far West Texas are some of the least populated in the state. Less than 4 percent of the state's total population is projected to reside in the Far West Texas region by 2010. Between 2010 and 2060, its population is projected to increase 79 percent to 1,527,713 (Figure 3), with 80 percent of the increase in El Paso County. In the year 2000, approximately 96 percent of theregion's 705,399 residents resided in El Paso County, where the population density is 760 persons per square mile. The population density of the six rural counties is approximately 1.1 persons per square mile. El Paso, one of the fastest growing cities in Texas, is the largest city in the region, with a year-2000 population of 563,662. This represents 83 percent of the total population of El Paso County and 80 percent of the regions's total population.

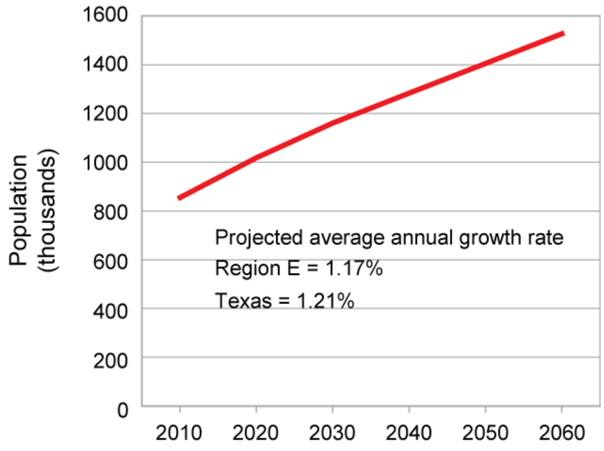

Figure 3. Projected population for 2010–2060.

The region's water demands will increase less dramatically than population growth during the planning period. By 2060, total water demands for the region are projected to increase 9 percent, from 662,608 acre-feet in 2010 to 721,071 acre-feet in 2060 (Figure 4). Total estimated year-2000 water consumptive use in Far West Texas was 665,793 acre-feet. The largest category of use was irrigation (508,266 acre-feet), followed by municipal (139,690 acre-feet), manufacturing (7,750 acre-feet), livestock (4,843 acre-feet), steam-electric power generation (2,962 acre-feet), and mining (2,282 acre-feet). Seventy-six percent of water use in the region is by the agricultural sector in support of irrigation. Twenty-one percent is used by municipalities, and the remaining 3 percent supports manufacturing, steam-electric power generation, livestock, and mining. Agricultural irrigation water use makes up the largest share of these demands in all decades even though it is projected to decrease 9 percent over the planning period, dropping from 481,042 acre-feet in 2010 to 435,657 acre-feet in 2060. Municipal water demand, however, is projected to increase 51 percent, from 155,375 acre-feet in 2010 to 234,351 acre-feet in 2060.

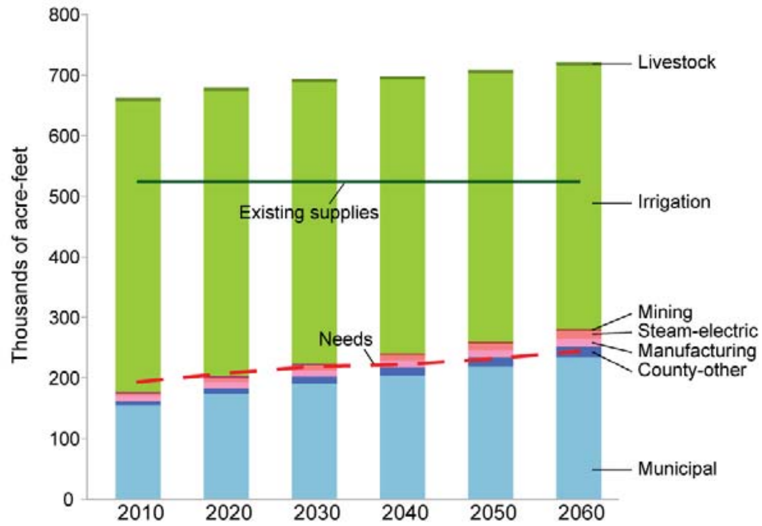

Figure 4. Projected total water demand and existing water supplies for 2010–2060.

Existing Water Supplies

The region's total water supply for 2010 is projected to be 524,301 acre-feet. Other than some irrigation use and El Paso municipal use, the Far West Texas region relies on groundwater for most of its water supply. Approximately 75 percent (395,458 acre-feet per year) of the region's water supply consists of groundwater from two major aquifers (Edwards-Trinity [Plateau] outcrop and the Hueco-Mesilla Bolsons) and six minor aquifers (Bone Spring-Victorio Peak, West Texas Bolsons, Capitan Reef Complex, Rustler, Igneous, and Marathon). The principal surface water sources are the Rio Grande and the Pecos River, supplying 82,246 acre-feet per year. Although no reservoirs are located in the planning area, a reservoir system in New Mexico, administered by the U.S. Bureau of Reclamation, regulates the Rio Grande and, thus, a portion of the area's water supplies. Direct reuse in the city of El Paso provides another 5,000 acre-feet and is expected to increase to over 23,000 acre-ft per year by 2060. Because of treaty and compact agreements as well as groundwater management district regulations, the total surface and groundwater supply is projected to remain relatively constant throughout the planning period.

Needs

In 2010, total water needs or shortages for the region are projected to be 193,171 acre-feet, with agricultural irrigation making up approximately 91 percent of the total, or 175,540 acre-feet (Figure 5). By 2060, water needs are expected to increase to 244,172 acre-feet, with irrigation again making up the largest share of the needs, 133,191 acre-feet (55 percent). Municipal needs are projected to constitute 81,883 acre-feet (34 percent) of the total 2060 needs. In addition, manufacturing, steam-electric power generation, and County-other categories are also projected to face needs.

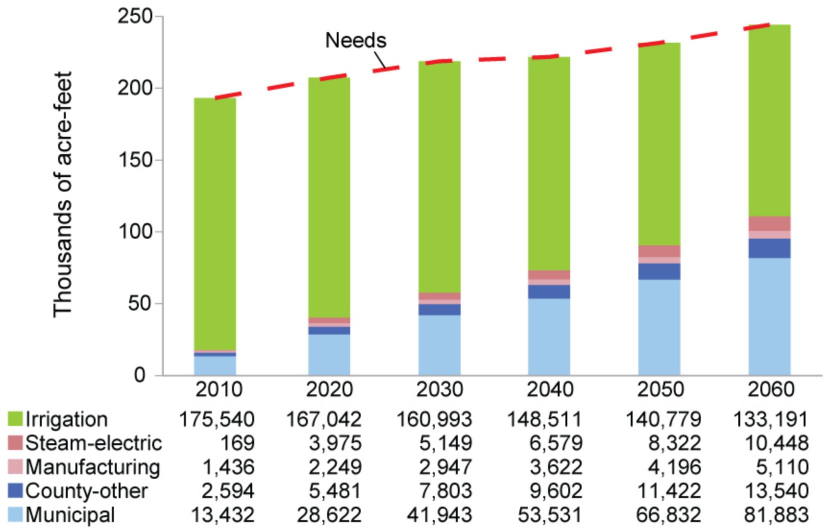

Figure 5. Projected water needs for 2010-2060

Recommended Water Management Strategies and Cost
To address water needs, the planning group recommended water management strategies for those water use groups that have projected water supply shortages (Figure 6).

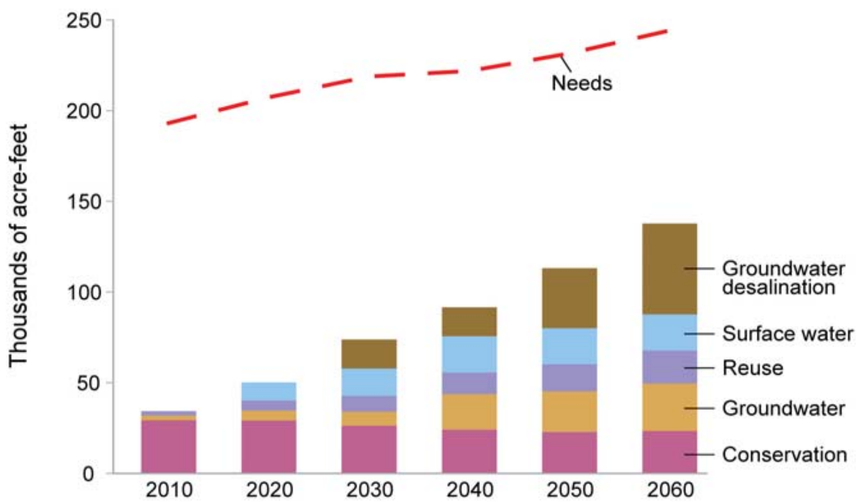

Figure 6. Recommended water management strategy water supply volumes for 2010–2060.

In El Paso County, an integrated approach was used to establish a feasible strategy capable of identifying sufficient future supplies to meet the needs of El Paso Water Utilities, the largest wholesale water provider in the county. The Far West Texas Planning Group considered six approaches that combined various potential surface water and groundwater sources at variable supply rates and times of implementation. Out of those six strategies, the planning group selected one, entitled "Balanced Approach with Moderate Increase in Surface Water," which is composed of the following elements:

- Increased conservation
- Increased reclaimed water use
- Increased use from the Rio Grande (developed conjunctively with local groundwater)
- Importation of groundwater from the Capitan Reef Aquifer (Culberson and Hudspeth counties)
- Importation of groundwater from the Bone Spring-Victorio Peak Aquifer in the Dell City area (Hudspeth County)

Recommended strategies for other entities in El Paso County include purchasing supplies from El Paso Water Utilities or developing groundwater by drilling additional wells.

Irrigation shortages in El Paso, Hudspeth, and Presidio counties are the result of insufficient water in the Rio Grande during drought periods. The quantity of water needed to meet the full demands cannot be realistically achieved. Farmers in the region generally approach this situation by reducing irrigated acreage, changing types of crops planted, or not planting crops until water becomes available. Because there were no economically feasible strategies identified, three counties in the region have unmet irrigation needs (over 133,000 acre-feet in 2060).

The total estimated capital cost to develop all recommended strategies during the 50-year time frame is $688,858,000.

3.0 Consideration of Climate Change in Regional Water Planning

3.1 Uncertainties in Regional Water Planning

Climate change is one of a number of uncertainties that are inherent in the regional water planning process. These uncertainties also include natural climate variability; the projection of future population, water demand, and availability of water supply; technology; science; policy; and the viability of recommended water management strategies. By revisiting the planning process every five years, regional water planning groups can address many of these issues. They can update population and demand projections and respond to changes in climate if a worse drought occurs. As policy changes at the federal, state, or local level, planning groups can adjust accordingly. And they can revise water management strategies based on newly acquired technology, updated cost figures, or the availability of new funding sources.

An approach for dealing with these uncertainties is of great interest to TWDB and the other regional water planning groups. Because of this concern, “Uncertainty and Risk in the Management of Water Resources” is one of TWDB’s six priority research topics for fiscal year 2009. TWDB is in the process of securing a contractor to research approaches for quantifying and considering the uncertainties and risks in water resources planning and management, focusing primarily on climate change and implementation of water management strategies. Specifically, the deliverable will be a recommended approach for integrating risk and uncertainty into the current round of regional water planning in Texas.

It is difficult to predict how drought may affect the Far West Texas region’s future water supplies, since climate is always dynamic and the climate of Texas is particularly variable. Regional water planning is based on the drought of record in the 1950s, which is the worst drought in recorded history in most of Texas. Although some argue that it is too conservative to plan for the drought of record, others argue that it is prudent to plan for an even greater drought. However, planning for the drought of record can address some of the uncertainty related to water supplies in the future (TWDB, 2007).

Drought poses one of the greatest challenges in water planning because its effects can be profound and it is generally unpredictable. Texas has experienced both long- and short-term statewide droughts as well as numerous regional droughts (TWDB, 2007). A normal part of the hydrological cycle, drought simply represents a drier-than-normal period. The severity of a drought depends on both its duration and intensity. It has three phases that typically develop in this order:

1. Meteorological drought, or a period of lower-than-normal precipitation

2. Soil moisture/vegetative drought, which is a result of meteorological drought and affects plants, wildlife, and crops

3. Hydrologic drought, which results in lower streamflows, lake levels, and water levels in aquifers

Assessing the uncertainty of drought in the Far West Texas region is particularly challenging. The region is unique because of the nature of its main surface water supply, the Rio Grande, which originates in Colorado and flows through New Mexico before reaching the Texas border. Because much of the flow of the Rio Grande depends on the spring thaw of winter snowpack in Colorado, water supply from the Rio Grande is more correlated with meteorological drought in Colorado than in Texas.

3.2 Potential Impacts of Climate Change on Water Resources

Climate change refers to variations in the global or regional climate over time, whether due to natural variability or as a result of human activity. Research suggests that over the 20th century the global average surface temperature has increased by about 1°F (Houghton and others, 2001). Eleven of the last 12 years (1995–2006) rank among the 12 hottest on record (IPCC, 2007). In addition, many areas, including the Northern Hemisphere and the tropics, are experiencing increased precipitation (Houghton and others, 2001).

Some of these changes have been attributed to human activities that have increased the concentration of carbon dioxide, methane, and other greenhouse gases trapping heat in the Earth's atmosphere. The greatest contribution to the human-caused greenhouse effect is the large amount of carbon dioxide produced by burning carbon-based fuels such as coal, oil, and natural gas. Greenhouse gases are also released during manufacturing processes, oil and gas production, and as a result of deforestation and agricultural practices. Since heat in the atmosphere drives the climate system, even slight changes in temperature are associated with significant changes in global and regional climates. To estimate global patterns of future climatic conditions under various scenarios, computer models of the climate system are used. Some projected changes appear to have already begun, such as significant warming and decreased snow and ice cover in polar regions.

The Intergovernmental Panel on Climate Change (IPCC), a scientific intergovernmental organization set up by the World Meteorological Organization and the United Nations, was established in 1988 to provide an objective source of information on climate change. The IPCC does not conduct any research but comprehensively assesses the latest literature relevant to climate change and its observed and projected impacts as well as options for adaptation and mitigation (IPCC, 2008). The main activity of the IPCC is to regularly provide assessment reports of the state of knowledge on climate change. The IPCC also produces special reports, methodology reports, and technical papers.

In 2007 the IPCC released its latest assessment report, *Climate Change 2007*, which is the fourth IPCC Assessment Report, and a companion report, *Summary for Policymakers*. This Assessment Report consists of four volumes, one of which is a "Synthesis Report" that integrates all information from the three other volumes. The findings of these and other IPCC reports are important because of their influence in the fields of climate change science and public policy. The 2007 findings were an impetus for the legislation that initiated this study.

The *Summary for Policymakers* (IPCC, 2007b) states that “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air temperatures, widespread melting of snow and ice and rising global average sea level.” The report states that many natural systems are being affected by regional climate changes, particularly temperature increases, and lists some projected impacts in North America:

- “Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources.
- “In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources.
- “Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts.
- “Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.”

The *Summary for Policymakers* goes on to give examples of the effects climate change could have on water resources due to changes in extreme weather and climate events, based on projections through the end of this century. Rising temperatures that occur more frequently would be virtually certain to cause effects on water supplies relying on snow melt. Heat waves with increasing frequency could also very likely cause increased water demand and water quality problems. Heavy precipitation events would likely cause adverse effects on water quality and contamination of water supplies but may relieve some water scarcity. And more widespread water stress would likely result from areas affected by increases in the frequency of drought.

Climate Change and Water (IPCC, 2008) states that watersheds dominated by seasonal snow cover are already experiencing earlier peak flows in the spring, and this shift is expected to continue under a warmer climate. At lower altitudes, winter precipitation will increasingly be in the form of rain instead of snow. In North America, projected warming in the western mountains is very likely to cause large decreases in snowpack, earlier snow melt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows by the middle of this century. Reduced water supplies coupled with increases in demand are likely to exacerbate competition for water resources. Moderate climate change in the early part of the century is projected to increase aggregate yields of rainfed agriculture, but major challenges are projected for crops that are near the warm end of their suitable range or that depend on highly utilized water resources.

The *Summary for Policymakers* (IPCC, 2007) recommends some examples of planned adaptation for the water sector, many of which the Far West Texas region already employs as water management strategies: rainwater harvesting, water storage and conservation techniques, water reuse, desalination, and water use and irrigation efficiency.

3.3 Potential Impacts of Climate Change on Far West Texas

Like water resources elsewhere, those in West Texas are affected by changes in precipitation, temperature, humidity, and wind. Water resources in drier climates, however, tend to be more sensitive to climate changes (EPA, 1997). Because evaporation is likely to increase with a warmer climate, climate change could result in lower river flow in the Rio Grande and lower levels in reservoirs, particularly in the summer. If streamflow and lake levels drop, groundwater also could be reduced. In addition, more intense precipitation could increase flooding.

Although there has been very little research on the impact of climate change on the Far West Texas region specifically, there are proxies for potential strategies and impacts on the region in terms of both policy options used in other western states and potential research tools used in Texas and elsewhere. This section discusses the potential for downscaling climate models to assess regional impacts of climate change and summarizes findings from investigations in El Paso and southern California that studied the impacts on water resources under different climate change scenarios. Section 3.4 discusses policy and research efforts in other western states.

Regional climate trends and global climate model downscaling
Some documented global climate trends have not been observed in Texas. Average rainfall does not appear to have changed significantly this past century in Texas on either a regional or statewide basis. Temperature trends are probably more significant than rainfall in water resources planning because of their relationship to surface water evaporation and irrigation demand. As was the case with precipitation, temperature has also not changed significantly in Texas.

Although there is a great deal of general knowledge about the potential effects of climate change on a global or continental scale, there is much less information available to assess potential impacts on a regional or local level. There are currently some 23 global climate models used around the world, the outputs from which are publicly available. These models have been used by the IPCC and others to estimate the potential impacts of climate change on water resources. However, there are problems in applying global climate models at regional or local levels. Although the models agree on a trend of global warming, they do not necessarily agree as to how changes might affect certain regions of the world, including Texas. For example, some models suggest that Texas will experience a decline in precipitation over the next several decades, but others indicate that the state may become wetter. Of the 23 models widely used, roughly half predicts drier conditions, and the other half predicts wetter conditions in East Texas. Most, but not all, predict less rainfall in the future for West Texas.

Global climate models describe climate trends, but they do not provide reliable information at a high spatial resolution. The models provide a reasonable representation of features such as trade winds and other phenomena that tend to operate on very large spatial scales, but at local levels, global climate models are generally not appropriate, primarily because the grids on which they operate are too coarse to capture regional aspects. *Climate Change and Water* (IPCC, 2008) acknowledges that there is a scale mismatch between large-scale climate models and the "catchment scale," that is, the watershed scale used for water management. The report goes on to say that "higher-resolution climate models are required to obtain information of more relevance to water management."

Global climate models typically have a resolution of 100–200 miles by 100–200 miles. Most hydrological applications require information at a 30-mile scale, or less.
There are two broad categories of downscaling: statistical and dynamic. Statistical downscaling involves developing relationships between point observations of weather with large-scale model results, usually using simple regression equations. The future projections of the global climate models are then used to drive the statistical relationships. Statistically downscaled outputs of the 23 models are publically available. Dynamic downscaling involves the development of a finer-scale climate model, usually using a large-scale global climate model to provide information at the boundaries. This latter approach is much more resource-intensive and can only be done one region at a time.

TWDB recently published a Request For Qualifications on choosing the appropriate downscaling approaches and models for hydrological applications in Texas. It is expected that this contract will be executed by the end of March 2009.

Investigation into Climate Change Impacts on
Municipal Water Management in El Paso

Dr. Bill Hutchison (2008), Water Resources Manager at EPWU-PSB, recently assessed the vulnerability of El Paso's municipal water supplies to historical variation of regional climate as well as to the consequences of predictions in the 2007 IPCC Assessment report. Historical variation was defined using published tree ring data for northern New Mexico, since runoff from northern New Mexico and southern Colorado represents the majority of Rio Grande flow feeding Elephant Butte Reservoir. This is the major regulating reservoir for agricultural and municipal users in southern New Mexico, Far West Texas, and Ciudad Juarez in Mexico. Based on the tree ring data, annual inflow to Elephant Butte Reservoir was simulated for 1,007 years (1001 to 2007). These simulated inflows showed that 50-year average Elephant Butte inflow has ranged from about

644,000 acre-feet per year to over 1,230,000 acre-feet per year. Current 50-year average inflow is about 800,000 acre-feet per year. The analysis was extended by considering precipitation changes based on 21 General Circulation Models described in the IPCC report. Due to limitations associated with these models in mountainous terrain, predictions range from a 25 percent decrease in precipitation to a 10 percent increase in precipitation. Temperature increases are predicted by all 21 models, ranging from 1^{o}C to 5^{o}C, which would affect reservoir evaporation.

The investigation included simulating 60 scenarios of various precipitation and reservoir evaporation conditions based on the historical variability and consequences of IPCC predictions. Each of the 60 scenarios included 958 50-year simulations, for a total of 57,480 simulations. Key results included estimated changes to surface water diversions, estimates of required groundwater pumping to meet demands under the current management approach, and estimates of resulting groundwater storage changes. Based on the analysis, future demands could be met with current infrastructure and under the current management approach though the year 2060 under all scenarios. The analysis highlights the effectiveness of past investments made in water infrastructure and the effectiveness of the current management approach to respond to climatic variability.

Planning for Climate Change in Southern California

A similar investigation performed recently for a region in southern California has a number of parallels to the Far West Texas region. Funded in part by the National Science Foundation, the RAND Corporation has been developing analytic methods to incorporate uncertainty about climate change into long-term planning efforts (Groves and others, 2008), specifically to evaluate the southern California region's vulnerabilities to and strategies for addressing climate change. Focusing on the region's most recent water management plan, the project developed a water management simulation model to evaluate how various water management programs would perform under different climate and management scenarios. The model evaluated the current water plan under a wide range of uncertainty conditions, including weather patterns, the effectiveness of water management strategies, and costs of supplies and management actions. Similar to Dr. Hutchison's study, the project used 21 General Circulation Models to define plausible ranges of temperature and precipitation changes.

As part of the decision-making methodology, a statistical analysis was performed to identify the characteristics of scenarios with the costliest outcomes. Although the analysis found that the current management plan is proactive in accommodating future growth, it also revealed the current plan is vulnerable to possible changes in climate. Specifically, the water management plan is especially vulnerable to future conditions where

- precipitation declines significantly,
- water imports decline significantly in response to climate change, and
- groundwater recharge declines.

To address key vulnerabilities, water management strategies were considered that went above and beyond those proposed in the current water management plan, including more aggressive water efficiency measures, recharge of groundwater with captured stormwater, and quicker development of reuse programs. Overall, the research showed that there are options to increase the region's resilience to impacts of climate change, particularly by increasing self-reliance through expanded reuse, conjunctive use, water efficiency, and adaptation over time to changing conditions. Furthermore, these types of local cooperative efforts will likely be lower in cost than imported supplies.

3.4 Policy and Research Efforts in Other Western States

Colorado

Colorado has undertaken a number of efforts to address the potential of climate change on its water resources. Currently, the Western Water Assessment at the University of Colorado is serving as climate science information broker to the water resource community. The Inter-Basin Compact Committee and Basin Roundtables have been formed in each river basin to assess current and future water uses and needs. At least two municipal water providers in Colorado have hired climate change specialists. The Colorado Water Conservation Board is developing planning strategies, and the Upper Colorado River has been selected to pilot test a drought early warning system for the new National Integrated Drought Information System. The state hosts meetings to share the latest information, understand the range of possible impacts, and scope possible actions, mitigation, and adaptation; the *Governor's Conference on Managing Drought and Climate Risk* is scheduled for October 2008.

Most recently, the Western Water Assessment for the Colorado Water Conservation Board released the report, *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation* (2008). Although the headwaters of the Arkansas, Platte, Rio Grande, and Colorado rivers are all found in Colorado, the impact of climate change on runoff in the Rio Grande, Platte, and Arkansas basins has not been studied as extensively as the Colorado River. The report, which synthesized climate change science based on observed trends, modeling, and projections, documented a study that projected a decrease in runoff of 5 to 10 percent in the Arkansas and Rio Grande basins by 2050. The report also cited a study by Hurd and Coonrod (2007) that projected a decline in streamflow of 3 to 14 percent by 2030 and 8 to 29 percent by 2080 for the Rio Grande Basin.

The synthesis report also identified four key unresolved issues, including the need for

- better modeling of regional and local processes, including finer spatial resolution to better represent Colorado's mountainous terrain and precipitation processes;
- Colorado-specific research, specifically on regions where there is little or no work, such as the basins of the Arkansas, Rio Grande, and the North and South Platte Rivers;
- understanding the causes of drought, with issues including runoff efficiency, effects of increased temperatures, and uncertainty in precipitation projections; and
- better hydrologic projections for the Colorado River.

New Mexico
Recognizing the potential effects of climate change in New Mexico, Governor Bill Richardson signed an Executive Order in 2005 that established a workgroup and directed reports and other initiatives to address climate change. As part of this effort, the Office of the State Engineer was directed to work with other state, local, and federal agencies and research institutions to prepare an analysis of the impact of climate change on New Mexico's water supply and the state's ability to manage its water resources. Using both global and regional climate models, the study (New Mexico State Engineer, 2006) found

- increasing temperatures in New Mexico, which are predicted to continue to increase;
- changes in snowpack elevations and water equivalency;
- changes in available water volumes and in the timing of water availability;
- increasing precipitation in the form of rain rather than snow due to increasing temperatures;
- smaller spring runoff volumes and/or earlier runoff that will impact water availability for irrigation and for ecological and species needs;
- milder winters and hotter summers, resulting in longer growing seasons and increased plant and human water use;
- increasing evaporative losses from reservoirs, streamflows, and soils due to hotter, drier conditions;
- increasing evapotranspiration by agricultural and riparian plants; and
- increasing occurrence of extreme events, including both drought and floods.

Simulations using a regional climate model showed snowpack remaining in the headwaters region of the Rio Grande but with a greatly reduced mass by the end of this century.

California

As one of the largest emitters of greenhouse gases, California has been perhaps the most aggressive state in addressing potential impacts of climate change with policies, strategies, research, and a variety of other efforts. As part of the California Water Plan Update, the California Climate Adaptation Strategy, and other water planning efforts, the Department of Water Resources is working with climate scientists, water managers, state and federal agencies, and local and regional stakeholders to incorporate climate change into California water planning and management, including the development of adaptation strategies. The State of California Department of Water Resources is studying how to apply and modify the Water Evaluation and Planning System to integrate climate change into water management planning for the 2009 State Water Plan.

Arizona
Recognizing the potential implications that global warming and climate variation could have on the economy, environment, and quality of life in Arizona, Governor Janet

Napolitano signed an Executive Order in 2005 establishing the Arizona Climate Change Advisory Group. The objectives of the workgroup were to establish a baseline inventory and forecast of greenhouse gas emissions in Arizona and to produce an action plan with recommendations for reducing those emissions.

With active stakeholder processes, the advisory group published the Climate Change Action Plan and the governor signed an Executive Order, which established a statewide goal to reduce Arizona's future greenhouse gas emissions. The Executive Order also created the Climate Change Advisory Group under the direction of the Arizona Department of Environmental Quality to begin implementing recommendations of the Action Plan. This group had the following five recommendations related to water use and wastewater management (Arizona Climate Change, 2006):

- Accelerate investment in water use efficiency through best management practices, incentives for implementation of water management improvement measures, and consideration given to developing a statewide water and wastewater savings plan
- Increase the energy efficiency of all water and wastewater treatment operations, with long-term programs that coordinate with the long-term investments in infrastructure
- Increase energy production by water and wastewater agencies from renewable sources such as in-conduit hydropower generation and biogas production from sewage sludge
- Encourage and create incentives for technologies to reduce water use associated with power generation
- Ensure that power plants use the best management practices and most economically feasible technology available to conserve water

4.0 Conference Proceedings

Conference presentations can be found in Appendix C (in the compact disk at the back of the report) and online at http://www.twdb.state.tx.us/wrpi/climate/climate_conference.htm

4.1 Presentations

Gerald North, Ph.D.
Distinguished Professor of Atmospheric Sciences, Texas A&M University
Global Climate Change and Texas Water

Dr. Gerald North has a Ph.D. in Physics from the University of Wisconsin (1966). He has been a distinguished professor in atmospheric sciences and oceanography at Texas A&M for the last 22 years, and he was department head for eight of those years. He has been Editor in Chief of the Reviews of Geophysics for the last four and a half years. He is a Fellow of the American Association for Advancement of Science, The American Geophysical Union, and the American Meteorological Society. This year he received the Jule G. Charney Award for his career in research in atmospheric sciences. He has also won the NASA Medal for Scientific Excellence.

Numerous indicators and assessments suggest that the planet is warming and the basic cause is the increase in greenhouse gases attributable to the burning of fossil fuels and land surface changes over the last two centuries. There has been considerable progress in gathering and understanding climate data over the last 30 years, along with improvements in our building and understanding of global and regional climate models. The models are now good enough to make projections into the future of climate for such regional areas as the U.S. Southwest and perhaps even Texas. All models say that Texas will be several degrees Celsius warmer over this century. Water is a primary concern and although precipitation and evaporation are more difficult to model, the indications are that available water will be scarcer in the next 50 years, particularly in the western portion of our state.

Bruce A. McCarl, Ph.D.
Regents Professor of Agricultural Economics, Texas A&M University
West Texas Agriculture Water and Climate Change: Economics of Vulnerability

Dr. Bruce McCarl is a Regents Professor of Agricultural Economics at Texas A&M University, a Fellow of the American Agricultural Economics Association, and part of the IPCC team receiving the 2007 Nobel Peace Prize. Dr. McCarl works on the economic implications of global climate change and greenhouse gas emission reduction including aspects related to biofuels, as well as environmental, forestry, and agricultural policy design.

Forces likely to affect future Texas irrigated cropping are reviewed. Results are then given on the effects of climate change in Texas relative to the United States and the Edwards Aquifer region. Results show Texas is quite sensitive both in the profitability of irrigated agriculture and in the cost of environmental protection.

John Nielsen-Gammon, Ph.D.
Texas State Climatologist/Professor of Meteorology, Texas A&M University Department of Atmospheric Sciences
Temperature and Precipitation Changes in West Texas: Models vs. Observations

John Nielsen-Gammon holds a Ph.D. from the Massachusetts Institute of Technology. After a brief period as a researcher at the State University of New York at Albany, he joined the faculty at Texas A&M University in 1991. He was appointed Texas State Climatologist by Governor George W. Bush in 2000.

Dr. Nielsen-Gammon's weather-related research involves studies of such phenomena as jet streams, extreme rainfall events, and coastal circulation systems. His air quality research includes field forecasting support, numerical simulation, and diagnostic analysis of ozone events in Houston and Dallas for the Texas Air Quality Studies (TexAQS) in 2000 and 2005–2006. Since becoming Texas State Climatologist in 2000, Dr. Nielsen-Gammon has worked on drought monitoring and forecasting, air pollution climatology, and improvements to the climate data record. He teaches courses in weather analysis, weather forecasting, and atmospheric dynamics.

Dr. Nielsen-Gammon was named a Presidential Faculty Fellow by the National Science Foundation and the White House in 1996 and has also received a Distinguished Achievement Award in Teaching at Texas A&M University from the Association of Former Students.

Computer-based climate models are in complete agreement that Far West Texas should become warmer and probably drier as greenhouse gases continue to accumulate. But greenhouse gases have been accumulating for more than a century, and they have been the dominant force on the global scale for at least the past 30 years. What can local climate observations tell us about present and future climate?

Temperatures have increased across Far West Texas over the past century. This is in contrast to the rest of Texas and the southeastern United States, which has actually seen a century-scale decline in temperatures. However, in all areas, temperatures have trended sharply upward over the past 30 years and are now at or above the previous period of warmth in the early 1950s.

Despite undergoing a period in the 1990s that was among the driest on record, precipitation in Far West Texas overall has increased slightly over the past century. The rate of increase is smaller than in the rest of Texas. Generally, in western Texas, New Mexico, and southern Colorado, no significant long-term precipitation trend is present.

In summary, given both model output and observations, temperatures are very likely to continue to increase and precipitation is more likely than not to decrease slightly. Because rising temperatures would lead to increased water demand by cities, agriculture, and ecosystems even if precipitation remained steady, the effects of droughts are likely to become more severe over time.

Charles Jackson, Ph.D.
Research Scientist, The University of Texas at Austin Institute for Geophysics, Jackson School of Geosciences
Projections and Uncertainties Concerning Climate Impacts on Water Availability in Western Texas

Dr. Charles Jackson is a climate scientist at the Institute for Geophysics of the University of Texas in Austin. His research considers uncertainties in climate model predictions of climate change. In particular, he is interested in understanding factors explaining natural fluctuations in climate such as glacial-interglacial cycles and abrupt climate change.

Dr. Jackson received his Ph.D. from the University of Chicago in 1998 and worked as a visiting scientist at the Princeton University/NOAA Geophysical Fluid Dynamics Laboratory before coming to the University of Texas in 2000.

A review will be presented of multiple model projections of Texas climate for the next 50 to 100 years. In general, predicting change for specific regions of the globe like Texas is difficult owing to the many remote and regional factors that can affect a given region's climate. The scatter among the multiple model projections for Texas precipitation illustrates this. Nevertheless, there appears to be sufficient agreement among models concerning the combination of factors that will increase aridity in western Texas. These projected changes appear to be significant when compared to tree ring proxies of regional drought over the past millennium.

Edwin Maurer, Ph.D., P.E.
Assistant Professor, Santa Clara University, Civil Engineering Department
Downscaling Global Climate Change Projections for Assessment of Water Resources Impacts

The warming temperatures we have experienced in recent decades are unequivocal and have been largely attributed to human activities. The climate disruption caused by the perturbed radiative balance of the planet is a complex picture, with significant variability in the observed and projected future impacts for different regions. One of the principal effects on humanity is that on water resources, which respond to changes in both temperature and precipitation in locally dependent ways. Western water resources, in general, are highly managed by constructed systems that were designed based on historical climate observations, leading to a high potential for vulnerability as climate diverges from historical patterns. Anticipating future changes and understanding what uncertainties are associated with different projected changes are essential to adapting efficiently to inevitable changes and motivating mitigation activities to avoid more severe impacts. This presentation presents a method for estimating local and regional projections of climate change and quantifying the principal uncertainties in a risk-based framework applicable to water resources management.

Brian Hurd, Ph.D.
Associate Professor, New Mexico State University, Agricultural Economics and Agricultural Business Department
Climate Change and the Upper Rio Grande Watershed: Assessing Impacts and Developing Insights for Strategic Adaptations

Dr.Brian H. Hurd is Associate Professor of Agricultural Economics and Agricultural Business at New Mexico State University. His research on the economics of environmental and natural resources spans more than 20 years in both academic and consulting arenas. His principle areas of teaching and research focus on the interactions of economies and natural resources, particularly interactions of weather, climate, and water on industrial, social, and agricultural systems. He received his B.A. from Colorado University at Boulder, and his M.S. and Ph.D. degrees from University of California at Davis.

With limited opportunities for new water sources in the Rio Grande watershed, continued population growth must necessarily compete with existing water users for available supplies. This presentation explores two aspects of climate change and the water resources of the Upper Rio Grande. First, the role of water and the effects of climate change on its use and economic productivity is examined by using scenarios of climate change, a model to estimate streamflow responses, and the RioGEM hydroeconomic model. Together, these are used to explore possible changes in patterns of water use, transfer, storage, and economic consequences resulting from long-run changes in climate. The analysis suggests that climatic changes are likely to diminish surface water resources—even for scenarios deemed relatively “wet”—and that competition for water will be exacerbated and is likely to heighten pressure for water transfers from agriculture. With the onset of more persistent and widespread shortfalls in streamflow, all water users will likely experience the adverse economic consequences that accompany diminished water supplies and rising water costs.

The second aspect highlights the potential for careful and systematic planning to enhance the adaptive capacity of the region and to identify initial strategies that can aid the region’s transition to greater water scarcity.

Connie Woodhouse, Ph.D.
Associate Professor, University of Arizona, Department of Geography and Regional Development
Reconstructions of Past Streamflow from Tree Rings: Placing the Gage Record in a Long-Term Context

Dr. Woodhouse is an associate professor in the Department of Geography and Regional Development at the University of Arizona with a joint appointment at the Laboratory of Tree-Ring Research. Prior to joining the University of Arizona, she was a physical scientist with the National Climatic Data Center of the National Oceanographic and Atmospheric Administration. In her research, Dr. Woodhouse focuses on the generation and interpretation of high-resolution records of climate for the past 2,000 years. A current topic of research is the reconstruction of streamflow and drought using tree rings to investigate hydroclimatic variability in the Colorado River and Rio Grande basins and applications of this information to resource management. Dr. Woodhouse received a B.A. from Prescott College, an M.S. in geography from the University of Utah, and a Ph.D. in geosciences from the University of Arizona.

The current climate is being impacted by human activities to a degree that has not occurred in the past and, consequently, the climate of the past will not be exactly analogous to the climate of the future. However, understanding the past climate can provide insights on what may be expected in the future. In the Southwest, tree ring data have been used to reconstruct high-quality records of water year streamflow for past centuries in the Colorado and Rio Grande basins. Tree ring-based reconstructions of hydrology provide information about a broader range of variability and extremes than provided by gage records alone, allowing recent climate trends and events to be assessed in a long-term context. The duration of drought events and the variety of sequences of flow years in the reconstructions indicate that the gage records contain just a subset of possible conditions. Understanding the range of conditions that have occurred in the past is useful for gaining insights on possible future variability, even without the impacts of climate change.

Nolan Doesken
State Climatologist/Senior Research Associate, Colorado Climate Center
Monitoring Colorado Climate, Tracking Changes, and Thinking Ahead

Nolan Doesken has worked at the Colorado Climate Center at Colorado State University since 1977. He was appointed State Climatologist in 2006. Mr. Doesken is actively involved in climate monitoring, research, outreach, and collaboration with emphasis on agriculture and natural resources applications. He is the founder of the Community Collaborative Rain, Hail and Snow network (CoCoRaHS), a volunteer network of citizens of all ages helping measure and report precipitation from homes and backyards across the country. He also oversees the operation of the Colorado Agricultural Meteorology (CoAgMet) network.

Large seasonal and interannual variability in precipitation and snow accumulation is common for the southern Rocky Mountain region, including the upper Rio Grande Basin. Understanding and adapting to variability is a sufficient challenge for water planners, managers, and administrators even without the additional uncertainty added by climate change. The extreme drought experienced over the entire state of Colorado in 2002 had a profound effect on attitudes about drought, climate variability, climate change, and firm yield. Organizations that were previously highly skeptical about including climate change scenarios in water resource planning have subsequently invested in research and planning. The Western Water Assessment at the Cooperative Institute for Research in Environmental Sciences at the University of Colorado is working closely with climate change scientists and water managers to provide climate information of value for planning and decision making. The huge uncertainty in future precipitation patterns does not make the planning process any easier. The Colorado Climate Center (Colorado State University) focuses on tracking current climatic conditions statewide. A “Colorado Climate Trends” Web site will be launched later this month to provide the public with current and unbiased information on recent trends (40–120 years) and variations in temperature, precipitation, and snow accumulation. In October 2008, the Governor’s Conference on Managing Drought and Climate Risk will be held in Denver to continue to encourage communication and planning.

Rio Grande Compact Commissioner Patrick Gordon

Commissioner Gordon received a B.B.A. in Finance from Texas A&M University and a J.D. and M.B.A. from Texas Tech University. He is a Shareholder in Gordon, Mott & Davis P.C. and his areas of practice include domestic and international tax, mergers and acquisitions, business and corporate law, international transactions, business transactions, and Mexico transactions He has served as a member of a number of boards and councils and was appointed to the Rio Grande Compact Commission in 2006.

Wayne M. Treers
Hydraulic Engineer, U.S. Bureau of Reclamation, U.S. Department of the Interior
Rio Grande Project— 100 Years of Hydrologic History and Climate Change

Wayne Treers has worked as a hydraulic engineer for 26 years with the Bureau of Reclamation and as a hydraulic engineer for 3 years with the U. S. Fish & Wildlife Service. Mr. Treers has served as Team Leader of the Water Operations Group of the Bureau of Reclamation in El Paso, Texas, and is responsible for directing and managing Elephant Butte and Caballo reservoirs to deliver irrigation water to Elephant Butte Irrigation District of southern New Mexico, El Paso County Water Improvement District No. 1 of Far West Texas, and Mexico under the 1906 Treaty between the United States and Mexico.

In 1905, the U.S. Congress authorized the building of Elephant Butte Dam and Reservoir and the associated irrigation delivery system to irrigate nearly 178,000 acres that encompassed the Rio Grande Project. A key component of the project was to supply irrigation water to Mexico under the terms of the 1906 Treaty between the United States and Mexico. This treaty represented the first apportionment of Rio Grande waters. In 1935, the U.S. Congress authorized the building of Caballo Dam and Reservoir for flood control and irrigation storage water as part of the Rio Grande Project. In 1938, Colorado, New Mexico, and Texas signed the Rio Grande Compact, which further apportioned the waters of the Rio Grande between the three states. Under the compact, the Texas portion is identified as the area from Elephant Butte Reservoir to Fort Quitman, Texas, which is essentially Reclamation's Rio Grande Project.

The water supply for the Rio Grande Project is managed in Elephant Butte and Caballo reservoirs. Nearly 70 percent of the annual flow to Elephant Butte Reservoir is derived from spring snow melt runoff from the mountain ranges of northern New Mexico and southern Colorado. Spring runoff forecasts in the upper Rio Grande Basin are developed and issued jointly by the Natural Resources and Conservation Service and the National Weather Service. Reclamation uses these runoff forecasts to make predictions of the rate and volume of water that will enter Elephant Butte Reservoir during the spring and the available water supply for irrigation to the Project water users.

The effects of climate change on the upper Rio Grande Basin hydrology and water supply to the Rio Grande Project is still unknown. Although we have over 100 years of hydrologic data and climatic history in the upper Rio Grande Basin, are these historical trends and averages enough to predict climate change, or will climate change yield new trends and averages? Finally, since 1945 when the Rio Grande Project's irrigated lands were fully developed, we have 63 years of water and crop demand data. How will climate change affect water supply and cropping patterns in the future on the Rio Grande Project?

Gary Esslinger, Treasurer Manager, Elephant Butte Irrigation District

Gary L. Esslinger is the Treasurer-Manager of the Elephant Butte Irrigation District. He is a third generation member of a pioneer farming family living in the Mesilla Valley. His grandfather, J.L. Esslinger, Sr., settled in La Mesa in 1913 prior to the completion of the Elephant Butte Dam. Gary's father, J.L. Esslinger, Jr., also farmed for over 50 years. Mr. Esslinger kept his roots in farming as well as other agricultural-based industry and lives on the family farm with his wife, Tina. They have three daughters.

Mr. Esslinger earned a Bachelor's Degree in Business Administration from Northern Arizona University in 1973 and went to work in Los Angeles for a large flour milling corporation. When he became tired of big city life, he returned to the Mesilla Valley and began working for Elephant Butte Irrigation District in 1978, where he has been for the last 30 years. Mr. Esslinger has had the honor of being appointed by Governor Bill Richardson to chair the search committee to select the State Engineer for New Mexico as well as being appointed to the Office of the Dona Ana Flood County Commissioner, a position he held from 2002 until 2006.

The western United States and particularly the area encompassed by the Rio Grande Project have experienced natural wet and dry cycles in the past. Current water flow trends differ in length and strength from past natural variations.

Changes over the past half century have meant less snowpack and more rain. These changes foretell water shortages, lack of storage to meet seasonally changing river flow, and perhaps more transfers of water from agriculture to urban use.

The Elephant Butte Irrigation District is addressing the impacts of climate change in the region and is developing its own adaptive management policies to meet these challenges, in particular, adapting our flood control infrastructure to be more accommodating for storm warning storage, sediment removal, reuse, and environmental enhancement. The localized monsoon season has the potential to capture sufficient runoff to offset decreasing snowpack runoff. However, current water policies have relied on the premise that historical water patterns will continue. The Elephant Butte Irrigation District is looking "outside the box" to develop innovative and localized projects that create opportunities for regional water supply problems to be resolved by regional solutions and local initiatives.

Bill Hutchison, Ph.D., P.E., P.G.
Water Resources Manager, El Paso Water Utilities - Public Service Board
Climate Change Impacts on Municipal Water Management in El Paso, Texas

Dr.Bill Hutchison received a B.S. in Soil and Water Science from the University of California, Davis, an M.S. in Hydrology from the University of Arizona, and a Ph.D. in Environmental Science and Engineering from the University of Texas at El Paso. He has over 25 years of professional experience and is a licensed Professional Engineer and a licensed Professional Geoscientist in Texas. Since 2001, he has worked for El Paso Water Utilities, and currently serves as the Water Resources Manager.

Municipal water supplies for the City of El Paso include both surface water and groundwater. As outlined in the 2006 Regional Water Plan, these supplies are conjunctively managed: when surface water supplies are reduced due to drought conditions, groundwater pumping is increased in order to meet demands. Water planners in the area have always understood the nature and consequences of climatic variability on managing water supplies. Considerable investments have been made to ensure adequate supplies under a wide range of climatic conditions.

This investigation assesses the vulnerability of El Paso’s water supplies to historical variations of regional climate as well as to the consequences of predictions in the 2007 Intergovernmental Panel on Climate Change (IPCC) report. Historical variation was defined using published tree ring data for northern New Mexico to simulate annual Elephant Butte inflow data for 1,007 years (1001 to 2007). The simulations show that the 50-year average Elephant Butte inflow has ranged from about 600,000 acre-feet per year to over 1,200,000 acre-feet per year. Current 50-year average inflow is about 800,000 acre-feet per year. IPCC precipitation predictions for the area are based on 21 Global Circulation Models. Due to limitations associated with these models in mountainous terrain, predictions range from a 25 percent decrease in precipitation to a 10 percent increase in precipitation. Temperature increases are predicted by all 21 models, ranging from 1^{o}C to 5^{o}C, which would affect reservoir evaporation.

This investigation included simulating 60 scenarios of various precipitation and reservoir evaporation conditions based on the IPCC predictions. Each scenario included 958 50-year simulations, for a total of 57,480 simulations. Key results included estimated changes to surface water diversions, estimates of required groundwater pumping to meet demands under the current management approach, and estimates of resulting groundwater storage changes. Based on the analysis, future demands outlined in the 2006 Regional Water Plan can be met with the current infrastructure and under the current management approach though the year 2060 under all scenarios. This detailed analysis confirms the effectiveness of the past investment made in water infrastructure and the effectiveness of the current management approach in dealing with climatic variability.

Jesus Reyes
General Manager, El Paso County Water Improvement District #1

Jesus A. Reyes is currently the General Manager for the El Paso Water Improvement District #1 in El Paso, Texas. Mr. Reyes was tapped for the General Manager’s position after serving on the Board of Directors for the District.

Raised in a small farming community in Canutillo, Texas, he was one of 10 children of Rafael and Estela Reyes. Growing up on the family farm taught him the value of hard work. Never one to shy away from a challenge, Mr. Reyes learned at a very young age to operate heavy duty farm equipment, plow and sow the fields, and irrigate hundreds of acres of farmland, and he continued to excel in school. He graduated from Canutillo High School, attended the University of Texas at El Paso, and married Martha Serna. They have been married 30 years and between them have four children and eight beautiful grandchildren.

Mr. Reyes has a law enforcement background, serving in the El Paso Sheriff's Department for 15 years He has also been a business owner who understands management and the importance of leadership. During his tenure at the Sheriff's Department, Mr. Reyes started out as a patrolman, moved on to become a Detective, Sgt. of Detectives, then was promoted to Captain of Detectives and went on to become the youngest Chief Deputy in the El Paso Sheriff's Department.

Mr. Reyes has always been involved in the community and has served on several boards and has been instrumental in managing several political campaigns. He has served on the El Paso County Parks Board, El Paso Airport Board, Alivane Board of Directors. He is also a member of the Paso Del Norte Planning Group. His political experience includes managing campaigns for his brother, Congressman Silvestre Reyes, Judge Gonzalo Garcia, County Judge Chuck Mattox and his wife, Martha Reyes, who currently sits on the Ysleta School Board.

This session will feature a presentation on these topics: 1) current water management and history of the Rio Grande Project, 2) telemetry system upgrade and water monitoring, 3) concrete lining of Riverside Canal, 4) automatic gate installation throughout El Paso County Water Improvement District, and 5) placement of canals with underground pipeline projects with school districts.

4.2 Recommendations and Observations from Facilitated Discussion Sessions

The following three concurrent facilitated discussion sessions were held after the conclusion of conference presentations:

- Potential Water Management Strategies to Address Climate Change in Far West Texas
- Research Needs to Address Climate Change in Regional Water Planning
- Potential Options to Fund Water Management Strategies and Research

A dozen or more conference participants attended each of these sessions, which were facilitated and recorded by TWDB staff.

Potential Water Management Strategies to Address Climate Change in Far West Texas

This session was facilitated by Dr. Robert Mace, director of TWDB's Groundwater Resources division. Key recommendations and observations are summarized as follows:

- In considering how potential impacts of climate change should be included in the Far West Texas Regional Water Plan, participants said that they would like to see a section in the plan that addresses climate change, possibly in the water supply section of the report. It was stated that the region should consider general climate trends as well as the drought of record.
- Participants suggested water management strategies that could offset potential impacts of climate change, including more municipal water conservation, lining of canals, incentive programs for rainwater collection, and promotion of "green building" to decrease water demand.
- Several participants thought that climate change should be considered in the context of general uncertainty in the planning process and that all sources of uncertainty should be addressed together.
- Some participants thought that the current model of drought of record planning does not allow for the adequate consideration of climate change and historical climate variability. It was suggested that tree ring analysis (such as the research by Dr. Connie Woodhouse at the University of Arizona) could allow for the consideration of more severe droughts occurring before the historical record.
- Participants discussed strategies to deal with the potential for increased flood flows, including natural attenuation and storage through the use of wetlands. It was mentioned that the U.S. Army Corps of Engineers "Forgotten River" study is trying to restore natural river habitat and flow regime to this river segment.

- Participants suggested that no policy or other statutory changes should be recommended, so that each planning group can have the flexibility to deal with these issues with consideration of regional variability.
- Participants differed in how they thought climate change should be addressed in subsequent rounds of planning. Some thought that planning groups should be required to address climate change, while another thought that it should be a “suggestion” since each region is different and there should be regional flexibility to address the issue as appropriate.

Research Needs to Address Climate Change in Regional Water Planning
This session was facilitated by Dr. Barney Austin, director of TWDB’s Surface Water Resources division. Key recommendations and observations are summarized as follows:

- Participants agreed that there are a range of research needs, and water is only one consideration of potential climate change impacts. Participants discussed the need for an “information broker” in Texas to serve as a data clearinghouse, host conferences, and determine priorities for research and funding. Such a position or entity could support the state climatologist.

- Management needs first must be discussed before research, and there needs to be a dialogue between scientists and managers.

- It was suggested that Far West Texas may not be the most vulnerable area of the state, but that wetter areas that rely on surface water may be more vulnerable. Vulnerabilities could be plotted and analyzed by river basin.

- A framework to address these issues could include an assembled team of scientists who are familiar with the regional water planning process in Texas. Such a team could perform an uncertainty analysis and develop a strategy for future water planning efforts.

- Participants said that we need to do a better job collecting and archiving real-time surface and groundwater monitoring data so we will have historical records for the future.

- There is a need for funding, and federal funding is currently difficult to obtain. There are opportunities for the partnering of researchers and water managers in the El Paso area.

- There should be an analysis of the sustainability of water management strategies that are proposed in regional and state water plans, including their relationship to energy demands.

- We need to know more about translating climate models into planning and which climate models are good for Texas. We need to have a better handle on local and global processes that affect Texas.

- There needs to be more research on low-cost energy sources for water projects.

- The best work is done at the regional level, which allows flexibility. Funds could be earmarked to consider climate change in the regional water planning process, with funding distributed in an equitable fashion.

Potential Options to Fund Water Management Strategies and Research
This session was facilitated by Carolyn Brittin, TWDB Deputy Executive Administrator of Water Resources Planning and Information.

Participants suggested a number of sources and programs to fund water management strategies and research to address the potential impacts of climate change. These included the following:

- International: North American Development Bank and the Border Environment Cooperation Commission

- Federal: U.S. Bureau of Reclamation, U.S. Department of Defense, U.S. Department of Energy, National Science Foundation, U.S. Department of Agriculture, U.S. Agency for International Development, Federal Emergency Management Agency, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Geological Survey, Congressional appropriations

- State: TWDB Research and Planning Fund, General Revenue Fund appropriations from the Texas Legislature, universities, Texas Commission on Environmental Quality

- Other: Private foundations, local entities

5. 0 Conclusions and Recommendations

Far West Texas, like much of the western United States, has historically relied on large-scale infrastructure to store and deliver surface water supplies. These surface water supplies are particularly vulnerable to changes in weather patterns. With the realization that the regional climate may have been more variable in the past than indicated by the historical record and may be even harsher and more variable in the future, a number of western states have taken on initiatives to address the potential impacts of climate change on their natural resources.

Because of these and other considerations, State Senator Eliot Shapleigh authored Senate Bill 1762 during the 80th Texas Legislative Session. As a result of this legislation, the Texas Water Development Board hosted the Far West Texas Climate Change Conference June 17, 2008, at the Carlos M. Ramirez Water Resources Learning Center in El Paso. Conference participants included representatives from the Far West Texas Regional Water Planning Group, water authorities, industrial customers, agricultural interests, municipalities, fishing and recreational interests, environmental advocacy organizations, and institutions of higher education. Along with a number of other related issues, conference participants reviewed

- current analyses of potential impacts of climate change on surface water resources in Texas and other Western states; and
- recommendations for incorporating potential impacts of climate change into the Far West Texas Regional Water Plan, including potential impacts to the Rio Grande in Texas subject to the Rio Grande Compact, and identifying feasible water management strategies to offset any potential impacts.

Recommendations provided in this section are summarized primarily from the content of conference speaker presentations and from recommendations and observations recorded during the three facilitated conference discussion sessions.

Consistent with the findings of the IPCC reports, conference presenters agreed that surface water resources within the Far West Texas region and the rest of the state are at risk from potential impacts of climate change. These possible impacts could include increases in temperature, which could significantly increase evaporation; increases or decreases in precipitation; and reductions in and earlier melting of snowpack that feeds the Rio Grande headwaters in Colorado.

Conference speakers presented evidence that these types of changes could occur as the result of natural variability as well as from future climate change. And since water planners in the region already understand the nature and consequences of natural climatic variability, local entities such as the U.S. Bureau of Reclamation, El Paso Water Utilities – Public Service Board, Elephant Butte Irrigation District, and El Paso County Water Improvement District No. 1 have planned and designed water infrastructure with such scenarios in mind. Suggestions for dealing with the potential impacts of climate change included the continued use and expansion of water management strategies that are already employed in the region, such as

- upgrading flood management infrastructure to provide adequate flood protection;
- adapting flood control infrastructure to capture more runoff from the monsoon season and accommodate sediment removal, reuse, and environmental enhancement; and
- continuing conjunctive management of surface water and groundwater supplies, direct and indirect reuse of wastewater, and advanced water conservation

Participants and presenters agreed that more research is needed to determine the potential impacts of climate change on Texas. It was suggested the state should evaluate which models are better at analyzing the Texas climate, identify the sources of uncertainty affecting predictions the state's climate, and understand vulnerabilities of water resources to potential evaporation. There was considerable emphasis on the value of tree ring-based reconstructions of streamflow to analyze natural variability in climate systems. Such reconstructions of hydrology can put shorter instrumental records in a long-term context and provide more comprehensive information for water planners to consider.

General policy recommendations from the conference included

- continuing a regional approach to considering climate change in regional water planning;
- establishing a consortium to provide a framework for further research and discussion;
- reconsidering the drought of record as the benchmark scenario for regional water planning; and
- providing more funding for research, data collection, and investments in water infrastructure.

Although climate change could potentially impact the resources of Far West Texas, water managers and planners are in a position to adaptively manage their water resources through the regional water planning process. As local, state, and federal policies change and more resources are secured to improve technologies for research and infrastructure development, the Far West Texas Regional Water Plan can adapt to address these and other uncertainties. Ongoing adaption and an iterative dialogue between water managers, planners, and stakeholders in the region and elsewhere, such as that undertaken at the Far West Texas Climate Change Conference, will bridge the gap between what is uncertain today and what is well within the reach of understanding and realization tomorrow.

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Appendix A
Far West Texas Regional Water Planning Group Membership

Far West Texas Regional Water Planning Group

<u>(Membership as of April 16, 2008)</u>

Executive Committee Members	**Designated Alternate**
Tom Beard – *Executive Committee Chair*	Conrad Arriola
Attorney at Law	General Manager, Brewster Co. GCD
Ed Archuleta – Exec. Committee Vice Chair	Bill Hutchison
General Manager, El Paso Water Utilities – Public Service Board	Hydrogeology Manager, El Paso Water Utilities – Public Service Board
Paige Waggoner – *Exec. Committee Secretary*	No alternate designated
Chuy Reyes – *Executive Committee Member*	Johnny Stubbs
General Manager – EP Co. WID #1	El Paso County WID #1
Teresa Todd – *Executive Committee Member*	Representative Pete P. Gallego
Rebecca L. Brewster – *Exec. Committee Alt.*	Okey Lucas
City Manager, Town of Van Horn	Mayor of Van Horn
Dave Hall – *Executive Committee Alternate*	No alternate designated

Committee Members	**Designated Alternate**
Jesse Acosta	No alternate designated
Planning Coordinator, El Paso County	
Janet Adams	John Jones
Jeff Davis County UWCD	Culberson County UWCD
Jerry Agan	No alternate designated
Presidio County Judge	
Randy Barker	Talley Davis
Manager, Hudspeth Co. UWCD #1	Secretary/Treasurer, Hudspeth Co. UWCD #1
Sterry Butcher	Patt Sims
Michael Davidson	Tom Williams
Visit Big Bend Tourism Council	
David Etzold	No alternate designated
Chase Bank Tower	
Sylvia Borunda Firth	No alternate designated
Dir. of Governmental Relations, Asst. City Atty.	
City of El Paso	
Howard Goldberg	Jorge Uribe
Supreme Laundry & Cleaners	Western Refining
Luis Ito	No alternate designated

Environmental Affairs Mgr., El Paso Electric Co.	
Carl Lieb	Anthony Tarquin
Assoc. Professor & Asst. Chair	Professor, Civil Engineering
Mike Livingston	No alternate designated
Livingston Company	
E. Anthony Martinez	Senator Eliot Shapleigh
Communications Director	
Office of Senator Eliot Shapleigh	
Albert Miller	Scott Adams
	Ft. Davis Water Supply Corporation
Jim Ed Miller	W.D. (Bill) Skov
Hudspeth County Reclamation District	President, El Paso Co. Farm Bureau
Kenn Norris -- *Region J Liaison*	Charles Stegall
Rick Tate	No alternate designated
Presidio County Rancher/Agriculture	
Teodora Trujillo	No alternate designated
Non-Voting Members	**Designated Alternate**
Raymond Bader – Non-Voting Member	No Alternate Listed
Texas Agricultural Extension Service	
County Extension Agent – Natural Resources	
Filiberto Cortez – Non-Voting Member	Woody Irving
Bureau of Reclamation, El Paso Field Division	Bureau of Reclamation, El Paso Field Division
Bobby J. Creel -- Non-Voting Member	No Alternate Listed
Associate Director, NM Water Res. Rsch. Institute	
Trace Finley -- Non-Voting Member	No Alternate Listed
General Land Office	
William (Billy) Finn – Non-Voting Member	No Alternate Listed
Water Accounting Division	
U.S. Section, IBWC	
Ron Glover – Non-Voting Member	No Alternate Listed
President, Hunt NR, Ltd.	
Otila Gonzalez -- Non-Voting Member	No Alternate Listed
Region J Liaison	
Adriana Resendez – Non-Voting Member	Aldo Garcia
CILA Mexico	CILA, México
Caroline Runge -- Non-Voting Member	No Alternate Listed
Region F Liaison	
Jack Stallings – Non-Voting Member	No Alternate Listed

Texas Department of Agriculture (TDA)	
Jim Stefanov – Non-Voting Member	No Alternate Listed
Deputy Director, Investigations & Research	No Alternate Listed
USGS Texas Water Science Center	Bobby Farquhar
Billy Tarrant -- Non-Voting Member	
Texas Parks and Wildlife Division (TPWD)	
Connie Townsend – TWDB Regional Planner	David Meesey
Texas Water Development Board	Texas Water Development Board
William Wellman – Non-Voting Member	Jeff Bennett
Superintendent, Big Bend National Park	Science and Resource Management
Consultants & Other Planning-Related Contacts	**Designated Alternate**
John Ashworth – Project Manager	
LBG-Guyton Associates	
Jake Brisbin, Jr. – WPG Administrative Officer	Barbara Kauffman – Project Manager
Executive Director	Deputy Executive Director
Rio Grande Council of Governments	Rio Grande Council of Governments
Tom Gooch, P.E.	Simone Kiel
Freese & Nichols, Inc.	Freese & Nichols, Inc.
Andrew Chastain-Howley – Regional Manager	
Water Prospecting & Resource Consulting	
Kevin Urbanczyk, Ph.D– Hydrogeology/Petrology	
Dept. of Earth & Physical Sciences	
Sul Ross State University	

Appendix B
Far West Texas Climate Change Conference Participant List

Far West Texas Climate Change Conference Participant List

Name	Affiliation
Janet Adams	Far West Texas Regional Water Planning Group
Bill Addington	Sierra Club, El Paso Solar Assn.
Pamela Aguirre	Texas Commission on Environmental Quality - Small Business & Local Government Compliance Assistance
Toby Alvarado	Horizon Regional Municipal Utility District
Ed Archuleta	El Paso Water Utilities - Public Service Board
Jack Arias	U.S. Environmental Protection Agency - El Paso Border Office
Lorenzo Arriaga	U.S. Bureau of Reclamation - Elephant Butte Field Division
John Ashworth	LBJ Guyton, consultant to Far West Texas Regional Water Planning Group
Barney Austin	Texas Water Development Board
Tom Beard	Far West Texas Regional Water Planning Group
Wayne Belzer	International Boundary and Water Commission
Barry A. Benedict	University of Texas at El Paso
Danny Borunda	International Boundary and Water Commission
Richard H. Bowen	Sierra Alta Water System
David Bowser	Livestock Weekly
Carolyn Brittin	Texas Water Development Board
Inez Marquez Burcham	Texas AgriLife Research Center at El Paso
Dan Carter	Las Cruces District Office Bureau of Land Management
Roger Chacon	El Paso Electric
Rita Crites	International Boundary and Water Commission
Benny Davis	Horizon Regional Municipal Utility District
Eloiso De Avila	El Paso Inter-religious Sponsoring Organization (EPISO)
Nolan Doesken	State Climatologist, Colorado Climate Center
Dale Doremus	New Mexico Environment Department
Diane I. Doser	University of Texas at El Paso
Ken Ducre	El Paso Inter-religious Sponsoring Organization (EPISO)
Corey Durr	Las Cruces District Office Bureau of Land Management
Andre Ellis	University of Texas at El Paso
Gary Esslinger	Elephant Butte Irrigation District
Billy Finn	International Boundary and Water Commission
Carlos Flores	U.S. Environmental Protection Agency - El Paso Border Office

Name	Affiliation
Mary Theresa Flynn	Federal Emergency Management Agency, Office of the Chief Counsel
Girisha Ganjegunte	Texas AgriLife Research Center at El Paso
Thomas E. Gill	University of Texas at El Paso
Commissioner Patrick Gordon	Rio Grande Compact Commission
Carla Guthrie	Texas Water Development Board
Dave Hall	Far West Texas Regional Water Planning Group
Ed Hamlyn	Center for Environmental Resource Management
Dan Hardin	Texas Water Development Board
Brian Hurd	New Mexico State University
Bill Hutchison	El Paso Water Utilities - Public Service Board
Jaime Iglesias	Texas AgriLife Research Center at El Paso
Charles Irvine	Blackburn & Carter, P.C.
Woody Irving	U.S. Bureau of Reclamation
Charles Jackson	The University of Texas at Austin
Sushma Jasti	Office of Senator Eliot Shapleigh
Laila Johnson	Texas Water Development Board
Richard J. Karlin	Awwa Research Foundation
Barbara Kauffman	Rio Grande Council of Governments
Jeff Langman	USGS-New Mexico Water Science Center
Kathleen Ligon	Texas Water Development Board
Ramiro Lujan	International Boundary and Water Commission, Mexican Section
Robert Mace	Texas Water Development Board
E. Anthony Martinez	Office of Senator Eliot Shapleigh
Edwin Maurer	Santa Clara University
Bruce McCarl	Texas A&M University
Heather McMurray	Sierra Club, El Paso Solar Assn
Ari Michelsen	Texas AgriLife Research Center at El Paso
Diana Montoya	City of Las Cruces
Jennifer Montoya	Las Cruces District Office Bureau of Land Management
Bill Mullican	Texas Water Development Board
MaryLynn Musgrove	United States Geological Survey
John Nielsen-Gammon	Texas State Climatologist, Texas A&M University
Genhua Niu	Texas AgriLife Research Center at El Paso
Gerald North	Texas A&M University
Joe Olmedo	Texas AgriLife Research Center at El Paso
Dan Opdyke	Texas Parks and Wildlife Department
Ivan Ortiz	Texas Water Development Board
Ian Partridge	

Name	Affiliation
Josephine Paul	El Paso Inter-religious Sponsoring Organization (EPISO)
Raymond Pawley	Bushmans
Porfirio Peinado	University of Texas at El Paso
Michael A. Pink	Parkhill Smith & Cooper
John R. Poland	U.S. Bureau of Reclamation
Gina Posada	Texas Commission on Environmental Quality - Intergovernmental /Border Affairs
Jesus Reyes	El Paso County Water Improvement District #1
Daphne Richards	Texas AgriLife Research Center at El Paso
Nancy Rivera	University of Texas at El Paso
Aimee M. Roberson	U. S. Fish & Wildlife Service
Andres A. Salazar	Freese and Nichols, Inc.
Lisa Santana	International Boundary and Water Commission
Senator Eliot Shapleigh	Texas Senator, District 29
Zhuping Sheng	Texas AgriLife Research Center at El Paso
Ursula Sherrill	
Al Soto	
Connie Townsend	Texas Water Development Board
Wayne Treers	U.S. Bureau of Reclamation
Teodora Trujillo	Far West Texas Regional Water Planning Group
Lois Tryon	Fort Hancock Water Control and Improvement District
Sonia Uribe	Texas Water Development Board
Elizabeth Verdecchia	International Boundary and Water Commission
Shirley Wade	Texas Water Development Board
Paige Waggoner	Far West Texas Regional Water Planning Group
Michael Wagner	Bushmans
J. Kevin Ward	Texas Water Development Board
George Watland	
Alison Williams	New Mexico Interstate Stream Commission
Rawles Williams	Sul Ross University
Connie Woodhouse	University of Arizona
Frank Wood	Hacienda del Norte Water District
Karl Wood	New Mexico Water Resources Research Institute