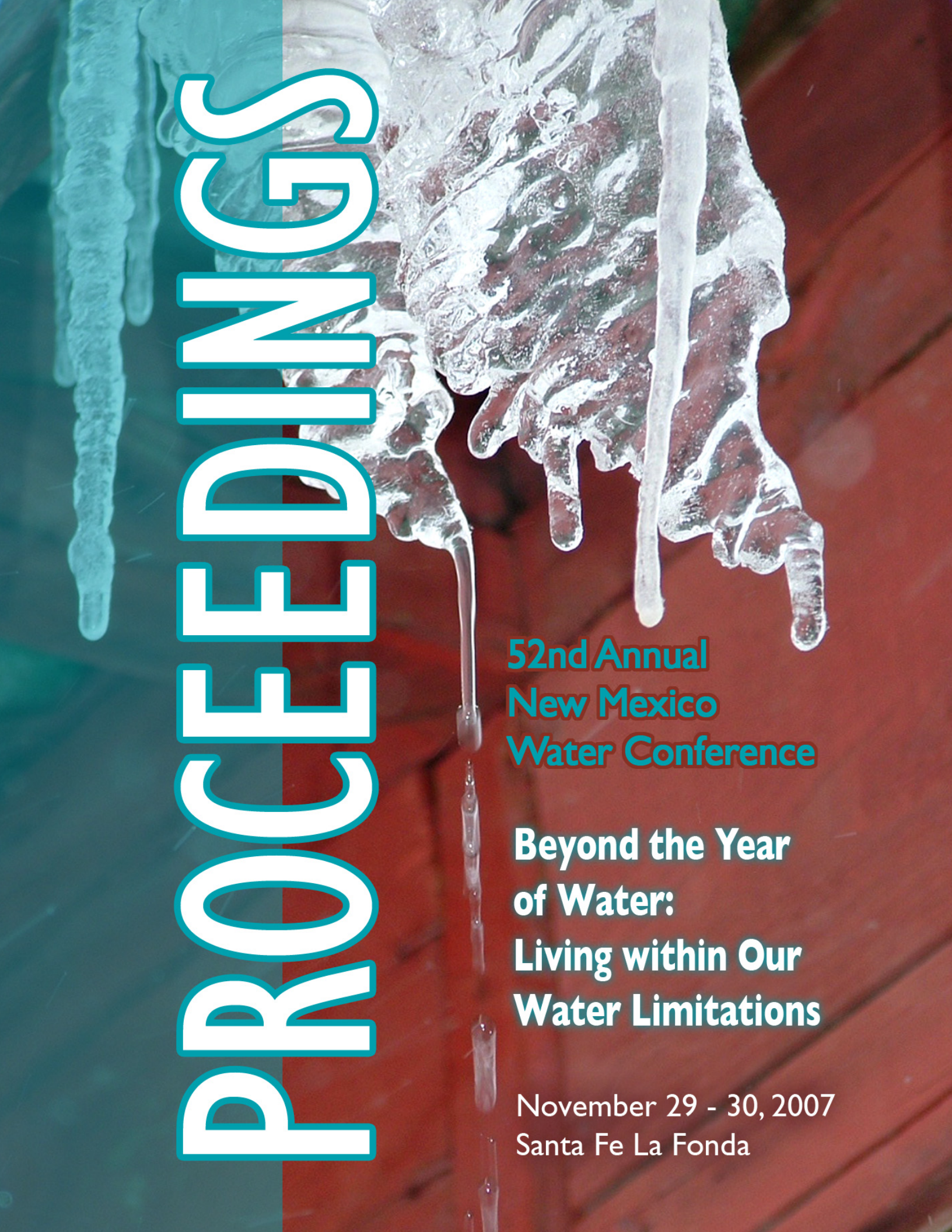

PROCEEDINGS

52nd Annual New Mexico Water Conference

Beyond the Year of Water: Living within Our Water Limitations

November 29 - 30, 2007
Santa Fe La Fonda

52nd Annual
New Mexico
Water Conference

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New Mexico
Water Resources Research Institute

TABLE OF CONTENTS

Water Conference Advisory Committee and Representatives

Cecilia Abeyta, Farm Bureau

Hilary Brinegar, New Mexico Department of Agriculture

Brent Bullock, Pecos Valley Artesian Conservancy District

Wayne Cunningham, Quay County

John D'Antonio, Office of the State Engineer

Gary L. Esslinger, Elephant Butte Irrigation District

Lt. Col. Bruce Estok, Army Corps of Engineers

Susan Fry Martin, Los Alamos National Laboratory

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John Hawley, Hawley Geomatters

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Fidel Lorenzo, Acoma Pueblo

Julie Maitland, New Mexico Department of Agriculture

Nathan Myers, US Geological Survey

Craig Runyan, New Mexico State University

Blane Sanchez, Interstate Stream Commission

John Shomaker, Shomaker and Associates

John Stomp, Albuquerque Bernalillo County Water Utility Authority

Bruce Thomson, University of New Mexico

John C. Tysseling, e3c, Inc.

Enrique Vivoni, New Mexico Tech

Ann Watkins, Office of the State Engineer

Linda Weiss, US Geological Survey

Mark Yuska, Army Corps of Engineers

52nd Annual New Mexico Water Conference

Beyond the Year of Water: Living within Our Water Limitations

Santa Fe La Fonda

Thursday Morning, November 29, 2007

8:30 Welcome and Opening Remarks
Director Karl Wood, Water Resources Research Institute
Santa Fe Mayor David Coss

9:00 USGS Water Programs and Initiatives
Robert M. Hirsch, Associate Director for Water, U.S. Geological Survey

9:30 Keynote Address: What Happens after "The Year of Water"?
New Mexico Lt. Gov. Diane Denish

10:00 Break

10:30 Competing for the Future - We Need a Different Model
John D'Antonio, NM State Engineer

11:00 New Mexico Indian Water Rights Settlements and Their Economic Impact on Tribes and Pueblos
Chairman Joe Garcia, All Indian Pueblo Council (cancelled)

11:30 Preview of Legislative Water Issues 2008
New Mexico Representative Andy Nuñez, Chair, Committee on Agriculture and Water Resources

12:00 Lunch on Your Own

Thursday Afternoon, November 29, 2007

1:30 Implications of a Growing Population and Changing Demographics in New Mexico
Adélamar Alcántara, Bureau of Business and Economic Research, University of New Mexico

2:00 Market Prices as Measures of Water Scarcity in New Mexico and the West
F. Lee Brown, H2O Economics

2:30 A Living River Fund
John Horning, Forest Guardians

3:00 Break

3:30 Climate Change and Its Implications for New Mexico's Water Resources and Economic Opportunities
Julie Coonrod, University of New Mexico

4:00 Panel Discussion: The Federal Perspective and Initiatives on Water
Moderated by Karl Wood, WRRI Director
Mike Connor for Senator Jeff Bingaman
Zane Vaughn for Senator Pete Domenici
Ron Morsbach for Congressman Steve Pearce
Johanna Polsenberg for Congressman Tom Udall
Tito Madrid for Congresswoman Heather Wilson

5:00 Reception hosted by Daniel B. Stephens & Associates
La Terraza

6:30 Dinner Banquet - Ballroom
Doc Warner, Doc Warner's Alaska Fishing Adventures

Friday Morning, November 30, 2007

8:30 Climate Research and Applications Needs in Support of Climate Services
Roger Pulwarty, National Oceanic and Atmospheric Administration

9:00 Governor's Task Force Report on Climate Change
David Gutzler, University of New Mexico

9:30 Western Agriculture at Risk from Climate Change and Competing Water Demands
Pat O'Toole, Family Farm Alliance

10:00 Break

10:30 What to Do with Water Left Over after Needs are Met?
Bob Grant, Grant Enterprises, Inc.

11:00 Future Climate Change Impacts on New Mexico's Mountain Sources of Water
Albert Rango, USDA-ARS-Jornada Experimental Range,
New Mexico State University

11:30 Water Productivity and Water Capital – Addressing Fresh Water Availability Limitations
Mike Hightower, Sandia National Laboratories

12:00 Adjourn

David Coss *was elected Mayor of Santa Fe in 2006. Among the Mayor's priorities is protecting Santa Fe's water and environment. This includes continuing to work with Santa Fe County to make the Buckman water project a reality, implementing smart growth policies that link water and growth, further developing water conservation initiatives, supporting local conservation design businesses, adopting aggressive green building standards, promoting alternative transportation, and supporting the Kyoto Protocols regarding climate change. Additionally, the Santa Fe River, which has shaped the region's history and drawn various cultures to reside here, is currently in a state of disrepair. David will continue to work to create a healthy Santa Fe River watershed connected by systems of trails and parks throughout the entire city. David grew up in Santa Fe and holds a B.S. in wildlife science from New Mexico State University and an M.S. degree in zoology from Southern Illinois University. After completing his master's degree, David worked as a surface water scientist for the State of New Mexico. During this time, he became active in his union and worked to create the New Mexico Environment Department and became director of the Environmental Protection Division within NMED. In 1995, David became Director of Public Works for the City of Santa Fe, where his dedication to restoring the Santa Fe River formalized. During that time, he was instrumental*

in creating the Santa Fe River Masterplan and worked on the river restoration between St. Francis Drive and Camino Alire. After working as city manager in 1996, David completed his public service career at the State Land Office where he continued his work in environmental protection and natural resource management.

WELCOMING REMARKS

Santa Fe Mayor David Coss
City of Santa Fe
200 Lincoln Ave.
Santa Fe, New Mexico 87501

I see the screen up there, and I was thinking only in Santa Fe would everybody be facing this way and the screen would be facing that way. It is a pleasure to be here this morning with the Water Resources Research Institute. I do kind of feel like I'm home a little bit. I used to go to lots of your meetings when I worked for the Environment Department in the Surface Water Quality Bureau, and I was staff for the Water Quality Control Commission for a long time, which included a lot of water people in it.

It is really fun to see the students from New Mexico State University. I always was proud of being from New Mexico State, but that wouldn't always serve you well when you were around Steve Reynolds, who was a UNM guy. I remember once we had a Water Quality Control Commission meeting in Las

Cruces, and the assistant dean of agriculture, Wayne Cunningham, who was also on the commission, spoke. We were feeling so great to be in Las Cruces, and it was my turn to get up and make my presentation. I said, "I'm proud to say I'm an alumnus of New Mexico State as well." I thought that was a good way to start the talk, but one of the UNM guys on the commission said, "Well, we won't hold that against you." And then Steve Reynolds added, "Yes we will." It was downhill from there.

It is the job of the mayor to welcome folks to Santa Fe. We are always very, very glad that you are in Santa Fe. It is obligatory for mayors to say, "I hope you do a lot of shopping while you're here." We are very, very proud of our 400-year-old city. We are very, very proud of this hotel and of this beautiful downtown that you're in. We are glad that you chose Santa Fe and that you are here meeting in Santa Fe.

The long-range supply planning efforts for Santa Fe have concluded that Santa Fe will not need a major additional water supply project in the next 40 years. I am actually hoping that with some conservation and smart use of our resource we can extend that indefinitely into the future.

I'll have to tell my friends at the municipal league who say they can't meet in Santa Fe because it is too expensive that the Water Resources Research Institute manages to do it. I think you will really enjoy being here in Santa Fe.

We have some of our water staff, like Claudia Borchert, here. If I say anything wrong, you need to talk to Claudia. We have a fantastic water system in Santa Fe. I think we really are a state and a national leader in that. You referred to our slight problems in Santa Fe. The year I got on the city council, we had the worst drought on record. We were a few days away, during Indian Market when there were an extra 50,000 people in town, from not being able to pump water out of our system. That kind of got everybody's attention. We had owned the water company for about four or five years at that point, but we said that things have got to change, that we have to do things differently in Santa Fe. We had to do a lot of things differently.

I think there is a great deal of effort and willingness on the part of the general public. We are getting further ahead of the curve right now, but there is a lot of work to do. I would like to say that through our implementation of water conservation strategies, the city of Santa Fe, the people of Santa Fe, have conserved approximately 37,300 acre-feet of water since 1995. I like to talk about the fact that we live in a community that is anti-growth but wants affordable housing for their kids. We are always trying to figure out that dynamic. Really since 2002, we used 2,000 acre-feet less per year than we used in 2000. That is a tribute to the innovation of the community and the conservation efforts in the community.

Our per capita water use in Santa Fe has dropped from 170 gallons per person per day to approximately 106 gallons per person per day, and that includes all uses, except wholesale utility customers, like Las Campanas. We compare ourselves to other communities. Maybe there are two models developing. Compared to the city of Phoenix who has a demand of 270 gallons per person per day, Santa Fe is at 106. I think that we can do a lot better.

The long-range supply planning efforts for Santa Fe have concluded that Santa Fe will not need a major additional water supply project in the next 40 years. I am actually hoping that with some conservation and smart use of our resource we can extend that indefinitely into the future. It is probably a good thing that we won't need one for another 40 years because we haven't figured out how to pay for the Buckman direct diversion project that we're building now.

I wanted to indicate some of the things we are doing. We are doing long-range water supply modeling and planning. We are working on our long-range water supply plan right now to meet the community needs for 40 years. We see our strengths and our weaknesses in the system. It is a great place for hydrologists to work because we use mountain water. We use aquifers along the Santa Fe River. We use the Buckman aquifer, which is not as connected to the Rio Grande as originally thought. Now we are working on a project to bring the San Juan-Chama water into Santa Fe. It is a very diverse portfolio of water rights and water sources that we have in Santa Fe.

We have been tying growth since 2002 to the understanding that our water resources are limited. Anybody that gets a building permit in Santa Fe now has to either retrofit toilets—I think it is eight or ten toilets to twelve per household now—or you have to bring water rights to the table to get a building permit in Santa Fe. I think that is the kind of program that has led to continued growth and continued economic

development in Santa Fe, but we have been flat in our water use. It went down 2,000 acre-feet, and we stay around 10,000 acre-feet of water use per year.

I had all of these great technical comments that the staff wrote for me, but I just wanted to leave it at that and say a few words. This is the group that is really going to help Santa Fe, help New Mexico, figure out its water future.

We think a lot in Santa Fe about the fact that we are 400 years old. You are very, very close right now as most of you probably know to the Santa Fe River. We kind of have to experience the Santa Fe River in relation to tourists. One question they ask, "Where is the river?" They can hardly believe it when you point it out to them. The other comment, which is even a little funnier, is that sometimes when you are by the Land Office, you will hear a group of tourists talking. The dad will say, "This, kids, is the Rio Grande." But it's just our Santa Fe River.

If you look at it now, it is inconceivable why anyone would form a villa de Santa Fe here. Our river is dead. It doesn't look like it would support water. It doesn't look like it would support agriculture. It doesn't look like you could get firewood from there. Why would you do that? Yet, we know that 400 years ago this was the desirable place to live. It has supported communities, and it has supported agriculture for over 400 years that we know of. When we talk to our Tesuque friends, they say it goes back a lot farther than that.

In my lifetime, the Santa Fe River has become a severely degraded river. There is a pipeline over the river that the City put in as a sewer line when I was a kid living by Casa Solana. It was 12 feet under the bed of the river. Now that pipeline is at the top of the 100-year floodplain. I can use words like 100-year floodplain. You can imagine that from the time I was a kid to the time I became an adult, and I know I'm getting older, that there was 30 feet of erosion, which means your water table came down 30 feet, which means your riparian system changed, which means you can't irrigate off the Santa Fe River anymore.

When you're mayor you have experiences like one I have every spring. Every spring, the farmers in La Bajada come to see me. They say, "If you don't let more water down the river, we are going to sue you as soon as the state gives us enough money to sue you." We've managed to avoid that situation year after year. It is a concern for all Santa Feans.

We are very active with the Farmer's Market. We really do want to sustain agriculture in New Mexico and especially northern New Mexico. We know that our water rights purchases off of the Rio Grande are going to have some effects.

To put it back into my political perspective, I hang around with a lot of union guys and labor guys. I was always talking about needing to restore the river. It is a sign of whether we will make it as a community in Santa Fe. They asked me, "Dave, why are you always talking about that?" I said, "Well, you know it is just interesting to me. I think it is important." Then they did some polling, because you always do polling to see what works and what doesn't. The polls came back, and my campaign manager, the old labor guy, says, "Keep talking about the river, Dave." In Santa Fe, that poll indicated a 75% approval, which was more popular than anything else I was talking about in that campaign.

The citizens want a restored Santa Fe River. They want a healthy watershed. They want housing and economic development and growth for their community, but they also want to know that the acequias are going to be there. They want to know that the farmers in La Bajada get the water that they've had for the last several hundred years and continue to farm. I think the Water Resources Research Institute and the kind of work that you folks do all over the state is going to give us those tools, techniques, and information so that we can continue to make this balance out in Santa Fe and all over New Mexico.

I have really enjoyed listening to the upstream/downstream dialogues that are going on concerning the Rio Grande. We all have great plans regionally for what we are going to do with water, but when you add it all up, we are all saying that we are going to take water from the other basins and bring it in here. It is great to get an upstream/downstream perspective on the Rio Grande. That is not what is going to happen; that is not what is going to work. We've got a lot of work still to figure out how we are going to live in New Mexico for another 400 years. I can tell you that the people of New Mexico, the people of Santa Fe, want us to figure it out so that we can have our cities, have our housing, and have our economies. We want living rivers. We want sustainable agriculture. That is the job that you guys have to help us figure out.

It is a pleasure for me to welcome you to Santa Fe. It is great to be back talking to WRRI conference participants. I wish you every success in your conference. Thank you for helping New Mexico and Santa Fe figure out how to make the best use of what is the most precious resource we have. Thank you.

Robert M. Hirsch *is the Associate Director for Water, U.S. Geological Survey. In this capacity he is responsible for the USGS water science programs nationwide. These include the collection and management of basic hydrologic data, studies of hydrologic systems, and basic research on hydrologic processes. Bob was born in Highland Park, Illinois. He received his B.A. in geology from Earlham College, an M.S. in geology from the University of Washington, and Ph.D. in geography and environmental engineering from Johns Hopkins University. Bob began his career with the USGS in 1976 as a hydrologist. He conducted and directed research leading to methods for analysis of the risk of water-supply shortages, water-quality trends, transport of pollutants in rivers, and flood frequency. He has published numerous journal articles, USGS reports, book chapters, and a textbook. He also was instrumental in the design and initiation of USGS programs including the National Water-Quality Assessment Program, Global Change Hydrology Program, and Watershed Modeling Systems Program. In addition to his role as Associate Director of the USGS, he also serves as co-chairman of the Subcommittee on Water Availability and Quality, of the Committee on Environment and Natural Resources of the National Science and Technology Council. Bob is a recipient of the Department of the Interior's Distinguished*

Service Award, has twice been conferred the rank of Meritorious Executive by the President of the United States, was the 2006 recipient of the AWRA William C. Ackermann Medal for Excellence in Water Management, and was elected a Fellow of the American Association for the Advancement of Science.

USGS WATER PROGRAMS AND INITIATIVES

Robert M. Hirsch, Associate Director for Water
U.S. Geological Survey
12201 Sun Rise Valley Dr.
Reston, VA 20192

It is a pleasure to be here. I was here a few years ago. I have lots of new things to talk to you about what's going on at the USGS in general and particularly in relation to water. The USGS is about 130 years old. It is a federal agency. It is strictly a science agency. We do not manage or regulate. We try to provide information that people need to manage and protect our nation's resources, in this case, water.

This area, this part of New Mexico, is really significant from a historical perspective for us in the USGS because stream gaging actually started not very far from here at Embudo, New Mexico, on the Rio Grande. John Wesley Powell, our second director, said, "You know, if we are going to develop the western United States, we need to know how much water there is, and we need to measure the flow of the rivers." Nobody really knew how to do that back in 1888. We hired some young engineers, a fellow named Frederick Newell out of MIT, and said go out and take a bunch of guys, take the railroad, get off at Embudo, and spend

a few months seeing if you can figure out how to do gaging. And they did. They developed some outstanding techniques, parts of which we still use today, although there are a number of things that we are modernizing and improving upon. The basic principles were really ironed out here in northern New Mexico at Embudo and spread throughout the country starting 119 years ago.

We have a great tradition of that kind of appraisal of the nation's water resources, not just surface water but also ground water. We are always looking at what the issues of the future are and how we need to go about responding to the issues of the future. We have in the USGS recently completed a strategic science plan, which we are going to be sharing more broadly with the wider community. This covers all of the USGS. Just a comment to those not familiar with it—the USGS has four major scientific disciplines within it: water, which I represent; the geology discipline; the mapping folks who we all know for the wonderful topographic maps; and the newest part of the USGS, which is our biological resources discipline that looks at fish and wildlife and the research science behind those things. This positions our agency better than almost any agency we can think of in the world to deal with the natural resource issues because so many issues cut across these many disciplines.

This positions our agency better than almost any agency we can think of in the world to deal with the natural resource issues because so many issues cut across these many disciplines.

The science strategy we developed in the USGS has six major topics that we need to focus on for the future. I will quickly go through what those are and state a little bit about the water aspects of those topics. The first one is ecosystems and understanding how ecosystems function and how they will function in the future. An absolutely crucial question and one that you all probably regularly hear in this state is the relationship between water, particularly flow temperature, habitat quality for a variety of aquatic organisms, and I would add riparian organisms as well. Silvery minnows would be just one example. We see this issue cropping up everywhere in the country, wet places, dry places—it really doesn't matter. It is the big issue right now in the Southeast. How much water do those fish or shellfish or what have you need? I consider it to be the gridlock issue in water resources nationwide—that is, coming up with a good, strong definition of the hydrologic needs of the species that we can defend and then work toward protecting the amount of water needed. Our biological and hydrological capabilities in the USGS are crucial to that issue.

The second topic in the science strategy is the subject of climate variability and climate change. I think we all recognize that the importance of understanding climate and what the climate might be like in the future is crucial to understanding what water resources are going to be like. One of the aspects we have particularly stressed in recent years on this topic is understanding seasonal shifts in runoff patterns in various parts of the country. For large parts of the United States in the hundred or so years of historical record on streamflow, we do not see a strong climate change signal in most areas of the United States. What we do see is that in those areas where there is snow and ice, which is significant to the hydrologic system, there are strong changes. We are seeing it strongly in New England. We are seeing it strongly in the Sierra Nevada and less so in this part of the country. I think if we really get in and look closely at some of the higher mountain areas and the source area of the Rio Grande up in Colorado, I think we will see it, which means an increase in flows during the wintertime because we are seeing more rain and less snow in a lot of these environments. There are more melt events. Conversely, there are lower flows in what is usually the snowmelt season, say April through June in various areas. A lot of the places where we have done these analyses, we can see strong seasonal trends, but when we look at the entire year we basically see no trend at all. What we are seeing from climate change to date is this seasonal shift in areas where snow and ice are significant to the hydrologic system.

A lot of work needs to be done, and I think it is going to combine the talents not just of hydrologists, but also of water resource engineers, economists, and others, thinking about a new paradigm for water management, a paradigm that recognizes a nonstationary world. The future is not going to look like the past, and we need to know how to develop, whether we are looking at the 100-year flood, looking at the safe yield of a reservoir, or things of that kind in this nonstationary world that we all now realize that we are living in.

The third topic is energy and minerals. Now that sounds mostly like a geologic topic, but they are important considerations for our water discipline at the USGS. Things like the Questa Mine here in New Mexico are a prime example where there are questions of understanding geochemistry, mineralized areas, and the whole issue of what you need to do to clean up and how clean you need it to be considering that the environment in its natural state was not completely pure with respect to heavy metals. This is an example where hydrology is crucial.

Another issue is the connection between climate and energy and water. The biofuel developments that are going on in the nation and the growing demand for corn have implications for water availability for processing and for irrigation. This is one of the things that I am very interested in watching. If anyone here has insights on it, I would love to hear from you later today. We do know anecdotally that there are areas of the country, particularly on the High Plains, where irrigated agriculture became uneconomical a decade or two ago, largely because of energy costs and increased pumping lifts. Now with the price of corn having increased so much, we are seeing some of those areas potentially coming back and being economical again. People are beginning to pump water to irrigate some of those lands that they may have stopped irrigating years ago. I do not know if that is a tiny phenomenon or a big one at this point, but I think it is an issue to be watched. Our energy future is clearly very much tied to and influenced by our water future.

Natural hazards are another really important area for the USGS and for people to think about with respect to earthquakes and volcanoes, hurricanes and their effects on coastal areas, but most certainly flooding and the importance of our stream gaging network. Our ability to provide up to the minute information directly to users as well as to the National Weather Service to facilitate their forecasts is really an important area. One of the research questions that we are very interested in is the question of the relationship between climate warming associated with the greenhouse effect and flooding. My own opinion is that there is a lot of hype going on about greenhouse warming and associated increases in flooding. Thus far, the empirical record is not at all clear that this is the case. What we see in the United States is increasing economic damages associated with floods over the last several decades, but as a physical phenomenon, the evidence is not at all clear that there is any kind of increase in flooding occurring. I think it is a very important research question and one important to hazard mitigation in the future.

The fifth topic in our science strategy has to do with human health, which is not a topic people often think about with respect to the USGS. Other parts of the USGS, particularly the biological division, are very interested in things like avian influenza and are doing a lot of important monitoring on issues like that. From a water perspective, we are very interested in the issue of mercury, for example, and understanding the geochemical and hydrologic conditions that bring about the methylation and movement of mercury into the food chain and the implications that has for animal health as well as human health. Also, advances in the understanding of pathogens and source tracking are important. If you find an area that has certain kinds of pathogens or bacteria in it, what was the source? Is it a wild animal source? Is it a domesticated animal source? Is it a human source? Is it a bird source? All these possibilities are out there. Before the taxpayer is asked to make huge investments or private industry is asked to make large investments to clean that up, we really need to know the source of the contamination. Using DNA-based techniques to try to answer these questions is a real frontier area for a wide range of scientific folks in the future.

Another issue is the connection between climate and energy and water. The biofuel developments that are going on in the nation and the growing demand for corn have implications for water availability for processing and for irrigation.

The sixth and final topic in our science strategy is something we are calling water census. I will say a little bit more about that because it is obviously central to our mission in the water resources programs of the USGS. We have been thinking about this idea of water census for a long time. The nation has a census of population, a census of agriculture, a census of manufacturing; we have economic statistics and all kinds of information about our nation and its resources. What do we have that pulls together the fundamental information about our water resources? The answer is that we really do not have anything. The fact is there

has been no organized national effort to look at our nation's water availability and water use nationwide consistently since 1978, which was the second national assessment conducted by the Water Resources Council. We think a broad overview of understanding our resources and how they are changing is part of what is needed for proper stewardship of our nation's water resources.

There is a story I like to tell about this whole idea of water census. It comes from your neighboring state of Texas and the drought they had in the late 90s. It was a very, very severe drought, and all kinds of key water managers in the state went into the office of then Governor George Bush to talk about the water crisis. Governor Bush said to them, "Well, how much water is there in Texas?" They were all kind of dumbstruck by the question. On the one hand, they said that was really kind of a simplistic question. As they thought about it and as I think about it, it is a really great question. We will answer it in perhaps somewhat complex ways. How much water is in the streams? How much water is in surface water reservoirs? How much water is in the aquifers in different parts of the state? How much water is in the soil? We break it apart into these various components, but that basic question remains of knowing what's out there and how that has changed on time scales of days, weeks, months, years, decades, or even centuries.

I think it is really an important perspective. It is not unlike thinking about your own personal finances or your business or your agency. What is our income? What is our outflow? How much do we have in the bank? Just basic questions like that set the stage for understanding where we are and enable us to plan for the future. To us, water census means taking a consistent and broad look at questions concerning basic statistics of streamflow, low flows, high flows, how they change over time if they are in fact changing, ground-water levels and their changes, and the amount of water we have in storage in our major aquifers. I would point out that we at the USGS in the Albuquerque office have a project funded by the New Mexico Office of the State Engineer to look at changes in storage in a portion of the High Plains aquifer in New Mexico to understand how those changes have taken place since development began and the rate of those changes currently. Conducting similar studies across many of our aquifers on an ongoing basis is important. Describing the depletion of our aquifers, describing the impact of that depletion on streams and wetlands, and describing our nation's water use and what the real trends are in water use is part of this study. One of the interesting trends I see in irrigation is actually a slight decline in the western United States and an increase in the eastern United States. These are interesting trends that we must stay on top of and understand if we are going to be able to look forward to their implications for our water resources.

...the water census really means organizing the information into models that look at the sources, storages, and the outflows of water including the human aspect.

Finally, the water census really means organizing the information into models that look at the sources, storages, and the outflows of water including the human aspect. The work we did years ago in collaboration with Albuquerque and the State in the Middle Rio Grande is an excellent example. We worked on understanding how the system evolved over 100 years of development and were able to ask "what if" questions about future strategies.

In 2002, Congress asked us about water availability and use and the need for an assessment. We provided them with a document that described what we think would be an appropriate program to analyze water availability and use by looking at water resources region by region across the nation. We published that blueprint as USGS Circular 1223. Congress funded us to conduct a pilot study of water availability and use and to put recommendations into practice to see what it looked like. Congress chose the Great Lakes basin as the test bed. I think what they had in mind is that they wanted to make sure Governor Richardson knew how much water there was up there to tap. That was the wisdom behind their plan. The products from that study are now coming out, and we have a new website with those products. We think that is an important effort. It forms an important part of our USGS science strategy.

I want to say a bit about some specific programmatic areas in the USGS and things that are going on currently. There always is a concern about the viability and the strength of our stream gaging program. I started off by mentioning that stream gaging by the USGS started right here in New Mexico at Embudo. We are very proud of what we have accomplished with a national network of about 7,400 stream gages nationwide, most of them real-time

gages. We have been concerned over the last 15 years with the stability of the network and the need to modernize it. I think we have made some headway on those issues.

We were seeing, particularly in the 1990s, the loss of gages that had very long records. With conditions like climate change and ground-water depletion, this becomes an important issue to be able to have records that are often as long as 80, 90, and 100 years. Those are great assets to the understanding of our nation's water resources. We do not want to lose them. Back in the mid-1990s in any given year, we were finding that something on the order of 100 to 150 long-record stream gages were being shut down every year and that was because of a lack of funding, both in our budgets and in our partners' budgets.

If you are not aware of it, stream gaging is very, very much a partnership activity in the USGS. In fact, the majority of the money that pays for our stream gaging comes from state and local agencies. In various parts of the country, those agencies were having budget problems and shifting priorities. We would find really important stream gages that would have to be shut down because there was no source of funding for them. We were losing as many as 150 per year of these long-record stations, where long is defined as 30 years or more.

In 2001, Congress responded to that concern and gave us a significant increase in federal funding for stream gages that enabled us to start on the process of building what we consider a federal backbone of stream gages with a very thoughtful design of where those gages ought to be. It is a little bit like the National Weather Service that designed their Doppler radar system. Congress didn't say that they would fund it only if they could find partners. Congress said, "This is important to the nation's safety and wellbeing, and we are going to put these out in a designed pattern and pay for them with federal funds." Our view on where the stream gaging ought to be is that we must have a base paid for with federal funds. The partnership would come into play when more gages are required based on locality and particular needs.

We did get a funding increase in 2001 that enabled us at least temporarily to stabilize the network. However, the funding did not increase for several years, and the effects of inflation had caused us to get back into the situation where we were losing somewhere on the order of 100 long-record stream gages per year. Fortunately the administration has considered this to be an important issue, and in fiscal year 2007, we received an increase in funding for stream gages in our budget. In 2008, there is a proposed increase. If Congress will pass the 2008 appropriation, I think we will see some positive results.

Just to give you a flavor of that, the federal line item for stream gaging, which is called the National Streamflow Information Program, in 2007 was funded at $16.6 million. The House appropriations bill calls for increasing that to $21.6 million. That is a 30 percent increase. That is really good news for the stream gaging network if it is enacted. The Senate also proposed an increase, but not as large. The Senate called for an increase from $16.6 up to $18.9 million, or a 14 percent increase. If Congress can enact either one or a compromise between the two, it will be good news for the stream gaging program. We feel that it will improve the network's stability and also the modernization of the network. Part of that modernization is moving from gages that report to the satellite and back down and into the internet on a four-hour time scale down to gages that report on a one-hour time scale with the modernization of our radios. We are very excited about the prospect of a more modern and a more stable stream gaging network.

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As I said, I think these partnerships for stream gages are extremely important. I want to say just a bit about stream gaging in New Mexico. Back about 20 years ago, we had 196 continuous record stream gages operating in the state. Today that number has grown from 196 up to 221. All indications are that there will continue to be some growth, particularly in some of the urban or fringe urbanizing areas of the state. We are getting more and more of the high data rate radios, so we are reporting more frequently. We have about 13 state and local agencies contributing to stream gaging. They provide, along with our cooperative funding, 66 percent of the total funds. We have six

federal agencies providing 25 percent, and then the National Streamflow Information Program monies, the monies that we control on our own are providing only about nine percent of the total funds and covering 19 of the stream gages. That federal funding has enabled us to add recently the Pecos River at Red Bluff gage and the Rio San Jose gage in 2007. We are seeing some progress.

I want to talk about new mechanisms for data delivery because we are really excited about the things the internet is doing in terms of enabling us to get the data to many kinds of users in an effective manner. We have a new system called IDA, the instantaneous data archive, a place where people can go to get data. We collect data on a 15-minute interval in most cases. For various kinds of studies, engineering studies of floods or water quality and so forth, understanding the true shape of the hydrograph is crucial. Downloading the data on a daily basis going back in history does not really give you the definition that you need in order to do some of those scientific studies. The IDA database, which we are gradually filling with all the data across our offices and across the country, goes back and fills in a lot of that 15-minute data that is so useful to scientists and engineers. We already have 1.5 billion individual data values in that database. We are only about halfway there, but that is now publicly available.

We are doing more and more with real-time water quality information in a variety of locations around the country to help people with operational decisions or public health considerations like bacterial counts.

We have a system called StreamStats and that application is being developed for the state of New Mexico. It has to do with the ability to get streamflow statistics at any given location. I think many of you are familiar with our regional regression equations that say things like the 7-day, 10-year low flow is a function of drainage area, elevation, percent forested, or various other characteristics of the watershed that are based on the data from our stream gaging. This system enables you to go onto a computer in a GIS environment and point and click on any point on any stream and have it return back to you the available stream characteristics at that arbitrary point and then return the corresponding regression estimates. It is a tremendous time saver to anyone who needs to develop that kind of information, whether it is the 100-year flow, the 7-day, 10-year low flow, the mean annual flow, or any of these kinds of statistics. It is a great system, and it should be operational fairly soon for New Mexico and is operational in a number of other states.

One emerging trend in our program is real-time streamflow, which is an important step forward for everyone. We are seeing more and more of the use of real-time delivery of ground-water level information. I used to scoff at the idea of real-time ground-water information because it seemed to me that things don't change that fast with ground-water, so why would I need it in real-time? What I have seen in various parts of the country is that it becomes a very useful tool. For one thing, it tells you if your equipment is not working properly because you can see either the lack of data or something that looks suspicious. It can tell you when you need to service the equipment, and if everything looks fine you can probably go longer periods of time without making a field visit. Particularly for those sites where the aquifer is very tightly connected to streams and to month-to-month climate variations, it gives you the ability to understand whether you are seeing recharge or declines. It helps in the management of a drought situation. Finally, and I think very importantly, real-time ground-water information increases public awareness of ground water. When people can actually see on a day-by-day basis what is happening to the aquifers in their part of the state, it helps to educate and make people understand what is truly happening to their aquifers.

We are doing more and more with real-time water quality information in a variety of locations around the country to help people with operational decisions or public health considerations like bacterial counts. We all know that currently there is no technology that measures bacteria in real-time. You still have to collect a sample and send it to the laboratory and wait for an incubation period and do a counting on the result. What we have found though is that at any given location on any given stream some things that we can measure readily in real-time, like turbidity for example, can be good statistical indicators of bacterial counts. There may be a lot of noise and a lot of error in that relationship, but there still is a relationship. It enables us to make an estimate of the expected concentration of say, fecal coliform, E. coli, or what have you, and the uncertainty bands to make statements like, "We

think there is a ten percent chance that this water is above the health criteria," or "We think there is a 95 percent chance that this water is above the health criteria." We are finding that public health agencies are actually using this information to make decisions about warning the public. We think that is a really exciting development.

Sediment is a very important topic in this state. I think it will become more and more important as the City of Albuquerque moves to withdrawing surface water from the Rio Grande. Sediment data collection is a very expensive process, very labor intensive, and we are finding that there are some new and emerging technologies for measuring sediment loads on a continuing real-time basis, using technology like multi-channel acoustic Doppler current profilers as well as some optical techniques that are still in the research phase. We think it is an important development.

Finally I will just mention a great new research tool. Fiber optic cable is a wonderful system for making temperature measurements. We have a new method where you can literally string a long fiber optic cable in a stream and identify the temperature anomalies. Those temperature anomalies tell you where the zones of ground-water movement into the surface water system are taking place and help to quantify the ground-water/surface-water interaction.

While I am on the subject of ground water and surface water, I also want to mention that we have a new model that is almost ready for public release within the next few months. The final documentation is in its final review phase. It is a model called GS Flow. It is a model that attempts to look at ground water and surface water as a very, very integrated system. It couples our watershed model called PRMS, our ground-water model MODFLOW, and a new unsaturated zone model that connects the two. Much work was done to make sure that we conserve mass and energy throughout the entire system and are able to look at large, large watershed aquifer systems. We did not want to look just at questions of ground-water/surface-water interaction of pumping right next to the stream and things like that, but to look closely at basin-wide effects on time scales of decades and even centuries and spatial scales of many miles. I think GS Flow will be a really great additional tool for the water resources community.

I want to quickly mention that the National Water Quality Assessment program is very active here in New Mexico with some water quality monitoring being done on both surface water and ground water. A very intensive study on the movement of contaminants to large public supply wells is going on in Albuquerque as part of a national effort to get a better understanding of the special characteristics of contaminant transport into large public supply wells.

Another program that is important in New Mexico in the future is our ground-water resources program. We are going back and restudying major aquifer systems that we looked at seriously in the 1970s and 1980s through our regional aquifer system analysis program. In fiscal year 2009, we are planning to go back to remodeling our High Plains aquifer system across all of the states of the High Plains area.

Sediment is a very important topic in this state. I think it will become more and more important as the City of Albuquerque moves to withdrawing surface water from the Rio Grande.

Something that may be in the future before the USGS is the transboundary aquifer study—legislation that was passed by Congress and signed by the president last year to look at transboundary U.S.-Mexico aquifers in the states of Texas, New Mexico, and Arizona. This has been proposed for funding in the Senate appropriations bill, but not in the House bill, so we do not know how that is going to come out. A million dollars has been proposed. Half of that money would go to the water institutes; half of it would go to the USGS for our internal use, and it would be split three ways into a Texas piece, a New Mexico piece, and an Arizona piece. Basically, it is one-sixth of a million dollars to the New Mexico Water Resources Research Institute and one-sixth to the USGS-New Mexico office for that work. We will wait and see what Congress does with that appropriation as to whether it moves forward. It would certainly be significant here in New Mexico.

Finally, I want to mention an exciting development from my perspective in the Congress. The Secure Water Act was recently introduced in the Senate, and Mike Connor had a lot to do with that. Senator Bingaman and Senator Domenici are cosponsors along with Senator Cantwell of Washington and Senator Johnson of South Dakota. It is a bill that focuses on the matter of water science and information for the

future of the nation. It focuses on the issue of climate change and its implications for water management. The idea is to engage all of the water agencies—the Army Corps of Engineers, the Bureau of Reclamation, the Department of Agriculture, NRCS, NOAA, and USGS—in this question of the implications of climate change for water resources management. It also calls for specific areas of enhancement of USGS water science and information, such as the National Streamflow Information Program, improvements in ground-water data availability, improvements in information about water use, and improvements in the methodologies. I think this is really important to the universities. Making the methods of water measurement more efficient and more accurate I think is crucial. It is specifically called out in this legislation. It calls for the assessment of water availability and use, really very much along the lines that I described at the beginning of my talk about the water census. We are very pleased to see this congressional focus on works of water science and information for the future of water management.

For the USGS water programs, partnerships are really the key to our success. We value those partnerships enormously. We have been at that partnership process for 115 years through our cooperative program. The Office of the State Engineer and the cities, the counties, the tribes, and other federal agencies are very, very important partners to us. They help us set our direction and provide a very large fraction of our funding. Our partnerships with the universities are also very important, including that other university (UNM) that you mentioned a few minutes ago as well because it happens to be fairly close to our major office in the state. We are always looking for an infusion of young, energetic talent from the students coming into our work place.

Question: When you were talking about your strategic science plan including climate change and shifts in seasonal runoff in snow and ice, some organizations and groups have been using tree ring data, ice cores, ocean phenomena, and they are looking at long-term changes in runoff. Is the USGS looking at long-term changes?

Hirsch: We are very much looking at those kinds of things. Julio Betancourt is a name fairly prominent in the area of tree ring study and other paleoclimate type research that we do. We are learning, for example, that over the last several hundred years there have been a number of very, very prolonged and severe droughts in the southwestern United States. In some respects, the 20th century was a pretty benign and plentiful time period. We are very much engaged in that kind of paleo perspective in water. At the same time, we think it is very important to look at greenhouse warming and the addition of carbon dioxide to the atmosphere and its affect as well as the changes that have occurred in the last few years as that phenomenon has increased in importance.

Question: Just one comment on a historical note. Mike Kernodle and I have a paper coming up in *Ground Water* on New Mexico's contributions to hydrogeology and hydrology starting with Powell, Newell, and Bryan and up to Theis, and the paper covers that work.

Hirsch: The paper demonstrates the important role the state of New Mexico and USGS people along with university people have played in the history of the development of ground-water science. I'd love to get a copy of that myself.

Diane Denish *is the first woman to be elected Lt. Governor in New Mexico. A lifelong New Mexican, Diane was raised in Hobbs and has lived throughout the state. She is the former chair of the Democratic Party of New Mexico and for twelve years owned a successful small business. Named one of the Top 100 New Mexicans in honor of her community leadership, Diane has served as Chair of New Mexico First, New Mexico Community Foundation, the state's Commission on the Status of Women, and the New Mexico Tech Board of Regents. The National Kidney Foundation, the YWCA, and the Albuquerque Arts Alliance have honored her for her achievements in public service. She was honored by the American Academy of Pediatrics as 2004's Child Health Advocate. During her time in office she has fought to improve education, increase access to health care, crack down on criminals who endanger children, and create more economic opportunities for New Mexicans – especially those living in rural areas. As chair of the Children's Cabinet, her accomplishments for children include the passage of the Pre-Kindergarten Act and the first-born home-visiting program.*

WHAT HAPPENS AFTER "THE YEAR OF WATER"?

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I am really pleased to be here. Before I even say anything, I want to introduce my chief of staff, Judith Espinoza, who is here. She is going to be leaving my office soon, but I just want to give her a lot of credit for the kind of institutional history she has brought and her vast knowledge of water issues and working with the State Engineer and Environment Department about various water issues in New Mexico. I am sure many of you know Judith, but it has been a pleasure for me to have her in my office and to have her policy expertise and the resource that she has brought to many of you. She has also used many of you as our resources when we are thinking about water policy in New Mexico. Thank you, Judith. I appreciate it.

We do not need to look much farther than the ruins at Chaco Canyon, where I just spent a day about a week ago, to know how zealously we have to guard what is the very best about our state and how delicately we have to treat this land of desert and mountains around us. We are nearing the end of "The Year of Water" in New Mexico. In 2007, Governor Richardson worked hard to put some focus on water issues in New Mexico. I believe that especially the focus on the finances for water needs has helped us accomplish a lot. In spite of just having a year of water, we know that water is going to continue to be an issue for all of us because frankly, as you all know better than

anybody, we have a fixed amount of water, like many other places. Our population continues to grow and grow and grow. On top of this, we have the continued climate change, something that is now kind of the buzz word, global warming. We know through science that climate change is real and that the consequences for all of us are here to stay. The consequences for generations to come are something that we can do something about maybe in a limited way, but we can do something about them.

Increasing desert climates and deforestation continue to expand all over the world, while at the same time the polar ice is melting. I am personally very grateful for what science has done and what the public arena has done to bring that to attention. As we think about it, it is not only affecting water policy, it is affecting all kinds of policy that is being made today to see what kind of carbon footprint is being made. I think the consensus is that the world is getting warmer, and that means change is coming. It is something that we have to deal with in the southwestern states. It could mean less snow and less snowpack and more intense rains but for shorter periods of time. For us, that is something we have to be thinking about. As we recognize our regional water needs throughout the U.S., I think what the governor and I have tried to do, at least to begin doing, is to work hard to focus our policies and resources of the state on water issues. We don't want it to just be "The Year of Water." We did accomplish a few things, and I would like to mention some of the things that happened during "The Year of Water" that are important to all of us.

We have now signed settlements, gratefully, with the pueblos of Nambe, Pojoaque, Tesuque, Taos, and San Ildefonso as well as with the Navajo Nation. I think that is an incredible feat.

We worked hard on meeting water infrastructure needs in 2007. We appropriated about $60 million for water infrastructure projects, including $12 million for the lateral pipeline to bring fresh water to communities between Bernalillo and Farmington, $20 million for drinking water and wastewater projects in communities throughout New Mexico, $16 million for the acequia infrastructure projects to ensure small farmers continue to be able to support their families through the land, $10 million for the Strategic Water Reserve to expand the fund for future water security, and we increased funding for the Water Innovation Fund. The Water Innovation Fund has been one way we think we can look to the future and spur innovative techniques for both conserving and desalinating and all kinds of things that we know we need to do. We must recognize that what we need to do is to continue to build a sustainable environment for our families, and that includes allocating money for the infrastructure needs. We need to act now, and that is important.

Let's talk a little bit about other things that we accomplished. We worked hard to clarify and protect water rights for New Mexicans. We have a lot of work to do on Indian water rights. Over the last few years, the administration has tried to move to address some very old water rights problems by negotiating settlements with the Indian water rights claims. We have now signed settlements, gratefully, with the pueblos of Nambe, Pojoaque, Tesuque, Taos, and San Ildefonso as well as with the Navajo Nation. I think that is an incredible feat. Those government to government relationships have become very, very important as we think about the future of water and water rights in New Mexico. Although all of those settlements have not been approved by the federal government, we chose to demonstrate what I call the state's commitment to solving the claims in a mutually beneficial manner and we allocated $10 million to the water rights settlement fund last year. It is just a show of fiscal responsibility, and I think it has greatly influenced Washington on the seriousness of our commitment as a state to finally settle many of these water rights claims.

One of the keys to good water management as many of you in this audience know even better than any of us is to know what you have and who has the rights to use it. I remember when I first got into politics, there were times when I thought—and I still think this from time to time—that we have a lot more water rights allocated than what we actually have water. That seemed a little scary to me as somebody looking to the future. We all know that water rights in New Mexico have a very storied history, and the key objective of our administration has been to protect the state's water rights as we move through our administration. It is a complicated but necessary method for ensuring that everyone's rights are protected—adjudication. None of us like to talk about it, but we currently have 12

water rights adjudications pending in the court affecting 65,000 property owners statewide. It takes up a lot of the judicial court time. That is not counting the Middle Rio Grande area where it is estimated that there are about 180,000 people who would be affected by some of these water rights. We have not yet begun the process of adjudicating the Middle Rio Grande region. That, frankly, gives people the chills when we start thinking about adjudicating those Middle Rio Grande water rights, not the least of which is someone like me when I start hearing about it as I travel around the state.

We know it is a difficult, onerous task for all of us, but I think the collaborative discussion has to continue among legislators, the courts, all of the stakeholders, the administration, the pueblos, and the tribal entities to see if in fact we can reach some consensus and a better way to do these adjudications.

We have also put into place processes for water rights owners to help facilitate the use of their water or if they desire the voluntary transfer of their water from one purpose to another. We have tried to make sure that we are accounting for and protecting the water that we already have.

We put a lot of the water research and investment into watershed protection and river restoration in New Mexico. This year, the New Mexico government stepped up and allocated $2.5 million to fund projects to restore rivers in New Mexico and the riparian ecosystems statewide. I think that is a huge step forward to have that recognition. Removing invasive salt cedar plants and other invasive plants is not done simply for nostalgia about how the river used to be. We know that those kinds of plants make water move faster through the channels, making it impossible to nurture the ecosystem surrounding it. In contrast, if we can nurture the systems as they should be with our native plants, they can create that sponge-like environment that traps and holds the water so that we do not become so desert like. I had the chance to explore the Gila project and some other projects in New Mexico to see what it means when you try to restore the natural flow of the river and what happens to the ecosystem. I think $2.5 million is the first in what I hope will be a continuing state program to sustain and restore rivers as they should be. I want to mention that Gila River project simply because I have a little house down in Hillsboro. As I go over those mountains to Silver City and have the chance to explore what happens in the environment, the Gila River has become one of those environments and places that I have kept my eye on.

Wastewater handling is another area in which we need to play a role. We need to use technology and wastewater as much as we can because we know we need to conserve and reuse water. I don't know if any of you saw the most recent article in the New York Times about "from the toilet to the tap." Did anyone see that article? It was about recycling sewer water to become drinking water.

We put a lot of the water research and investment into watershed protection and river restoration in New Mexico.

That is something to look forward to. In the past, the cost effectiveness of cleaning up wastewater was too great for any of us to consider, but as the value of water rises, as it becomes like the new gold, more people need the water that we have, and people are bidding on water rights around here, technology will become not only a possibility but an effective way to conserve and protect New Mexico's water supply. I have been grateful for all the people I have been able to talk to about the Water Innovation Fund and the ways that the fund can help not only to advance that technology but to improve that technology.

The people in Cloudcroft who have had a serious water issue over the last few years have already realized how important treating wastewater is, and they are getting ready to build a state-of-the-art treatment plant that will purify their water to the point that it can be returned to the municipal water supply. I think every community in New Mexico needs to be thinking about that. I like to say that in many ways in New Mexico, in all areas, we have been investing in innovation. I do not think there is any area as much needed as water innovation and water technology. We need to be investing in that innovation for the future of conserving and purifying water so that we can continue to have an adequate water supply.

We need to try to grow our water supply. Now how are we going to do that? Every time it rains, I take a little credit for it, because that is what you do in politics. If it rains or we get a high snowpack, we take credit because it is something we did. That's just the way it is. There is not much that we can do to grow our water supply except to think about growing well in New Mexico—how we plan for the influx of the population, how we plan developments, how we plan

infrastructure, how we make sure that we have the most up-to-date sewer and water lines that are in good repair and don't leak. While we can't actually grow the amount of water, we can think about how we grow in New Mexico. I think we are all committed to doing that. As we look at people who come to New Mexico, we have two new enormous developments just in Albuquerque, Mesa del Sol and the SunCal development on the west side, which are going to result in hundreds of thousands of homes added to the community. We need to hold developers accountable for how they develop the areas, how they have not only energy efficient, but water efficient residences, and what the requirements are for building the houses so that they use an efficient amount of water, that they have efficient toilets, dishwashers, washing machines, and so on.

Our administration has been one of the first ones to develop a state water plan. I am committed to ensuring that we continue to do that.

That brings us to individual accountability. We still need a long-term media message to individuals and families about what water conservation really is and how an individual can play a role in that. I think, like anything we do in this country, long-term sustained media messages educate people, whether it is about the use of tobacco, the use of drugs, or water conservation. Over a long period of time, it will have an impact on our children and their families.

We've got some other options. We've got desalination, pumping brackish water from the ground and cleaning it for municipal use. I come from an area of the state where there is a lot of brackish groundwater and that is down in southeastern New Mexico. Sandoval County and Alamogordo are both looking very seriously at the desalination approach and making sure that that happens. Like I said, that new option "from the toilet to the tap," cleaning up the sewer water, either for irrigation or in some cases drinking water, is going to become a very practical thing to do not just in New Mexico but in this country. There is a little note on here that says "Yuck!", and maybe we think of it that way, but I think in the future as technology improves we will have to do that.

Last of all, where some of us come in is to establish a comprehensive and coordinated strategy for dealing with water in New Mexico. Our administration has been one of the first ones to develop a state water plan. I am committed to ensuring that we continue to do that. We have to continue to work with our regional water plans because they are comprehensive. Many of them have been very insightful and have brought great ideas to the state. Just in November, Governor Richardson appointed, by executive order, a water cabinet to try to unify and coordinate the direction of all executive agencies that have any responsibility for dealing with our state water resources because we know that there are pockets of responsibilities out there that do need to be coordinated.

What we know is that we have to keep working at it. We have to work together. I like to say that no big problem that we have in New Mexico can be solved without everybody taking responsibility for some portion of the solution. It happens in healthcare, it happens in education, and it is happening in water. Communities, municipalities, the federal government, the state government, individuals, businesses—everybody has to be thinking about what their role is in conserving and preserving water resources in New Mexico.

We believe so much about what we love here is precious about the environment. Our water supply, we know, is limited and precious. Like many other states in the West, we are going to be fighting about water and where we get it. We know that it is time to be smart and to work hard and to work together to get the most out of what we actually have here, in this wonderful place that we call the Land of Enchantment. I would say to you that as we bring this "Year of Water" to a close that I hope we have taken some baby steps in thinking about what we have to do with the future. It is my very strong belief that the "Century of Water" is really just beginning in New Mexico.

Question: Is the water cabinet in place today?
Denish: The water cabinet is in place today. Judy probably knows about it; it has representatives from the Environment Department and the Office of the State Engineer. John D'Antonio probably knows better than I do who is on the water cabinet, but it is in place today.

Question: The regional plan is really important, but we are having trouble getting funding for the regional plans.
Denish: I think what we need to do as we look at our water cabinet is think about the funding mechanism for the regional plans so that the regional plans can

feed into the state water plan. I know it is difficult because there are not that many resources for planning, but I do think it is part of the overall infrastructure to have a long-term strategic plan.

Question: What do you see as the most relevant water-related issue for the 2008 legislative session?
Denish: The big push in this upcoming legislative session is going to be on healthcare. We are going to think about universal health coverage. The funding issues, primarily the water issues, will be related to funding and continuing the Strategic Water Fund, the Water Innovation Fund, and the Infrastructure Fund. John may know if he has some legislative issues that are coming up, but the governor has agreed to keep the legislative call very narrow this year, because he might not be in town that much. We’ve got a very narrow call in place right now. Unless it rises to kind of a sense of urgency, I think that that call will stay fairly narrow.

Again, I want to say thank you. I do want to say to all of you that I hope your holiday season is one of happiness and your new year, 2008, is one of great prosperity and that you will share with me, as I know all of us do, the hope for peace in the world. Thank you.

***John D'Antonio**, New Mexico State Engineer, is a registered professional engineer in New Mexico and Colorado, and has experience in hydraulic design, acequia rehabilitation, water resource management, and water policy development. Before he was appointed by Governor Bill Richardson to the state's chief water post, John was Cabinet Secretary of the New Mexico Environment Department in 2002. He served as the Director of the Water Resource Allocation Program for the Office of the State Engineer from 2001 to 2002 and served as the District I Supervisor in Albuquerque from 1998 to 2001. For 15 years, John worked with the U.S. Army Corps of Engineers as a hydraulic design engineer; as the Chief of the Hydrology, Hydraulics, Sedimentation, and Floodplain Management Program; and was the project manager for the Acequia Rehabilitation Program. A native New Mexican, John received a bachelor's degree in civil engineering from the University of New Mexico in 1979. He has been a member of the Governor's Blue Ribbon Task Force on Water Issues from 1998 to the present. In his post as State Engineer, John is the Secretary of the Interstate Stream Commission, Chairman of the Water Trust Board, Governor's Water Infrastructure Investment Team, and the Governor's Drought Task Force. He is also the New Mexico Commissioner to the Rio Grande, Costilla, and Upper Colorado river compacts.*

COMPETING FOR THE FUTURE – WE NEED A DIFFERENT MODEL

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Good morning, everybody. It is great being here again. It was nice to hear the lieutenant governor give introductory comments on some water issues that I will go a little bit deeper into. It is also great to have some additional time on the agenda.

What I want to do today is relate to things that are happening globally, regionally, and nationally and compare those issues to what we are trying to accomplish locally. You can only affect things and have a say on what is happening locally. However, it goes

both ways. You can do things locally that have some impacts statewide, regionally, nationally, and globally. You really must pay attention to everything that relates to water and climate and incorporate the best ideas and sound science into achieving the best results possible.

New Mexico is a small state, big in geographical area, but seemingly small with respect to the importance within our nation. There is a lot of really good water policy that comes out of the state of New Mexico. When I go to Western States Water Council meetings, many other states' water administrators are asking a lot of questions and paying a lot of attention to what we are doing here in New Mexico. Quite frankly, I think we are cutting edge in a lot of water management areas. Nationally, it is extremely competitive when we look for federal funding to assist with our water infrastructure and water management needs.

First, let's look at global trends. Economic forces are eclipsing political forces. There are many issues regarding economics around the entire globe. We are finding out that the world is flat. Technology and telecommunication advances are happening constantly. We have population growth, more urbanization – people moving into cities. There is greater productivity, a growth in self-determination, greater affluence, and a global market democracy that is starting to drive many issues.

In the United States, looking at national trends, we know that we have an aging and growing population. We have huge debt, growing costs, and low savings rates. You see this in the news every day. I'm a water guy, but I also pay attention to what is going on in other areas. There is growing competition for fiscal resources. Water competes every year against education and health care, especially rising Medicare and Medicaid costs. We have to be realistic in our expectations of how much money is going to be available to fund water initiatives. My feeling is that we have an insufficient focus on first things first. We spend money in many areas that really don't address our basic needs, and it is a concern to me when our basic needs regarding water are not met.

There is a new evolving federalism. As you know, the Government Accounting Office (GAO) controls the purse strings at the national level. We have dealt with the Office of Management and Budget (OMB) regarding our national issues involving Indian water rights settlements, without much promise of finding available funds. The GAO talks about not being able to grow ourselves out of our debt problems as a nation.

Looking statewide, we've had 100 years of water management. We've been managing surface water, from 1907 to today. We look west-wide, and billions of dollars have been spent in the western United States on complex water systems, reservoir systems, pipelines, and what not. Those systems have been built to sustain current populations and are based on 19th and 20th century ideas, resulting in many federal water projects. Most projects have already been constructed, and we are now looking at these massive reservoirs and massive water systems in light of growing populations and wondering how these systems will accommodate the growing West. I know I say the West, but the concerns are expanding nationwide. Look at what is happening down in Atlanta, Georgia. People in the East never had to worry about groundwater pumping and its effects on surface water supplies. Water shortages continue to spread as our population continues to grow. We are going to see people and states east of the Mississippi River that are really getting into the same issues and dealing with the same types of water supply and quality problems as we are dealing with in the West.

When we say infrastructure needs, we are talking about building pipelines and water supply projects but we also need administrative modifications. We need administrative modifications within the West for how we manage water. We will talk a little bit about the prior appropriation system, but we need some flexibility within that system in order to manage and accommodate growth and deal with variable supplies of water. We cannot rely on the federal government for all of our funding needs. It is not going to happen. Bob Hirsch spoke this morning and, as always, discussed the technical side of the USGS' role in providing information to assist our nation's water management challenge. When we look at federal funding, it seems that the states are putting more and more money into supporting the USGS' program, because that data and information are so important. More existing projects have been built with mostly federal funding. Existing federal budgets are shrinking for new water-related infrastructure, and if we think we can depend on the federal government for everything, we need to take another look.

I see Mike Connor in the back of the room. He does a great job for Senator Bingaman and is an excellent resource for the State of New Mexico. We

work with him all the time, especially on big projects as we try to cost share the projects using federal dollars. However, funding sources are drying up as we are competing with education, health care, environmental needs, and others. We are also competing with the other states for infrastructure funding.

The "phenomenon of predictable surprise" is not really that much of a surprise. "Drought, economic collapse, and pending doom" are all predictable cries coming from a lot of the western states and areas around. Yet the West, I feel, has ignored many of these issues: inappropriate water rights and allocations, groundwater management and use, real land-use planning, and water use efficiency. As I look around the western United States, I am appalled by how other western states manage their groundwater supplies. It is simply amazing when you talk about the growth that is happening in our neighboring states; look at Arizona and how big the population is and how dependent it is on supplies that are linked to and tied to the Colorado River system. Arizona is a junior priority on that particular system and is undergoing phenomenal growth. We need to pay more attention to land-use planning issues and water use efficiencies. Most of the West has assumed that we can grow as fast as desirable and that we will find water. We hope that is true, but it will depend on our engineering and technological expertise. Can we find new water to meet the demand? Every western state is projecting doubling their population within the next 40 or 50 years. It is a major consideration as we look to the future.

How do we act locally using a different model? There exist a huge demand for water infrastructure projects; tremendous costs of repairing old and building new infrastructure; the need to eliminate environmental degradation; the need to manage the resource for certainty of supply; and the need to address the impacts of climate change. We must consider the environmental impacts as many state and federal courts are handing down decisions that require re-engineering and redesign to mitigate those impacts. We also need to manage the resource for certainty of supply. Our active water resource management initiative is our attempt to act "locally" to address the state's variable water supply. What about climate change? The fear that warming temperatures will cause more extreme weather events puts another layer of complexity on how we manage our water. Are we going to have less water in the West like most of the predictive models seem to indicate?

Let's talk about climate change in New Mexico. The evidence is clear that we have warming over land and at higher altitudes and latitudes. There are changes in snowpack that will result in different snowmelt conditions and the timing of the runoff. The mountain snowpack constitutes our natural reservoirs. All of our water supply systems were built in the 19th and 20th centuries by utilizing those mountains as our natural reservoirs. One to two degrees of temperature warming will raise the elevation of the snowpack and will negatively affect our supplies. Our most recent drought in the West is now the drought of record, eclipsing the 1950's drought.

It is unclear how temperatures will affect our summer monsoons, and summer monsoons in New Mexico are of utmost importance to our water supply. We have seen some pretty good rainfall amounts in the last couple of years. The systems built in the 19th and 20th centuries do not accommodate or account for increased summer monsoons. If we have a much greater reduction in our snowpack and an increase in summer monsoonal precipitation, how do we capture that precipitation? Last year we sent a whole lot more water to Texas than we should have, had we a system in place that could have captured and stored more peak monsoonal runoff. The monsoons were good for New Mexico, and because most of the rainfall fell below the El Vado gauge, our delivery obligations to Texas did not increase. How do we capture some of those peak flows? We could divert that water, store it underground, and later recover it if we were to make some very expensive system modifications. An enhanced monsoonal season could make up for a reduced snowpack, but only if system modifications are made. However, we do not know very much about the warming temperatures and what affect they will

What about climate change? The fear that warming temperatures will cause more extreme weather events puts another layer of complexity on how we manage our water. Are we going to have less water in the West like most of the predictive models seem to indicate?

have on our monsoonal moisture. There seems to be a correlation between greenhouse gas emissions from fossil fuels and warming temperatures. The science is pretty clear that our temperatures are warming and seem to contribute to even greater extremes in our water supply.

If the rest of the region is depending on our energy, they are also depending on some of our water...states are looking at our energy resource potential. Therefore, they are also looking at our water.

Let's look at energy from fossil fuels. Worldwide 80 percent of energy comes from fossil fuels. Nationally, 85 percent of our energy comes from fossil fuels. In New Mexico, we are blessed with an abundance of oil and gas. New Mexico has nine percent of the U.S. natural gas production, and we are fourth in the nation in reserves. We produce more electricity than we consume, which means we are net exporters of electricity. We also export 30 percent of the crude oil produced in our state.

We need to be aware of the connection between water used and energy produced. When you export energy, you are also exporting water, if water is being used to produce that energy. Often, water is used in cooling and other energy production processes. If the rest of the region is depending on our energy, they are also depending on some of our water. We have to pay attention to that. Energy transmission for regional systems is the key, but it is also a constraint in getting energy to other states. Believe me, states are looking at our energy resource potential. Therefore, they are also looking at our water. We need to investigate regional markets for energy as well as for water, but at the same time consider our interstate compacts. We are subject to eight interstate compacts within the state of New Mexico and must account for any additional depletion to any of our systems that are associated with energy production.

Let's talk about a new approach moving New Mexico to a clean and sustainable energy economy. We need to move toward clean and sustainable energy, but how do we do that? We have significant wind and solar resources. Nuclear power should be a consideration. We have got to be concerned about using the safe and proliferation-resistant technology that is available now. Nationally, the second largest uranium reserves are in New Mexico. Again, New Mexico is going to be looked at to solve some of the region's growing energy demands, and we can't forget to take into consideration the effects to our water supplies.

As a state we have a lot of energy goals. Governor Richardson has been very active in working to put comprehensive energy goals in place. Some of his goals are to reduce greenhouse gas emissions by ten percent by 2020 and 75 percent by 2050. I am going to mention some of the governor's energy-related goals that are meant to address and reduce the carbon footprint that seems to be related to our climate change concerns. By 2025, we hope to produce as much electricity from clean and renewable sources as we do from fossil fuels. Other goals include: reducing our gasoline usage by 15 percent by 2012 and 50 percent by 2025; switching from petro-diesel to bio-diesel; looking for a reduction in energy and lighting in buildings by 2025; and recycling non-organic materials. All of these goals, if attained, could have a very favorable production impact on our water supply because energy production and water use are connected.

We also need a new approach for our water and wastewater infrastructure funding. Our lieutenant governor talked a little bit about this, and I will give you some more detail. Current planning for water and wastewater infrastructure is fragmented and decentralized. This has to do more with wastewater project funding and getting more regional projects built to allow the available funding to serve more people. One big problem we have in New Mexico is the capital outlay funding process. Our legislators, senators and representatives, receive two-thirds of the capital outlay, and the governor receives the other third. As you would expect the senators and representatives fund capital projects within their districts. Their portion of the capital outlay effectively acts as their re-election campaign fund. Most of the money goes out in piecemeal form, some for water projects and some that doesn't go to water projects. Often times the money, because it is not adequate to fund an entire project, remains in an account and is not even expended. There are millions of dollars in unused accounts because these resources aren't pooled together to build a more significant and cost effective regional project. We need to fix the capital outlay process.

We need to build projects that are regional in nature that provide more benefits at a reduced cost. We need to look at the available funds that are administered by multiple agencies within the state of New Mexico. Let's

take a look at these available funding sources. The first one is direct appropriations from the legislature. There is also a rural infrastructure loan fund that comes through the Environment Department (NMED). The Water Project Fund is managed by the Water Trust Board (WTB) in conjunction with the New Mexico Finance Authority (NMFA). There is a drinking water state revolving loan fund that the NMED and NMFA administer. Other funds include the clean water state revolving loan fund (NMED, NMFA) and a water innovation fund that the governor set up under the Department of Finance and Administration (DFA) and NMED.

There are also CDBG grants (DFA, CDBG Council); the USDA loans and grants; the planning grants that come from the DFA, NMFA, and NMED; technical assistance grants through the NMED; and other local and federal resources. Funding applications are duplicative, as entities chase potential funding sources in a fragmented and decentralized manner, which we are attempting to fix.

There are missed opportunities by not putting funding sources together with projects that are regional and ready to go. We miss aligning funding with community needs. We need to ensure projects provide long-term solutions and are fully funded. Many times, projects are not fully funded, and if the funding stops, we have a partially built project. We need to identify needs for planning and design and align technical assistance and capacity development with funding priorities. We need to look at a drinking water project and make sure that project proponents are charging adequate water rates, have an asset management plan in place, and have adequate water rights; that they have everything in place to make them a viable drinking water project.

The state water plan was a requirement for my agency to complete within the first year of taking over as State Engineer. The plan itself became a policy document with nearly 100 implementation strategies. The plan charges the New Mexico Interstate Stream Commission (ISC) in collaboration with the New Mexico State Engineer's Office (OSE) and the WTB to update the plan every five years. Here are some excerpts from the first state water plan: It is "a basis for prioritizing infrastructure investment" and ensuring "effective collaboration, consultation, and public participation in the development and implementation of water policy by applicable state agencies." Are we effectively collaborating with the NMED and Energy, Minerals and Natural Resources Department (EMNRD)? Both have watershed programs. Also we are involving NMED with water quality issues and the Department of Agriculture (NMDA) with irrigation efficiencies.

In the discussions that we have with other state agencies, we need to make sure that policy that is set at the governor's level is followed consistently from agency to agency. We have a great policy analyst in Mr. Bill Hume, who helps oversee all the natural resource agencies management of the resource to ensure we've undertaken the best collaborative effort possible.

There was a house joint memorial (HJM86) that passed about three years ago. This was mainly geared towards water/wastewater projects. It looked at developing criteria to ensure that resources are utilized wisely as a condition of getting funding and collaborating with the NMED. NMED has a drinking water bureau and a construction programs bureau – they receive most of the funding for wastewater projects and oversee the project construction. Do the proposed projects have a financial plan, an adequate rate structure, an asset management plan, OSE/NMED/federal compliance, an adequate governance structure, and participation in regional efforts? Is the project a candidate to participate in a regional effort, instead of tax dollars paying to build a wastewater treatment plant for two or three different entities that are within a geographical region that would warrant only one – using economies of scale to build a better overall project?

The lieutenant governor mentioned the Water Cabinet that was established through a recent executive order. The executive order establishes a new division within the NMED and also assigns responsibilities to some of the agencies to better collaborate on water issues. The executive order should help drive the collaborative effort necessary to properly and comprehensively update the state water plan. The Water Cabinet consists of the following agencies: the Office of the State Engineer; Interstate Stream Commission; New Mexico Environment Department; Department of Agriculture; Department of Game and Fish; Energy, Minerals and Natural Resources Department; Department of Finance and Administration; and New Mexico Finance Authority.

How do we envision this process working? We are going to establish a uniform application process; so, as communities are interested in acquiring project

funding, they complete only one application, submitted to this newly established division within NMED. This new division will evaluate applications by conducting technical and fiscal review using appropriate agency staff. The State Engineer's office will be looking for the project to have adequate water rights and NMED will look for Safe Drinking Water Act compliance. We need interagency coordination for fiscal and capital planning. What is the best source of funding for this particular project? The projects will be put into the proper funding category as we try to make the dollars go farther. As we continue through the process, we need to prioritize the funding recommendations. These recommendations will go to the state legislature and to the Water Trust Board so that supplemental funding can be provided to those projects that didn't already receive funding through a particular funding source. This process will ensure that we are funding projects that are ready to go, that are technically feasible, and are appropriately funded from the best source available instead of the fragmented and decentralized approach previously used.

...drought opened our eyes, and it continues to open our eyes. We are in a record drought now...

The large regional water supply infrastructure projects will utilize a slightly different process. The OSE and ISC will conduct technical and fiscal reviews. The big infrastructure projects include the Ute pipeline, the Navajo-Gallup pipeline, a potential salt basin pipeline, or a potential Gila basin project. These big water supply projects will require federal funding and/or federal matches. The importance of these projects is to maximize the beneficial use of New Mexico's water for use in New Mexico. The ISC statutorily has the responsibility of looking at those water supply projects, and along with the OSE, will conduct the required technical review. These large water supply projects still need to undergo this interagency coordination for fiscal and capital planning in order to prioritize funding. Additional recommendations are then made to the Water Trust Board and to the legislature for supplemental funding. To recap, you've got two classes of projects: the water and wastewater regionalization projects that have mainly drinking water and wastewater compliance issues (best handled by NMED) and the bigger water supply projects that have interstate and sovereignty issues (best handled by the OSE/ISC). This new process will bring many benefits to New Mexico: quickly completing local projects, strengthening local management and fiscal capacity, maximizing use of available funds, improving maintenance and asset management, and ensuring projects are designed for the long-term and are fulfilling those long-term needs we have as a growing state.

Again, drought opened our eyes, and it continues to open our eyes. We are in a record drought now, which eclipsed the 1950's drought. When you look at climate change and its potential impacts, they are probably similar to dealing with a prolonged drought. If warming temperatures cause reduced precipitation, as anticipated, we will have another layer of complexity to include with our hydrologic models and a greater concern on managing our more limited water resources.

Now more about the state water plan. Another section (C.2) in the state water plan mandates establishing a clear vision and policy direction for active management of the states' waters. The policy statement that comes out of the plan is: "The State shall promote water markets that enable the efficient management and movement of water rights within the State in accordance with the applicable legislative and legal safeguards." Also from the state water plan section (C.2), "resources should be allocated to fully implement active water resource management in accordance with the following: where the economic consequences of lack of ready water markets are high." Also from the state water plan concerning water rights transfer policies that are intended to strike a balance to meet both short-term shortages and long-term economic development needs, "The State shall support the creation of water banks to allow for the temporary reallocation of water among voluntary water bank participants." Again, discussing what we can accomplish locally, we need to create water markets to help facilitate water transfers during drought cycles. Another important strategy from the state water plan is that "The State Engineer will review existing statutes and regulations, propose revisions, and implement authorized revisions to expedite water rights transfers." Again, more active water resource management language. Also from the plan, "The State Engineer will encourage the creation of water banks in areas that are experiencing significant growth or are prone to water supply shortages in order to ensure economic vitality."

The legislature passed law 72-2-9.1 that basically directs the State Engineer to administer now. It requires the State Engineer to adopt rules for priority administra-

tion and to promote the expedited marketing and leasing of water rights. If you have seen the Santa Fe newspaper the past couple of days, it discussed the enormous workload required to complete water right adjudications statewide. The adjudication process is slow. It is going to take several years to complete adjudications, so how does one administer water in the absence of completed adjudications? There must be a mechanism in place to administer water during times of shortage and in the absence of a completed adjudication.

Continuing with Active Water Resource Management (AWRM), I will go through these slides fairly rapidly because most of you are familiar with this subject. Again, it is our practical way to establish a reliable water supply within the state of New Mexico. Protecting our senior rights, protecting our economies, and setting water management tools for each region of the state are all part of AWRM. We have to promulgate specific basin rules and regulations for a number of basins within the state of New Mexico. These tools will help protect senior water rights, ensure compliance with interstate stream compacts, and curtail illegal and over-diversions. Historically, the state engineer did not do a very good job of enforcing illegal and over-diversions; however, we are moving into the "administer now law," which will help us move in that direction.

The second part of the law requires the state engineer to adopt rules for priority administration. If there is an adequate water supply, we do not have to worry about priority administration. When supplies are short, there are junior users that must be curtailed. I like to use the comparison of the sub-prime lending market fiasco. If you don't have rules, if you just indiscriminately start lending money out – or if you just start giving water out, one day there will be a day of reckoning. The lending market should have better considered those higher risk individuals that would probably default under higher variable interest rates. If you start recognizing more and more junior water rights, there is a point where there are not enough water rights in the bank to cover those uses. You have to protect the seniors. You must be able to curtail the junior uses when supplies are short.

I was asked by a legislator this week, "John, it seems like you are against priority administration?" No. That is not it at all. I never said we are going to do away with priority administration. Priority administration is the law, but how can we better manage water in a priority system by allowing a curtailed junior to acquire water on a voluntary basis from a senior, so that you do not have to curtail the junior user? If you let the market place work, it will be more efficient than if you cut off junior uses, especially those that provide jobs or other essentials to the local community. That is critical for New Mexico moving forward during drought times and being able to have a functioning economy. Priority administration requires district specific rules and regulations, a water master manual, and metering and measuring devices so that fair and accurate water administration can be conducted in the field by a water master. We have hired ten water masters in the last couple of years. They are out in all the major stream systems of the state. We've got seven basins within the state of New Mexico that are priority basins and where we are moving forward with active water resource management. We need to promote expedited leasing and marketing in affected areas.

Since 2001, prior State Engineer Tom Turney and then ISC Director, Norm Gaume, came up with the three M's of active water resource management, which were "measurement," "management, and "markets." The question that is often asked of me is what happened to "markets"? Where are the markets? "Markets" are an essential component of AWRM if it is to work properly.

Some elements of AWRM are permitting transfers, metering, and limiting the diversion of water to the amount authorized by existing water rights. Those are also the essential elements of a functioning water market within the state of New Mexico.

If you don't have rules, if you just indiscriminately start lending money out – or if you just start giving water out, one day there will be a day of reckoning.

In lieu of priority administration, if all parties in a particular basin can agree to an alternative means of administration, then we will attempt to put in place this alternative.

One form of alternative administration is being implemented down on the Pecos River. The Pecos plan involves buying farmland and water rights and taking that farmland out of production. That is the plan that the local stakeholders came up with to balance the hydrologic condition in lieu of priority administration. If we would have instituted a priority call, the call would have been considered "futile" because we would have to go so far back into the call to actually get wet water

to the river that there would have been a $200 to $300 million economic impact to the state of New Mexico.

Most stream systems in New Mexico are considered fully appropriated, which means there are no new sources of water available. I say that because desalination of brackish supplies is a new potential source of water, but one still has to take into consideration impairment to fresh water supplies if the two sources are hydrologically connected. Water for new uses must come from water right transfers. We've got to balance the depletions within our system. Approximately 77 percent of New Mexico's water is used for agricultural purposes. If you are in a fully appropriated basin and you wish to allow for a new use, you must file an application to change place and/or purpose of use, typically from agricultural to municipal industrial or domestic use. That's the only way our cities can grow. New Mexico's population is expected to increase by 85 percent by the year 2040. How does that happen without taking some water from agriculture? It's got to happen if you are going to avoid additional depletions. That is how we account for keeping our stream systems whole within the state of New Mexico.

We have had the ability to license water rights since 1907. The state has not licensed very many of its water rights. Licensure provides water rights owners with the greatest certainty afforded in New Mexico water law, short of a water rights adjudication decree. A lot of you know about Judge Reynolds' decision regarding the state framework rules and regulations for AWRM. The decision stated that the state engineer could administer water, but if you want to do it by priority, you have to have a decree or a licensed right. You cannot just administer water based upon the best information that's available in our water right files, which is what we wanted to do. You've got to be able to refer to a decreed or a licensed right. Prior to Judge Reynolds' decision, we contemplated expanding our licensure program. After his decision was rendered, an additional focus has been in place to expand licensing of water rights. If we can get more rights licensed, it allows for more certainty with respect to that water right and should help facilitate market transfers.

The licensing of water rights will greatly facilitate an eventual adjudication. Typically, a judge doesn't go behind a state engineer's license when they are looking at adjudicating the water right. The number of contested sub-files in future adjudication will probably be reduced,

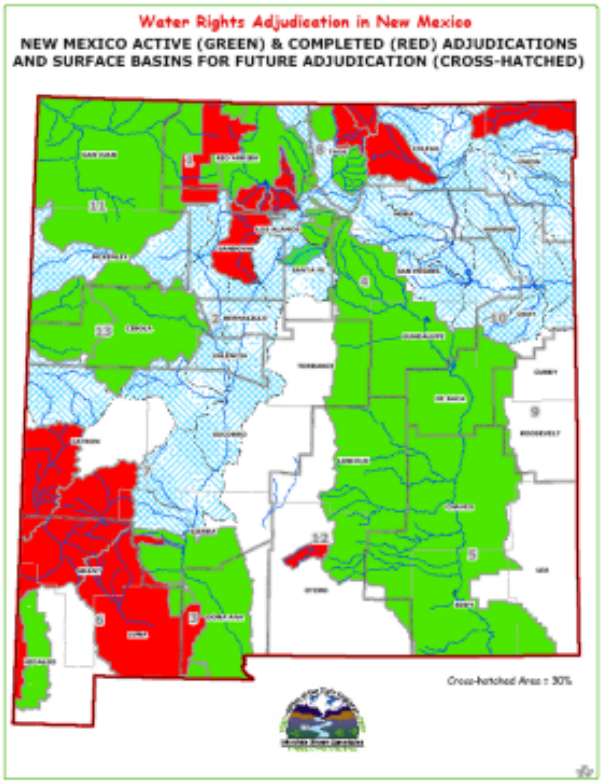

Figure 1. Water Rights Adjudication in New Mexico

which will help expedite finishing the adjudication. The economic community often asks about certificates of transferability. Licensure would serve this purpose as a license would bring more certainty, regarding that water right.

Let's talk more about adjudications. Figure 1 shows green and red parts of the state – obviously the connection to chile in New Mexico. If you look at the red areas, those are the only areas in the state that are fully adjudicated. The green areas are areas that we are actively working on. We have 12 active adjudications involving approximately 65,000 defendants, including 17 or 18 tribal entities. This cross hatched area, represents about 30 percent of the surface area of the state and represents our future adjudications. The Middle Rio Grande is the big one. Potentially it has many more claimants than are in the current adjudications process. In order to finish our current adjudications, we have estimated that it is going to take another 15 years. If you take into consideration how our litigation and adjudication program bureau is funded with about $6.3 million a year for those 15 years, that translates into about $95 million. That is the reality of finishing these existing adjudications, and that's without starting the Middle Rio Grande.

How do we proceed? We have been talking with the legislature regarding adjudication reform. For the past couple of years we've been discussing this subject with the Administrative Office of the Courts. Our Chama adjudication has been considered most successful as it is focused on public notice and public outreach. We hold informal field offices which allows local communities to get involved more easily. We have follow up field inspections of individual claims when requested. We exhaust all opportunities for settlement before there is an evidentiary hearing and formal discovery is ordered. These are processes that we try to follow.

What often happens is the adjudication process takes a detour when the judge issues alternative procedural orders that govern deadlines, how defendants must respond to settlement offers from the state, and other procedural matters. Often times special masters put out their individual orders, so it takes the "Chama" approach, and it detours it making it longer. We are currently meeting with the administrative office of the courts to plan for future adjudications. We need to evaluate what worked best on existing adjudications within the state of New Mexico, but also evaluate other states' processes. We are going to actively pursue that information with a goal to make future adjudication suits faster and more efficient and less intimidating for water rights claimants. We have an Ombudsman program going on at the Utton Center which will hopefully contribute to that process becoming less intimidating for the claimants. We are also discussing the advantages of using alternative dispute resolution (ADR). We recently hired a full-time person to focus on opportunities to solve water rights disputes using ADR procedures.

Now to re-cap quickly the direction my agency is embarking on: "If we are to meet the economic challenges and environmental concerns of this century, we must be able to utilize a different model that allows us to act locally and accrue benefits statewide, nationwide as well as globally." That is my final slide and thank you for your patience. Now, are there any questions?

Question: Do you think the carrying capacity of the communities ought to be considered by those communities for their water needs? By carrying capacity, I'm talking about population.

D'Antonio: The question is about carrying capacity and communities' growing population. To me, it always comes to the political will in each individual community. When I say political will, I mean mostly counties and county commissions are interested in economic growth. They are interested in the tax-base growing. At what point does that change to a public welfare issue or concern regarding water supplies? The political will to control population must come from local government. With respect to the State Engineer's Office, there are a lot of things we can do. If an entity wants to grow, they have to go and obtain water rights. If they acquire water rights, transfer just the consumptive use portion, which is all we will allow, we can maintain the water balance by controlling depletions. That is what we are interested in doing: maintaining the water balance with no new depletions. Our state's population will continue to grow. One of the fallacies out there is that just because people are moving to New Mexico, it doesn't necessarily translate to more water use. If you have a strong water management agency that is controlling depletions, you can accommodate growth because you are changing from an existing use to a new use. You are essentially drying up that old use for a new use, without actually using additional water.

When it comes down to individual and political will in different communities, local politicians have to get involved and say, "Enough. We've grown enough." Or they have to find ways to import more water from somewhere else, which is really what most politicians lean towards.

Question: Let's say you were made king of the East. Mr. Hirsch talked briefly about what is going on in Georgia and Florida. If you were able to go in there and say, "Here is how we are going to do it," and you had this toolbox of the Bureau of Reclamation and the Corps and USGS and the interstate compacts and AWRM, what would you do? What would you tell them they need to do? They haven't done anything, and they're going to be like us soon. What would you advise them to do?

D'Antonio: I'd hire a good water attorney, first of all, to represent me! What they are now experiencing are interstate issues. They are looking at delivery obligations for endangered species act issues during an extreme drought. They need to manage actively their resource. They need accountability, and they need to protect existing uses. In areas east of the Mississippi River, most aren't subject to interstate compacts. If water levels continue to drop in the East like they have in the West, water attorneys are going to have more and more

work. Essentially, I would put measuring and metering devices in-place, if they don't have them already, insist on accountability of resources, and look at biological opinions for some of the endangered species act issues to see if more reasonable agreements can be made that take into consideration a variable supply or drought scenario that would allow critical habitat areas to utilize less water.

I think a lot of the things we are doing in New Mexico such as building the silvery minnow refugia, propagating endangered species in captivity, and reintroducing them into the river system are truly innovative and applicable in other places. Also, modification of the biological opinion, which allows some drying of the river under certain hydrologic conditions, was critical and is the area where the federal government is really going to need to help states meet ESA obligations.

Out West we laughed about the group going to Washington from three southeastern states to challenge that ESA requirement that has been in place for decades. It will be interesting to see what happens, when the majority of the votes in Congress are east of the Mississippi and they start running into the same laws that we have had to comply with in the West.

Question: I always, in light of my outreach programs, have liked to encourage the fact that we are all part of ag. water. When I go to the store and put my hand on that head of lettuce, which is 90 percent water, I am part of ag. water. The question is whether that head of lettuce came from Chile or from that local farmer that is just outside the city limits. I am glad to have those farmers. I just want to know about the emphasis of these initiatives of the water innovation fund and all these things. Where is the transfer of technology leading to alternative sustainable ag., not that the farmer has to stop being a farmer? Everybody is losing farms to build homes. I support this active management and where this is going, but I teach even school grade children that when they go and pick up that tomato and that cabbage they are part of ag. water. When we look at global warming, fossil fuels, and carbon emissions, is that tomato going to come from Chile or from our local growers that are taking a different approach and conserving water while they do it?

D'Antonio: The question has to do with agriculture versus municipal and industrial development and whether I am just looking at taking water from ag. and putting it into municipal and industrial development. That is not the case. John Stomp is back there with the Albuquerque-Bernalillo County Water Utility Authority. They have done a great job in their plan looking 50 to 60 years out into the future on growth and how to accommodate it. It is certainly not just from the acquisition of water from the agricultural community. There is a whole conservation component in their plan. The use of their renewable supplies – San Juan-Chama water to help preserve groundwater – that is also part of their plan. They, at some point, are going to have to go beyond 50 and 60 years and convert some water from agriculture to municipal and industrial development.

Let's be honest: there is a lot of agricultural product that is getting exported out of this state also. When you talk about exporting agricultural products out of the state, you are also talking about exporting our water out of the state. It is just not being used for statewide sustenance of our local crops within the state of New Mexico.

The other point I want to emphasize is that the ag. community holds senior water rights and their rights are protected in my administrative scheme – always. As an example, if you are going to allow for the city of Las Cruces to grow – because it is going to grow as a university town and a desirable place to live – 90 percent of the water in the Lower Rio Grande is used in agriculture – you are going to have to transfer some of that water from ag. to municipal and industrial use. I think EBID is well positioned to be able to do that and will accommodate those needed water supplies.
The people that remain in agriculture only become stronger. Let's take the Pecos situation for instance. The fact is, there is a short water supply down there. Regarding the settlement agreement, we are taking 12,000 acres of land and water rights out of production in order to meet the minimum requirements of the Pecos Settlement agreement. For those farmers that remain in agriculture, their water supply will become more sustainable because the hydrologic balance is being corrected, which is going to make them even more profitable. The Carlsbad Irrigation District is going to have an assured supply of water, whereas before, even though they were seniors on the system, it was difficult for them to get their water because they were at the downstream end of the system.

My feeling is that if you have a strong water management agency in-place, you are going to protect agriculture. The reality is that if you live in a fully appropriated basin, the growth is most likely to come

from agriculture. Conservation is always a consideration. Any permits that I issue have a strong conservation component to them. They require per capita use restrictions, which help with conservation. A lot of the cities and municipalities in the state are doing a great job at conservation, and they need to keep it up. We will continue to put pressure on them to make sure that a permitted water right or water rights transfer is not contrary to conservation within the state of New Mexico.

Question: Are we the only state having problems with the adjudication laws?
D'Antonio: No. We are not the only state having problems with the adjudication laws. One of the problems is that we have been resource short on completing adjudications. Since 1907 – for the first 80 or 90 years since then, there was not a lot of emphasis put on finalizing adjudications. We have actually made and we are getting ready to internally prepare a report for the legislature that shows the progress made on completing sub-file orders within the state. The significant progress that we have made the last five years is directly correlated to additional resources that we have received from the state legislature. We have made a lot of progress, but the fact is that it is a cumbersome process. It is difficult because of the sporadic funding that we have received. Also, we have had to stop and start hydrographic surveys, essentially recollect that information as the survey data becomes stale after a period of time.

We've got other issues regarding adjudication reform, and as we look forward, we are going to take the best processes from past and current adjudications in New Mexico as well as investigate experiences from other states. Just because we are behind where we should be in completing adjudication does not mean we are doing it wrong, and I don't want to make changes for change's sake only. We don't want to change processes unless we are certain that change will expedite the remaining adjudications and better utilize taxpayer dollars. We are looking at reform seriously. Thank you everybody. I appreciate your time today.

Andy Nuñez *was born and raised on the family ranch in Roswell. He is one of 11 children, seven boys and four girls. Six boys served in the military; the youngest was killed in Vietnam. Andy served three years in the US Marine Corps from 1953 to 1956. In 1957, he entered New Mexico State University on the GI Bill and received bachelor's and master's degrees. Andy went to work for the US Department of Agriculture for seven years in the Gallup area. He then returned to NMSU to work in the International Program office for seven years traveling to Mexico and Central and South America. Subsequently, Andy left NMSU and took a position in Puerto Rico on a two-year contract to establish a Farm Bureau organization. Upon returning to New Mexico, he started farming and ranching in the Roswell area until 1986 when he bought a farm in Hatch. In 1990, Andy started working for the New Mexico Farm and Livestock Bureau as Organizational Director and Lobbyist. In 1992, he was hired by NMSU as Legislative Liaison and General Director. He remained in this position until 2000 when he won the election as State Representative.*

PREVIEW OF LEGISLATIVE WATER ISSUES 2008

New Mexico Representative Andy Nuñez
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The legislature gives us so much money to operate on and you know how the legislature is. I complain the same way that John D'Antonio did about not being able to do an adjudication because he hasn't received any funding. Well, we've given him all the funds he can use each year. I don't know exactly what John covered before I got here this morning, but I have reviewed his PowerPoint presentation. Some of it I don't understand, and some of it I don't agree with. I want to start with what I am supposed to be talking about today. I am supposed to discuss legislative water issues for the 2008 session and what we legislators are going to be doing. This year's session is a fiscal session. Only those things that have to do with money will be heard unless the governor puts other items on the call. There will be some issues that will be put on the call. I'm afraid it is going to be more than what we can handle, which means we will probably go into another special session and spend some more of the state's money.

The first thing I have on my list here is adjudication. John covered a little bit about it. This is a process that really has taken a long time. Yesterday the Water and Natural Resources Committee hearings ended for this year. We set up an adjudication subcommittee, because we feel that the adjudication process is taking too long. John talks about the Middle Rio Grande adjudications taking 15 years and more. We think that is just way

too long. We think we need to move a little faster and get a few things done. We've created a subcommittee, which includes the administrative offices of the courts, the Office of the State Engineer (OSE), the attorney general's office, DFA, the legislative finance committee, and the legislative council service. This group is supposed to develop a detailed amendment to the adjudications statutes in anticipation of the Middle Rio Grande adjudications. That is going to be the big problem. John said, if I'm not mistaken, some 80,000 people will be involved with the Middle Rio Grande adjudication. That is a lot of people. We are going to establish a Middle Rio Grande adjudication pilot project and adopt a statute general reform goal for the Middle Rio Grande adjudication. We are going to create a Middle Rio Grande water court, effective July 1, 2009. We will endorse general fund appropriations adequate to support the Middle Rio Grande pilot project and practical resources for the Office of the State Engineer.

We are going to establish a Middle Rio Grande adjudication pilot project and adopt a statute general reform goal for the Middle Rio Grande adjudication. We are going to create a Middle Rio Grande water court, effective July 1, 2009.

We feel that the statutory reform should include providing for a change in the role of the Office of the State Engineer to technical experts rather than plaintiff in a claim-based system, an alternative and less intimidating means of serving notice. John was on our committee, and we raked him over the coals for two days straight. The acequia people came up with a bunch of recommendations. Some of these small farmers are already intimidated when the state engineer goes in there and serves them notice. They are just scared to death. They don't see the adjudication process as the way it should be. I think John is taking that into account. They've got an Ombudsman who is going to be working with them. That is something that is really needed.

We are also going to try to get John enough funds for Indian rights settlements. He has requested, if I am not mistaken, $13 million for three settlements. That will be one part that we will be bringing up this session. There are some more land purchases on the Pecos to settle a settlement. John told us a couple of days ago that OSE needed more technical staff and a few more lawyers. My question was, "Well, how many lawyers do you have?" I suggested that they need more technical people and fewer lawyers. You've got Hernandez over here who you can use. I know that we will be putting some money into that. John won't have to worry about the money. It is going to be there.

We have the New Mexico Rural Water pipeline project over on the east side of the state. They will require a lot of money. All of these issues will be coming to us over this 30-day session. The Gila River settlement—we put some money into it last year, and the governor vetoed it, but we are going to go back and put some more money in. There was wording in the legislation that someone told the governor was bad, so he vetoed that bill. We only have, I think, until 2012 to get that thing settled or, I believe, Arizona is going to get our water. We must put some money in there and get that study started or we are going to do without water.

Of course, given that I am a farmer in the lower Rio Grande, we need some money down there for more metering and other work that John and Gary Esslinger are doing. John, I hope we will get some money for that also.

I am not sure what is going to happen with the domestic wells issue. We haven't mentioned that issue in any of our meetings lately. I hope that those things kind of go by the wayside. I know that someone is going to bring up the water use forfeiture law—the use-it-or- lose-it law. It comes up every year, and we'll see if we can put a little money into it this year.

Some are recommending that we extend the 40-Year Water Plan to 100 years, to modify section 72-1-9 and to add utility companies, water utilities, and water sanitation districts to all of this. That issue may be coming up.

The Water Trust Board is one issue that I wasn't in agreement. The Water Trust Board in my estimation and the estimation of a lot of legislators wasn't doing what it should have been doing. Perhaps the changes that they are recommending may work. I'm against appointing the cabinet by executive order. I think that ought to be done by the legislative process. We need to fund it some way. The way we have seen it and the impression given to a lot of legislators by the Water Trust Board is that a lot of the money that has been doled out has been more about political power than need. We have some improvements in Albuquerque where there is a lot of the political power that in my

estimation should have never been approved for funding. I'm kind of leery. I've always introduced the bill to get that Water Trust Fund up to $100 million, which is what the original law indicated. I'm a little leery about asking for any more money to be put in there until we get this Water Trust Board going in the right direction because that is a lot of money to be used. There is some $60 million in the fund. The original law said $100 million, and I would like to see it get to that $100 million. Eventually we will get it there.

There will be new funding requests for salt cedar control and for riparian restoration after salt cedar control. The state forest service will be asking for forest restoration funds. I am sure we will put a little bit of money in there. For the salt cedar project, I would like to see a continuing resolution so that they do not have to come back every year. Last year, the money was vetoed out, so we were stopped for a year. That is a project that needs to get done. I would like to see the money stay in there for a certain period of time, so that we can continue clearing salt cedar and saving what water we can.

I'd like to mention some of the bills that will come up during this session. One of them I've mentioned already, which is the Pecos River alternative water rights retirement method. This is another bill that we introduced last year, whereby the Office of the State Engineer can purchase land with water rights in the Pecos valley to satisfy the Pecos settlement. This bill allows the state engineer to go ahead and purchase just the water and let the owner keep the land, and the land remains on the tax rolls. The governor vetoed that bill last year. We are going to reintroduce it this year, and hopefully it will get through. We thought we had everyone behind it last year. Why the governor vetoed it I have no idea.

We also have funding requests for aquifer mapping. We do not know just yet how much money is being requested in that bill.

The Utton Transboundary Resource Center appropriation will come up again to fund the Center's work on cooperative, interdisciplinary resource planning, and conflict avoidance across political boundaries. We are probably going to fund that.

Concerning the precision irrigation appropriation, there is a gentleman from Australia who made a good presentation on the subject, and I think we are going to introduce that bill and see if we can get funding for that one. The Mutual Domestics are asking to become a member of the Water Trust Board. I don't think the governor will add them, but they would like to be on the Board, and they are going to try to get on the agenda. The water adjudication memorial that I read awhile ago is simply going to be a memorial. It will be heard.

If you listen to some of the financial people who we have in the legislature, they say we have a lot less money than we had last year. For ten years I lobbied for the university before I became a legislator seven years ago. Every year, you would go up to Santa Fe and be told they had less money than the year before. For some reason in January, they find all kinds of money somewhere. I don't see how we can have half as much money this year as last year when oil and gas prices haven't gone down. Oil just went up to about $98 a barrel, and gas stayed kind of close. Gas brings more money in than oil, but we still have a lot of money in the coffer. That doesn't mean we have to spend it. We need to use it prudently. I think we are going to do that.

For the salt cedar project, I would like to see a continuing resolution so that they do not have to come back every year.

I think that's all. I think I spent all the money for the session.

Question: I keep hearing that 180,000 will be impacted by adjudication in the Middle Rio Grande. I want you to clarify something. I called the assessment's office for the district. The Middle Rio Grande Conservancy District basically from Cochiti to Bosque del Apache—the majority of the irrigators in the Middle Rio Grande—only sends out about 15,000 assessments. Everybody who irrigates has to pay an assessment to the district in addition to the property taxes that are paid by everybody who lives within the district. The qualified electors in the district are only 94,000 people. That is everybody that lives within the district boundaries. The assessments or irrigators are only about 15,000 people. I ask where that 180,000 comes from. I don't know. No one will tell me. I don't think it's even based on noncontiguous tracks, because my dad gets 16 bills when they only have two parcels. I think there is a little bit of a misconception about the number of impacted people.

John D'Antonio: That is a good question. We are still trying to get a handle on the numbers. It is not just owners. It is sub-files. Sometimes a parcel of land has multiple sub-files with respect to it. There are some

other issues. We looked at it from an acreage standpoint, about 150,000 acres. There is also the complexity of having the state's largest metropolitan area with Albuquerque and Rio Rancho, the six Middle Rio Grande pueblos, and the conservancy district itself. When you talk about the layers of complexity with respect to that adjudication as it moves forward, it is a huge effort. We will look at that. It is one of the reasons we tried to set up the Middle Rio Grande pre-adjudication bureau. We tried to do it last year; hopefully we can get it funded this year. Its purpose is to get a handle on putting a plan together and getting a really good estimate on how much it is going to take to do that. We will get a better handle on the exact numbers once we get that group together.

Question: It just seems real disingenuous to talk about 180,000 parties without parceling out what the complexities might be.
Nuñez: I need to correct that. I didn't say 180,000. I said 80,000 because that is what I heard, but that is still a lot of people.

Question: Do you anticipate funding agricultural efficiency improvements?
Nuñez: Are you talking about the federal funds? Yes. I am sure we will, but we do not know how much, probably $5 million.

Question: Is your understanding of the adjudication process involving the whole sum of everybody, or are we keeping that adjudication of water rights to the sovereigns of the states and pueblos, or users individually?

I am leery about even giving the state engineer more money than he can spend in one year.

John D'Antonio: With the six Middle Rio Grande pueblos and their sovereign status, federal and state law with respect to how they come together when you are doing adjudications are two different animals. The reason that we look at separating them out and have done that in other areas is that the Navajo settlement agreement actually settled the Navajo claims in the San Juan basin. It didn't involve the non-Indians. There are other issues to fully complete that adjudication. We are talking about two different processes. Because the Indian water rights settlements involve the trustee responsibilities, they are a federal entity, and given their sovereign status, they must be dealt with differently. The only way you can do that is through negotiated settlement agreements. What you wind up doing is entering into negotiated settlement agreements to establish and come up with a negotiated settlement on what the six Middle Rio Grande pueblo's water rights are within that basin. That is far different from looking at the adjudication on the state-based rights, which goes through an adjudication process. You are looking at beneficial use. There are some linkages to it, but it gets far too complicated for me to explain. I would rather have one of my attorneys explain it. Suffice it to say that it is very complex, and it will be two different things: a non-Indian portion with the state-based rights that will go through state-based adjudications and the Indian settlements. We are looking at adjudication reform, so for future adjudications there may be something a bit different. There are the protracted negotiation settlement discussions that take place between the sovereign nations, the United States, and the state of New Mexico. That doesn't end there. Even the Navajo Nation settlement is not a settlement recognized by the federal government until there is authorization and the Department of the Interior secretary signs off on it. There are still some things that need to happen even with the Navajo settlement. The Navajo, the water settlement, and the San Juan settlement are just done with the state and those respective pueblos or tribes. There is still a federal portion that has to happen, so we are still quite a ways out. It is really complex.

Question: John expressed some concern about our agricultural products leaving the state. I think what he was trying to say is that he doesn't think Hatch chile should leave the state.
Nuñez: He said we are exporting our water when we export our pecans to China and our chile to California and Texas. For those who don't know it, there is a grocery store in Texas that has a chile festival for Hatch chile on a regular basis down there.

Question: The bill on the Gila River that the governor vetoed last year I think was in excess of roughly $900,000 for studies. Will the 2008 legislative session try to put the original amount back in again?
Nuñez: I think what we want to do is put the amount that Greg and others think they need. I am leery about even giving the state engineer more money than he can spend in one year. That money sits there, and the

state is paying the interest on it. If they ask for that $900,000 or $1 million to do it, that is probably what we will try to give them.

John D'Antonio: It wasn't a bill that was vetoed. It was a line-item authorization for $945,000 for hydrological studies for the Gila. We have included in our budget a request for $1.5 million to include additional hydrological studies to make sure that everything is taken into consideration and to meet those 2012, 2014 deadlines. That is a special request within our budget for $1.5 million.

Nuñez: I'm sure that is probably what we will recommend as well.

Response: The people down there are very happy to hear that.

Question: In your itinerary here, Mr. Chairman, you put down Colorado compact issues. Would you elaborate on that a little bit please?

John D'Antonio: The Colorado issues are heating up and have been heating up for some time. It is potential litigation with respect to the Colorado River issue. We have addressed potential litigation with our friends here from Texas over the last few years on deliveries. The Colorado River system is really interesting because you have seven basin states essentially. You've got the upper basin, which is New Mexico, Utah, Colorado, and Wyoming. And you've got a lower basin, which is Arizona, California, and Nevada. The lower basin is far in excess of their apportionment on that particular river. The upper basin has not used their full apportionment. There are some issues with Arizona in a seven basin states agreement that had been signed. They are sort of backtracking on whether or not they want to be part of that agreement. Part of it is because Arizona has the junior priority on that lower basin system. They've gone and developed a lot of their property and a lot of their growth is based on Colorado River water, Arizona Project Water. They feel they need to apply for every drop of water they can get. Part of the money that must be appropriated is to make sure we've got a stake to ensure that New Mexico gets its apportionment off that river. It leads to interstate litigation. In that regard, there is probably some money associated with lawyers. Sorry, Andy, we need lawyers to defend the state and the state's waters. I am sure that is part of it.

Nuñez: The federal environmental impact statement is still in progress with the Colorado River, and it is expected to be done by this December.

Question: You were saying that the state engineer can buy just the water rights down on the Pecos and let the landowner keep the land and keep it on the tax rolls. How are you going to adjust that tax rate on unproductive farmland?

Nuñez: The land can still be used for grazing. It doesn't mean it is completely unproductive. It is just taken out of irrigated agriculture. There are people who can use that for grazing, and they have livestock water that they can use. They don't sell all the farm, just a piece of it. The cattle can water in another place.

Question: I was listening to the news and there were some issues regarding the drilling for our natural resources as we become more energy independent. As a state that has energy resources of oil and gas and the concerns about the penetrations of the drilling activities through aquifers in Santa Fe County, this is really important. Just outside of Carlsbad, I am familiar with an interesting and innovative group that is preparing to demonstrate beneficial use of produced water. How are the state engineer and legislative actions going to deal with the productive use of these produced waters?

The federal environmental impact statement is still in progress with the Colorado River, and it is expected to be done by this December.

Nuñez: We recently heard a presentation by a company that has done just what you are saying. They are obtaining produced water right there at the well site and cleaning it up. They have two on the Navajo reservation, and they are just starting another one in Farmington so they can use it for golf courses. They can improve that water to where it can be potable water, but they can also use it for other things. They made a presentation to our committee. They are working on it.

John D'Antonio: You asked about well construction standards. There are strict well construction standards to protect the aquifer. As they drill down, they have to seal off those intervening aquifer areas as they get to the source. There are probably nine or ten barrels of water produced for every one barrel of oil. When this water comes up, it obviously needs to be treated. What Mr. Nuñez was talking about was a distillation

procedure that can turn the product into distilled water and could be used. OCD is a division within Energy and Minerals that has jurisdiction over produced water. We are trying to stay out of gaining jurisdiction, unless it goes to a beneficial use that has further jurisdictional issues with it. We are trying to work closely with them and will be working with them during this next interim period to come up with rules and regulations that make sure the source is protected, any jurisdictional issues are taken care of, and that water is permitted if it needs to be, while giving them the flexibility to use that water so we can save freshwater supplies.

Adélamar Alcántara *is a Senior Research Scientist with the University of New Mexico Bureau of Business and Economic Research and an Adjunct Research Professor with the University of New Mexico Community and Regional Planning Program. She is the Founding President of the Filipino American National Historical Society Rio Grande Chapter, President of the Filipino American Association of New Mexico, New Mexico State Chairperson of the National Federation of Filipino American Associations, and Executive Director of the Asian Family Center of New Mexico. In 2006, Dely founded the Asian Family Center of New Mexico. She received a B.A. in philosophy and an M.A. in demography, both from the University of the Phillipines, and an M.A. and Ph.D. in sociology from the University of Hawaii at Manoa. For her community advocacy work, she was awarded the 2001 Frank J. Miranda Bridge Award for Human Rights, the 2004 Governor's Award for Outstanding New Mexico Women, and the 2007 Lifetime Achievement Award from the Filipino American National Historical Society Rio Grande Chapter.*

IMPLICATIONS OF A GROWING POPULATION AND CHANGING DEMOGRAPHICS IN NEW MEXICO

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Thank you for inviting me. I am not going to be talking about the implications per say. I would like for you to draw the implications from my presentation. We will start not with numbers. For those of you who are expecting that demographers are wedded to numbers, I will dispel that myth this afternoon. I am going to show you a lot of pictures.

Figure 1 shows the age structure of the population that shows the past, the present, and the future of New Mexico's population. How can demographers show you that in a picture? Through what is called a population pyramid. The population pyramid shows you where this population has been in terms of past fertility, mortality, and migration. The demographers long before I was even born were very clever because they discovered that you could put these bars on their side and create a pyramid. If the fertility is high and there is no migration, this would be a perfect pyramid because attrition is only through mortality. Just to explain what this means, these are the results of fertility five years ago because that says zero to four years. If you compare this bar to the bar on top of it, you see that fertility in New Mexico has been declining. Where there is a bulge or an indentation that you don't expect or is a deviation from a pyramid, in this country there has not been an epidemic to cause such a mortality

pattern, so these are primarily due to migration. This is also due to migration. As you go up the ladder, it shows that the older the population gets, the fewer the number of people.

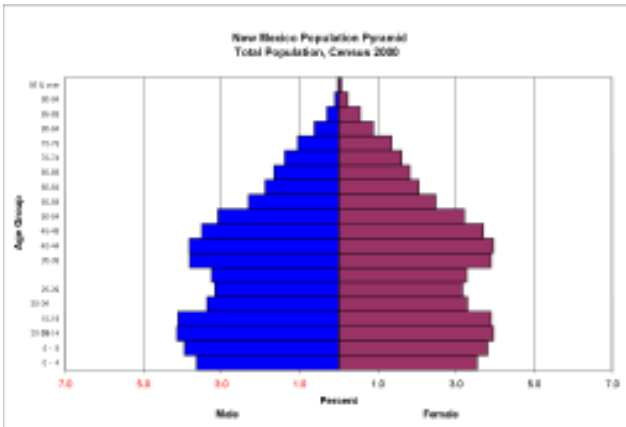


Figure 1. New Mexico Population Pyramid - Total Population

Figure 2 is the Anglo or the White Non-Hispanic pyramid. It is a much older population. Fertility is much lower, and you see this prominent bulge in the middle. Most of you have heard about the baby boom generation; most of this bulge is accounted for by the baby boom generation. There is an expression among demographers: the baby boom generation is like the pig in the snake. Wherever they are, the bulge is there. This is most pronounced among the Anglo population. Figure 3 shows the Hispanic or Latino of any race. Fertility is high among Hispanics or Latinos. Some evidence of migration is also noted in the Hispanic population pyramid. It seems like no one is exempt from the baby boom except for people from Asia like me. Filipinos have a boom all the time, so you have a perfect pyramid.

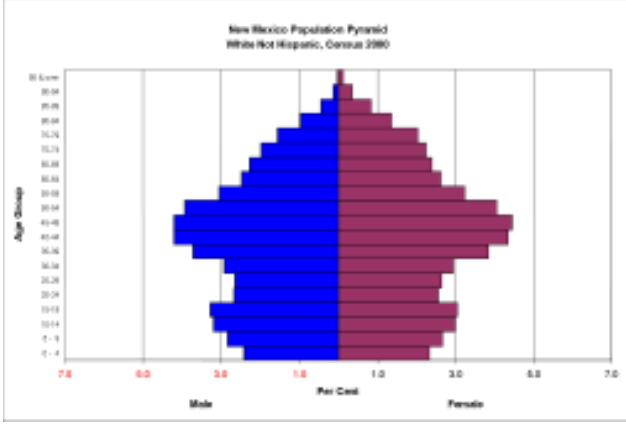


Figure 2. New Mexico Population Pyramid - White Non-Hispanic

Figure 3. New Mexico Population Pyramid - Hispanic or Latino

Figure 4 is the Native American population. You can see that even among Native Americans fertility is already declining. The Native American population pyramid reflects a long history of high fertility, but even among Native Americans, out migration is evident among the population in the labor force age groups. Notice the indentation in these age groups.

With the exception of Chinese and Japanese, Asians are recent arrivals to New Mexico (Figure 5). These are migrants. The Asian population pyramid points to the predominance of females. Among Native Hawaiians and Other Pacific Islanders (Figure 6), there is an overrepresentation of the population in the labor force ages, which is shown by the protrusion at the midsection of the population pyramid. This shows that most Hawaiians and Pacific Islanders migrated to New Mexico for employment, mostly in the military.

Figure 4. New Mexico Population Pyramid - Native American Population

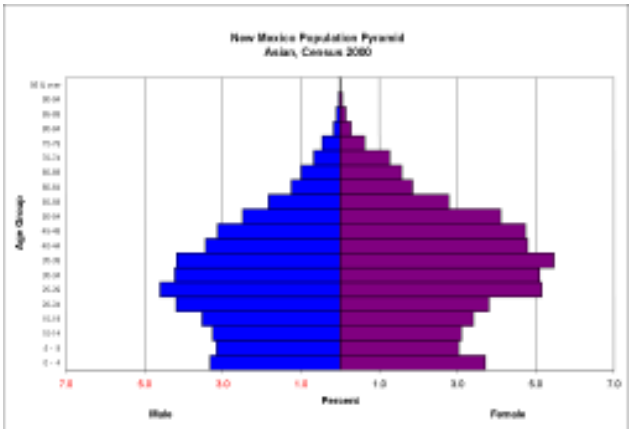


Figure 5. New Mexico Population Pyramid - Asian

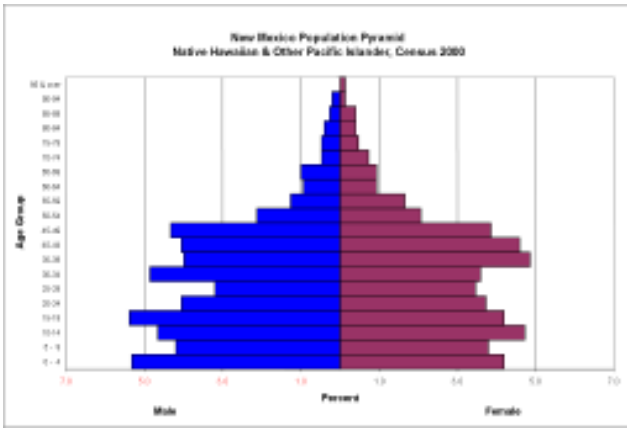


Figure 6. New Mexico Population Pyramid - Native Hawaiian and Other Pacific Islander

Generally when people respond "Some Other Race" or do not indicate a race in the Census form, the Census will classify them as White Non-Hispanic (Figure 7). In the upcoming Census 2010, if you do not yourself specify your race but instead check the box "Other," the Census will do a "hot code" and will designate a race and or ethnicity based on your neighbors' characteristics. My thinking is it is better to self identify than be identified based on some statistical model by the Census. In the past, about 97% of those who identified themselves as "Some Other Race" were reclassified as White Hispanic.

The population pyramid of "Two or More Races" shows that this is a very young population (Figure 8). The bottom of the pyramid is broad and as the bars progress to the older ages, they gradually decline, and past the middle age groups, they quickly taper off. The broad base shows the dominance of children among those who identified with more than one race indicating the increase in interracial couplings in New Mexico. The Census 2000 was the very first time that "check as many as apply" was an option in the race question.

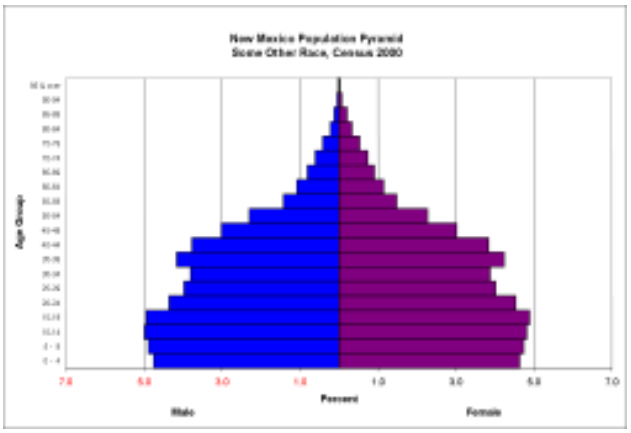


Figure 7. New Mexico Population Pyramid - Some Other Race

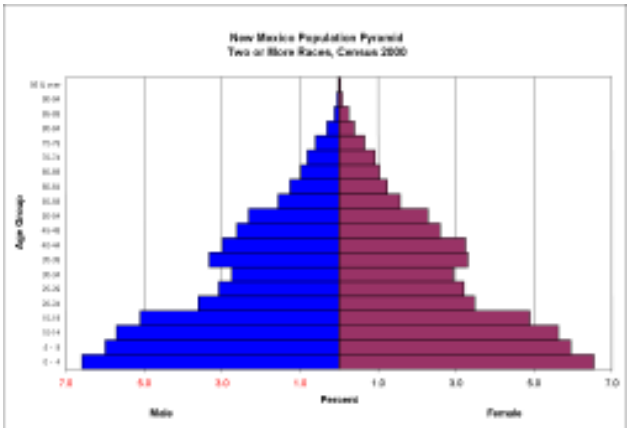


Figure 8. New Mexico Population Pyramid - Two or More Races

Minorities have a higher dependency ratio (Figure 9). Demographers define dependency ratio as the number of people who are dependent on the working age group, which is 18 to 64. This is a theoretical concept that serves as a rough measure of economic dependency. It does not reflect the actual employment situation in a given population. A "true dependency ratio" can be calculated by adjusting both numerator and denominator for the actual number of people not working; that is, the not working people will be added to the numerator and taken away from the denominator. In times of high unemployment, this dependency ratio will be higher than the "theoretical dependency ratio" measure as mentioned earlier. Nevertheless, dependency ratio is a good quick measure of the population's economic burden. Minorities have a higher young dependency ratio because their population below 18 years old is large. This is particularly true among the population group that was of "Two or More Races." Among Anglos or White Not Hispanic or Latino, the

young dependency ratio is considerably lower. The population pyramid of the "Two or More Races" shows a young dependency ratio of about 80 to 90 per 100 whereas that of the Anglos shows 30 per 100. Clearly these two population groups have different requirements for social services.

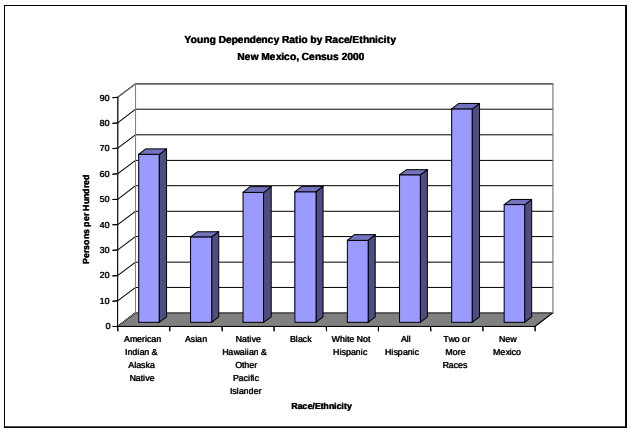


Figure 9. New Mexico Young Dependency Ratio by Race/Ethnicity (100 Anglos between the ages of 18 to 64 years support 30 people below age 18 years)

Since I knew that this presentation would be to members of water assemblies throughout the state, I wanted to know if there was a difference in water consumption between a young and an old population. I posed this question to my staff who have children. Their unanimous response was, "Of course. If you have babies and a teenager, water consumption goes up. As you get older, water consumption levels off." I don't know. I'm looking at the audience, and I see grey hairs like mine. You can tell me the older we get the less water we use.

New Mexico is aging. We are aging very fast because of the baby boom generation. Figure 10 shows projection pyramids. We start with 2010. If you recall, the 2000 population pyramid is slightly broader here. Here we have 2000, 2010, 2020, and 2030. The older the population gets, the more barrel-shaped it looks. Even among actual people we see a thickening of our middle, by the time you get to middle age, your body starts to look like a barrel. Thus, anytime you see a barrel-shaped population pyramid, think aging population.

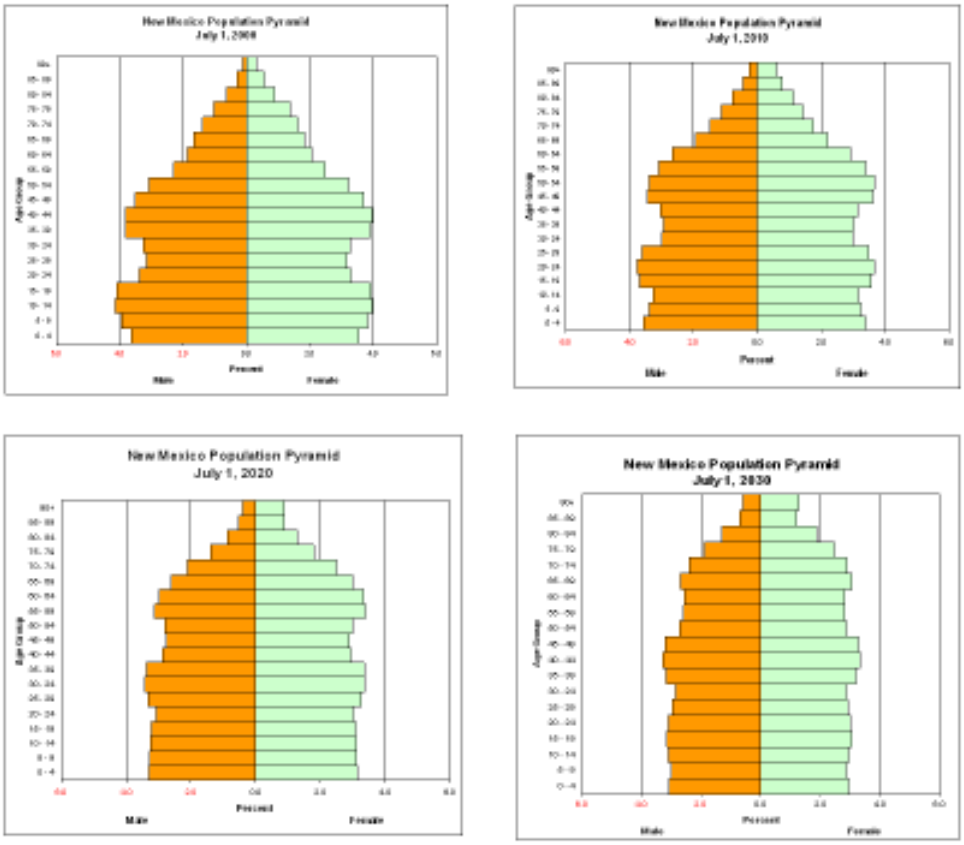


Figure 10. Population Pyramids 2000, 2010, 2020, and 2030

The population of New Mexico is growing, but growth is uneven. Figure 11 has a trend line that shows population growth in New Mexico. The pink line is metropolitan areas and the yellow is non-metropolitan areas. The future New Mexico population is more metropolitan than rural. Employment and educational opportunities are located in cities and urban areas. Unless there is a reversal of current economic growth patterns, the rural areas in New Mexico will continue to lose population as their labor force migrates to urban and metropolitan areas for employment and education. In some cases, migration is motivated by proximity to a health care facility, a hospital, or a health clinic. Figures 12 and 13 reiterate the urbanization of New Mexico. The metropolitan population overtook the rural population in the 1960s such that by 1970, the majority of New Mexicans reported that their place of residence is a metropolitan or urban area. The point of no return is gone. This is just to show you in maps (Figures 14-16), and if you watched the star shapes here, you will see that they start growing but they concentrate those large counties. The last figure is 2020. You can see the growth around those metropolitan areas.

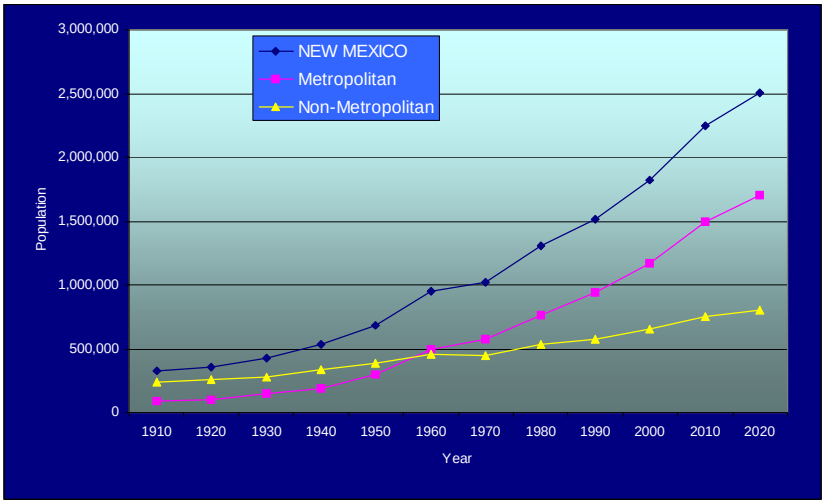


Figure 11. Population Size of New Mexico's Population by Metropolitan and Non-Metropolitan Areas: 1910 to 2020 (2010 and 2020 are projected numbers)

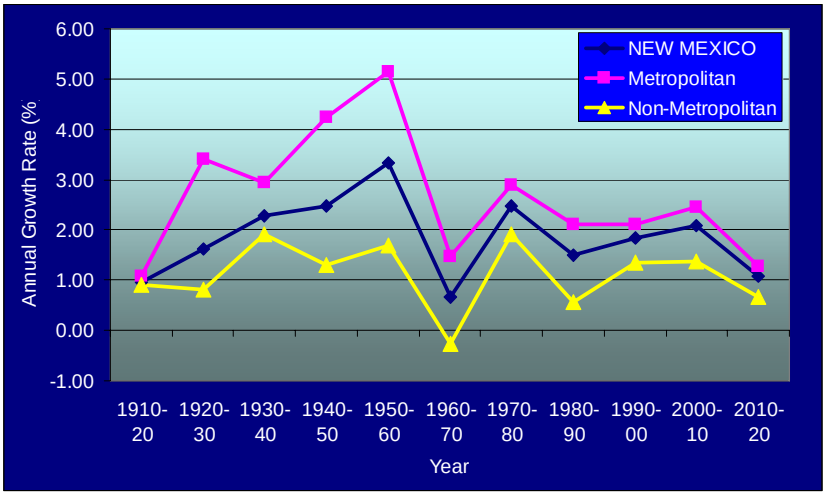


Figure 12. Annual Population Growth Rate (%) in New Mexico, by Metropolitan and Non-Metropolitan Counties: 1910 to 2020

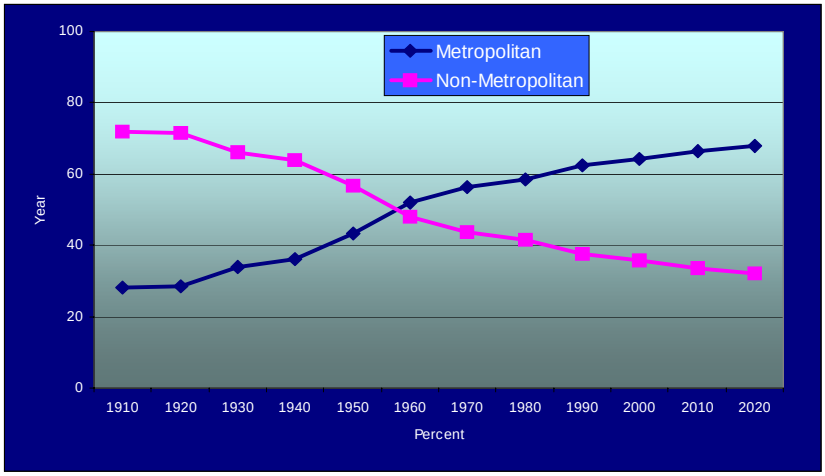


Figure 13. NM Population Distribution by Metropolitan and Non-Metropolitan Areas: 1910 to 2020

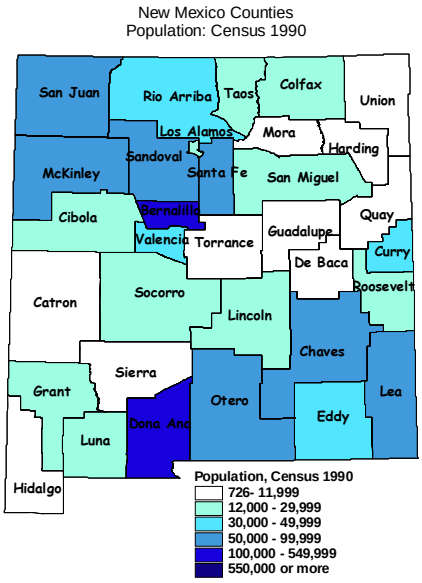


Figure 14. NM Counties Population Census 1990

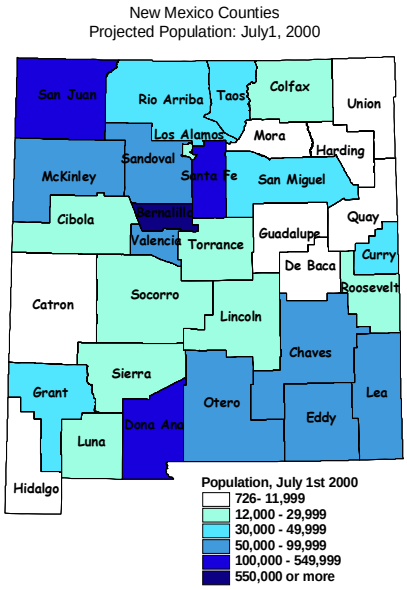


Figure 15. NM Counties Population Census 2000

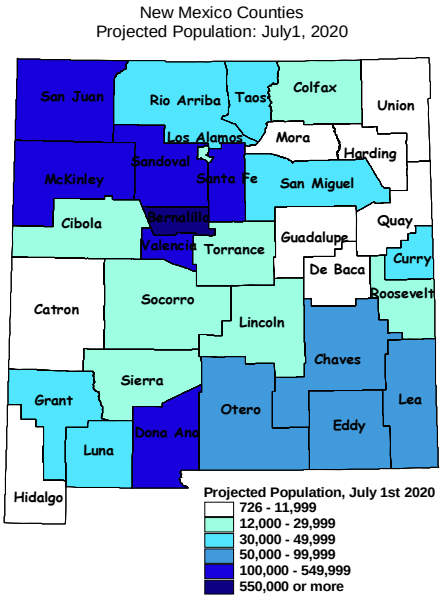


Figure 16. NM Counties Population Census 2010

Figure 20 a, b, and c depicts annual population growth rate trendlines. You can see that they all go up and down. They follow the same sawtooth pattern. Those of you who have lived here all your life or most of your life at least know that population growth in most of New Mexico counties follows the boom and bust of the economy. If the economy improves, you retain your people or you attract people. Even if you don't have any in-migration, if you retain your population, you will still continue to grow. I would like to dispel the myth that only migration accounts for population growth. Growth also occurs because of what is called natural increase or the difference between births and deaths. Even in the absence of migration, if the population is young, fertility will outnumber deaths. However, as the population becomes more barrel-shaped, deaths will outnumber births. In this case, migration becomes the engine of population growth. A good example is Sierra County. Sierra County grows primarily by migration, and it is retirement migration. Natural increase in Sierra County is negative, which means that deaths are more than births. Yet, Sierra County has been growing at a fairly decent rate of about 2% every year. Growth patterns among age groups are extremely variable. These are growth rates in percent. You can see the different age groups here. You can see that their growths are very different from the older age groups. Whether you are in a metropolitan county in New Mexico or a non-metropolitan county, these baby boomers are going to dominate population growth, until they die out. The middle aged and the elderly will continue their dominance as the children of the baby boomers come of age. Demographers are always looking for labels. After the baby boom are the baby boomlets. Starting in the year 2030, these boomlets will reach retirement age (65 years old). Between the boomers and the boomlets, New Mexico's population pyramid will become more barrel-shaped and will retain this shape for a very long time.

Table 1 shows projection numbers that were done in 2004; they will be revised soon, especially in light of a faster than anticipated growth mid-decade. Regardless, BBER projects that by 2020 New Mexico will have a population of about 2.5 million. This will be somewhat higher in the revised projections that will be produce sometime in 2008. In 2006, we estimated that New Mexico has reached the 2 million mark.

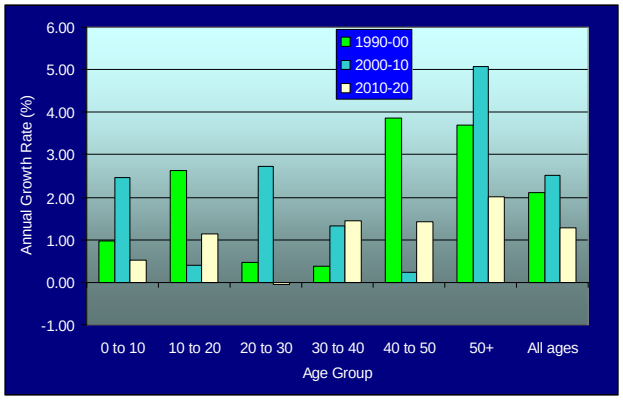


Figure 20a. Annual Population Growth Rate (%) in New Mexico, by Place of Residence Age Group: 1990-2020; Metropolitan Counties

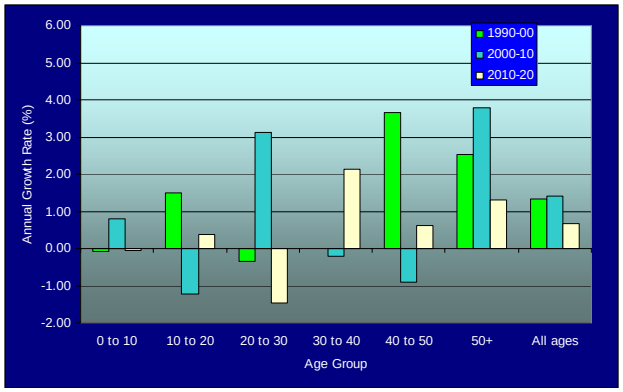


Figure 20b. Annual Population Growth Rate (%) in New Mexico, by Place of Residence Age Group: 1990-2020; Non-Metropolitan Counties

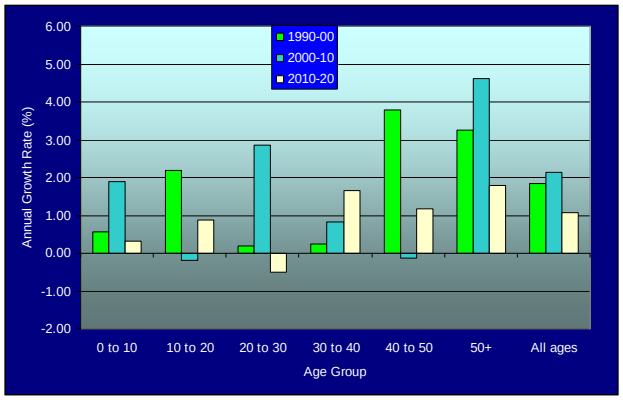


Figure 20c. Annual Population Growth Rate (%) in New Mexico, by Place of Residence Age Group: 1990-2020; New Mexico

Table 1. Projected New Mexico Population by Place of Residence July 1, 2010, 2020

Age Group	Metropolitan		Non Metropolitan		New Mexico	
	2010	2020	2010	2020	2010	2020
0 - 10	219,595	231,233	108,722	108,164	328,317	339,397
11 - 20	189,700	212,750	98,231	101,972	287,931	314,722
21 - 30	208,350	207,076	106,799	92,305	315,149	299,381
31 - 40	196,861	227,389	84,630	104,758	281,491	332,147
41 - 50	184,187	212,505	84,640	89,987	268,827	302,492
Over 50	500,118	612,077	269,486	307,332	769,604	919,409
All Ages	1,498,811	1,703,030	752,508	804,518	2,251,319	2,507,548
Percentage Distribution						
Age Group	Metropolitan		Non Metropolitan		New Mexico	
	2010	2020	2010	2020	2010	2020
0 - 10	14.7	13.6	14.4	13.4	14.6	13.5
11 - 20	12.7	12.5	13.1	12.7	12.8	12.6
21 - 30	13.9	12.2	14.2	11.5	14.0	11.9
31 - 40	13.1	13.4	11.2	13.0	12.5	13.2
41 - 50	12.3	12.5	11.2	11.2	11.9	12.1
Over 50	33.4	35.9	35.8	38.2	34.2	36.7
All Ages	100.0	100.0	100.0	100.0	100.0	100.0

New Mexico's population is increasingly becoming more diverse (Figure 21). Each race is represented by these different colors. Hispanic is not a race, according to the Census and the Office of Management and Budget, even if most Hispanics consider it a race. For purposes of presenting the minority population, Hispanics have to be taken out of the "White Race." Minorities include White Hispanics, Blacks, American Indians, Asians, and Native Hawaiians/Pacific Islanders. These "Two or More Races" are debatable whether they are going to be considered as minority or White. But for this presentation, I have included them in the Minority category. There is a debate among demographers and statisticians as to how to handle "Two or More Races."

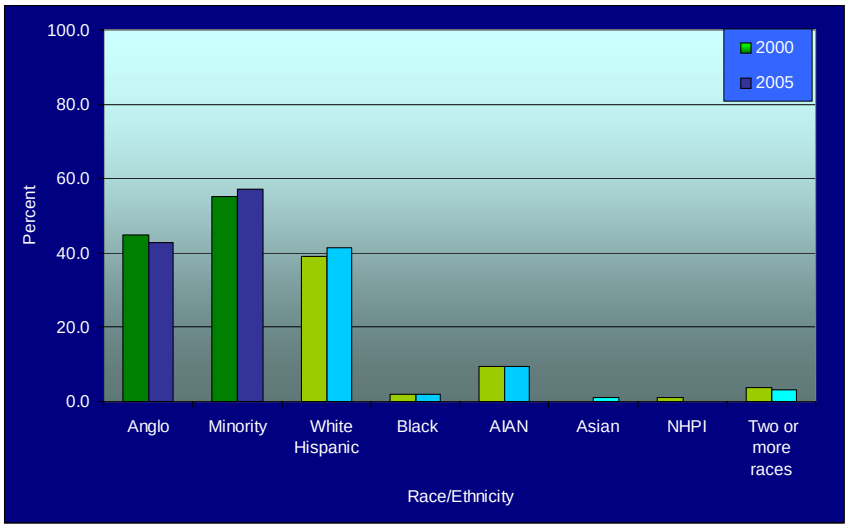


Figure 21. Race Ethnic Distribution of New Mexico Population: Census 2000, American Community Survey, 2005

Demographers—being demographers—want consistency across time, especially as we calculate fertility, mortality, and migration rates. Thus, the introduction of this "Two or More Races" category poses a major consistency problem. We don't have numerators to the denominators that have these two or more races. Births are reported as single race; deaths are the same way; school enrollment data, hospital discharge, and all of those are in single race categories. To be able to have consistency in measuring these events, I end up redistributing the "Two or More Races" population to single race categories.

Figure 22 is the race ethnic distribution of births. You notice that minority births have predominated since 1990. This dominance of minorities in the births data might have been true even prior to 1990 but we did not have race breakdowns in earlier data. Anglo births are declining. Hispanic births are increasing. American Indian, Black, and Asian births are steady. They are not declining or increasing, just holding their ground. These red bars represent Anglo deaths. The bars in Figure 23 show that Anglos are the most numerous in the number of dead people. The pink ones are Native Americans. The green represent Blacks or African Americans. Hispanic deaths appear to be increasing but only slightly. When you look at this figure and the previous figure on births, you can see that the state is going to be increasingly more Hispanic and minority and will be doing so at a rapid rate.

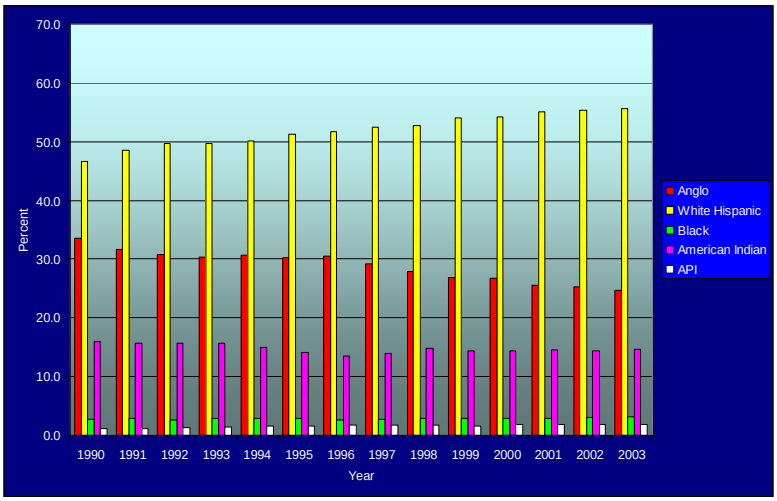


Figure 22. Race/Ethnic Distribution of Births in New Mexico 1990-2003

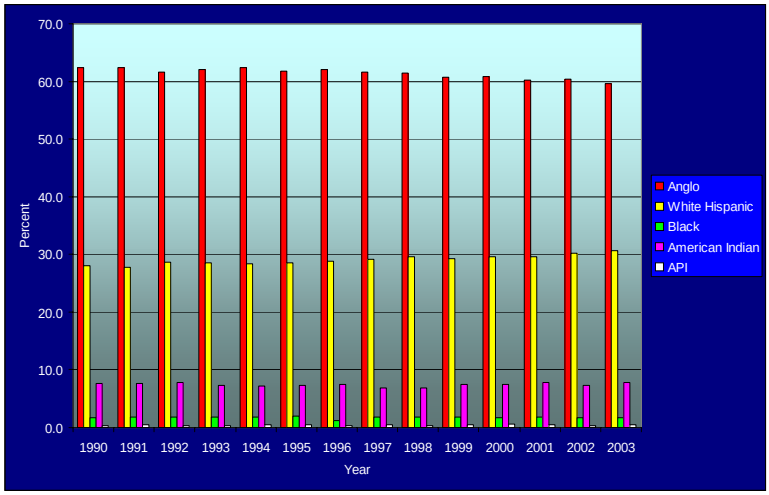


Figure 23. Race/Ethnic Distribution of Deaths in New Mexico 1990-2003

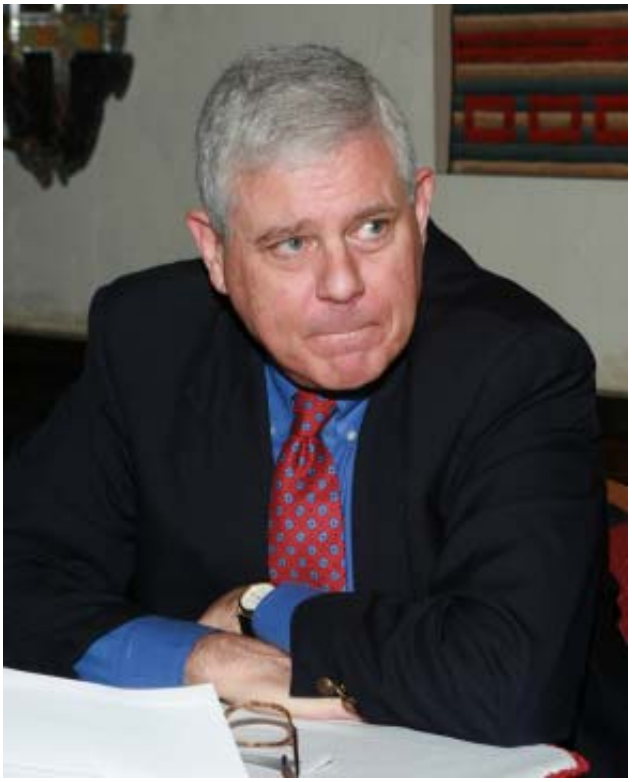
Growth will be in and around areas where there is employment and housing, where educational institutions are located, where retirement infrastructure is available, where there are amenities to attract upwardly mobile adults and affluent retirees, and where water is available to sustain population and economic growth. I put question marks around the last one, because if we live in Nevada or Los Angeles, or anywhere in California, they do not really have a lot of water, but they are growing very fast. People tell me, "Dely, when you do your projection can you put in water as a constraint to growth?" I have yet to find a model where I could incorporate water as a variable for the projection that I do. However, I am not opposed and I am very interested in looking at a simulation or developing scenarios of what if the consumption goes down or up, what if? That would be exciting to me, but I do not know how to do it with the demographic model that I am using currently. I am willing to go there. In fact, I just had two very bright young men, one just finished his Ph.D. and one is finishing his Ph.D., show me all of these models. But how do we model water here? I'm looking at Lee Brown, and maybe he can show me. He's an economist. Maybe the economists can show me how we can model the water component in the population projection equations. I know that water is a constraint to growth, and some towns in the past have become ghost towns because of lack of water. Given improvements in technology, I do not know whether or not water is a limit to population growth. I am thinking of Las Vegas and California. They seem to keep growing at a very rapid rate. I'm not an advocate of rapid population growth. I am just asking the question "Is water a limit to population growth?"

Question: How do you determine in years like this one, 2007, what the population is? How do you update your population in a noncensus year?

Alcántara: We call them intercensal estimates. The Census Bureau does its own. We do our own. We disagree with the Census Bureau. We find their numbers to be much lower than what we expect. How do we do it? We collect a lot of indicators. We collect building permits, births, deaths, IRS returns that the Census provides us, motor vehicle driver's licenses to look at migration, and school enrollment in some cases—not in every case. We look at those and see how the population is growing given these different indicators. Our major methodology is the housing unit method. We start with the housing that is collected by the Census and then add to it the new building permits that we get from the Construction Industries Division, from special permitting places. There are 22 special permitting places. They are cities and some counties that give permits. We use those. We start with what is called the persons per household or average household size from the last census and the vacancy rates also from the last census. These items are our starting points. We start looking at what school enrollment is, whether it is growing or declining. In cases where we know that the population is not growing very fast because the building permits, births, and deaths are not really changing that much, then we use the last census persons per household and vacancy rates. However, for places that we know are growing very fast, like Rio Rancho, we adjust these statistics based on the rate of change between, say, 1990 and 2000 in the persons per household. The vacancy rate is very tricky. When available, we use data from the apartment association to calibrate the vacancy rates, but that is only available for metropolitan Albuquerque and Santa Fe. Starting in 1999, the American Community Survey has been collecting data on a monthly basis, but the data are only available for seven counties. We use the vacancy rates from the ACS when appropriate. We do some measurements in terms of the vacancy rates vis-a-vis the relationship of the state vacancy rates and the county vacancy rates. We use that as a guide to calibrate the local area vacancy rate. The Census is our main source of information for housing statistics. There is a clamoring for sub-county population estimates. The challenge to produce populations at the sub-county level is great. Currently, we are geocoding or address matching our births, deaths, building permits, and driver's licenses that we have up to 2004. We are still trying to get permission to use data from 2005 to 2006 from the MVD. The match rates are really poor in a lot of cases. There is a lot of imputation and a lot of judgment. However, if I am not comfortable with the numbers generated from all these indicators, I will make a field visit. I will go and talk to the local people. For example, when I had a project for Lea County, I went to Lea County and interviewed hotel, RV operators, college administrators, employers, and construction workers. I wanted to get a sense of the current population situation in the county. I wanted to know not only numbers of people moving into Lea County but also their characteristics—that is, age and gender and if they have children, how old their children are. I was told that Lea County is busting at

the seams. I said, “Ok. I haven’t been there in a long time.” I went to Lea County and it is true. They do not have enough housing, so people are in hotels and RV parks. The Louisiana Energy Services (LES) who will operate the uranium enrichment plant near Eunice allows for hotel stays. LES claims that when the plant is fully operational, it will employ a maximum of 1,800 people. That is the long answer to your question.

F. Lee Brown *is Professor Emeritus of Economics and Public Administration at the University of New Mexico and principal in his consulting firm, H2O Economics. His academic and consulting work has specialized in water resource economics, policy, and management with particular emphasis on markets for water and water rights. He has published numerous books and articles in the field.*



MARKET PRICES AS MEASURES OF WATER SCARCITY IN NEW MEXICO AND THE WEST

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Good afternoon. I'm pleased to have this opportunity to talk with you today about market prices for water and water rights in New Mexico and the West. Water limitations are increasingly shaping the way we live and work in this region, and the prices which emerge from the marketplace provide a socially important instrument in our collective management of this precious resource. Prices warn us when a commodity is in short supply, provide incentives to both conserve and seek additional supply, and guide us in reallocating it from uses that produce less economic value to those that produce more.

This afternoon I am going to report recent prices from various basins around New Mexico and other western states, draw a few conclusions about patterns in those prices, and then conclude with an assessment of just how well markets are functioning in measuring the relative scarcity of the resource. I have obtained price information for New Mexico from numerous sources on an ad hoc basis since there is no organized market or other mechanism for tabulating and reporting prices. In fact, as a non-disclosure state by statute, price information in New Mexico is proprietary, and it is increasingly difficult to obtain in the very places, for example the Middle Rio Grande, where it is most important. As a consequence, I cannot confirm the accuracy or timeliness of all of the prices I report. For basins in the rest of the western states, I have made

use of the Water Strategist, a California publication that regularly reports water transactions around the West.[1]

Before presenting and discussing the prices I have tabulated, I need to make two important distinctions about the units whose prices are being reported. First, we need to draw a fundamental distinction between sales of water rights and sales of what I term 'bulk water.' The latter term refers to the raw water commodity itself and is perhaps more commonly known in the trade as leased or rented water. Water transactions occur in both forms, and unfortunately occasional failures to carefully distinguish between the two have led to confusion and even litigation.

Second, water rights themselves are measured in different units across states and even across basins in the same state. In the Lower Pecos and Gila basins in New Mexico, for example, it is customary to refer to 'water right acres' as the number of irrigated acres to which a property owner holds water rights. In most other New Mexico basins, rights are measured in terms of the number of acre-feet of consumptive use per annum (afcu/yr) to which the owner is entitled. In the tables that follow, I have separated prices for water rights and prices for bulk water. And, in New Mexico at least, I have converted all prices to acre-feet of consumptive use per annum. I have not been able to determine the units of measurement used by the Water Strategist, though the publication does distinguish between sales of water rights and sales of bulk or leased water.

Table 1 reports recent prices of water rights across a number of basins in the West. I have ranked them roughly from the highest to the lowest price, treating the Water Strategist values as though they are based upon consumptive use rather than diversion. All of the New Mexico values measure consumptive use rights. I'm going to leave this slide up for you to review while I make a few observations about its content.

- The highest reported price consists of entitlements to recycled water, and the proceeds from the sale are used to pay for the recycling plant. Nevertheless, this appears to be a bona fide transaction which represents actual willingness to pay for water rights by a residential development on the Monterey Peninsula of California. Per capita income in the residential development is over $70,000, compared to around $30,000 for New Mexico and $54,000 for Los Alamos County, the latter having the highest per capita income in the State. This price of $250,000 per acre-foot per annum is the highest price I have personally seen reported.
- Prices in the Santa Fe tributaries are the highest in New Mexico and rival prices paid for Truckee River rights in the Reno/Sparks area of Nevada. While expensive, they are well below the Monterey Peninsula area.
- Generally speaking, prices of tributary rights are higher further up in the watershed compared to lower in it. That circumstance arises from the fact that you can transfer tributary rights to the main stem but not the reverse. Therefore, the tributary price should always be greater than or equal to the main stem prices, and if there is any development whatsoever in the tributary, the price there should be above the main stem. In New Mexico that behavior can be observed in the progressively higher prices in the Lower Pecos paid for water rights in the southern Rio Hondo, tributary to the Pecos.
- Let me call attention to the diverging prices in the Middle Rio Grande. There is now a premium being paid by buyers wishing to transfer water rights to the Santa Fe area. This greater willingness to pay is influencing the basin market generally but even more so it has driven up rights in Sandoval County, which don't face as many protests as do water rights transferred from Socorro County to the Buckman well field or direct diversion. The higher prices in the reported range for the upper portion of the Middle Rio Grande are being paid for rights in Sandoval County.
- It appears that prices paid for water rights to be transferred to the upper portion of the Middle Rio Grande have now passed comparable values in the Colorado Big Thompson (CBT) District in Colorado. The CBT is the State of Colorado's largest transbasin diversion project through the continental divide above Denver and is one of the oldest water markets in the West. It is noteworthy that (1) more CBT shares are now owned by municipal and industrial users than irrigators and (2) CBT shares were the object of speculative investment in the late 1970s and early 1980s, which caused the prices to increase to six times their previous value before falling back to the previous level. Subsequently, of course, prices there began climbing again but more slowly over time.

TABLE 1
RECENT PRICES OF WATER RIGHTS IN WESTERN STATES
(AF is acre-feet of consumptive use per annum in New Mexico; unknown otherwise)

STATE	PRICE RANGE (per acre/foot)	BASIN/DISTRICT	QUANTITY
CA	$250,000	Monterey Peninsula Water Mgmt District	6 AF
NM	$35,000 to $45,000	Santa Fe tributaries	various
NV	$5,500 to $45,000	Truckee River	1858 AF
NM	$20,000 to $35,000	Middle Rio Grande (upper basin use)	various
CO	$12,500 to $19,167	Colorado Big Thompson Project	844 AF
NM	$9,000 to $20,000	Middle Rio Grande (lower basin use)	various
NM	$10,500 to $14,000	Rio Hondo (upper tributaries)	various
AZ	$12,000 to $12,700	Prescott Active Management Area	136 AF
NM	$10,000 to $12,000	Taos tributaries	various
NM	$7,000	Rio Hondo	various
NM	$3,000 to $5,000	Lower Rio Grande	various
AZ	$2,000 to $3,000	Tucson Active Management Area	137 AF
UT	$800 to $2,500	Central Utah Water Conservation District	59 AF
NM	$2,300 to $2,400	Roswell Artesian Basin	various
TX	$2,000 to $2,250	Lower Rio Grande	281 AF
CO	$1,852 to $2,160	Little Thompson District	32 AF
TX	$2,000	Edwards Aquifer Authority	5572 AF
WA	$1,750	Cities of Olympia, Turnwater & Lacey	up to 7000 AF
AZ	$1,000 to $1,500	Phoenix Active Management Area	1111 AF
OR	$700	John Day River	1000 AF
OR	$302-$900	City of Madras	48 AF

- As a general statement, prices of water rights in New Mexico are somewhat higher when compared to other basins around the West. Nevertheless, there is considerable variation in prices from one basin to another in the State. But the low prices in Oregon have not been seen in New Mexico for a long time. In the early 1960s prices in the Middle Rio Grande were between $200 and $300 and were still stable around $4,000 as recently as the 2000 to 2002 period.
- The rapid escalation of prices in the Middle Rio Grande began around 2004 and is the result of numerous factors, in no particular order: (1) a change in State Engineer policy that now requires rights to be purchased in most of the basin before pumping rather than when the effect of pumping reaches the Rio Grande, (2) a sharp increase in building permits beginning in late 2003, (3) the limited supply of pre-1907 water rights, (4) an increasing number of protests, and 5) speculation.
- Prices along the main stem of the Lower Pecos prior to the Lease/Purchase program instituted by the New Mexico Interstate Stream Commission were about half of what they are now, due in large measure to that program. However, dairies and pecan farms have also contributed to the higher prices. Yet, even at current price levels, adjudicated rights in the Lower Pecos main stem are decidedly below Middle Rio Grande levels.
- Prices for groundwater rights in the Lower Rio Grande initially sold for around $500 shortly after the basin was declared and were still around $2,000 in 2002 before climbing recently.

Table 2 reports recent prices paid for bulk water in western states. Again, I have ranked them roughly in descending order of magnitude and, again, I have assumed that all units are in consumptive acre-feet. Let me make a few comments about these prices as well.

- The longer the term of the lease, generally speaking, the higher the price.
- Volume does not appear to make much of a difference.
- The Tucson and Flagstaff prices are for reclaimed water.
- New Mexico is generally in the mid-range of these prices.
- Prices per acre-foot are generally quite lower than the implied price of bulk water derived from prices of water rights. That is, if the water right is considered a capital asset that yields bulk water each year, then a 5%-10% return on capital would imply significantly higher prices for bulk water than the market is producing. For example, if a water right is worth on average, say $20,000 in the Middle Rio Grande, then with a 5%-10% rate of return an acre-foot of bulk water would be worth $1,000-$2,000. That is not the case. See CBT water particularly.

TABLE 2
RECENT PRICES OF BULK WATER IN WESTERN STATES
(AF is acre-feet of consumptive use per annum in New Mexico; unknown otherwise)

STATE	PRICE RANGE (per acre-foot)	BASIN/DISTRICT	TERM
OK	$645	City of Owasso, City of Bixty	40 years
AZ	$610	City of Tucson	long-term
NM	$500	Jicarilla/Santa Contract	50 years
AZ	$308 to $726	City of Flagstaff	long-term
CA	$90 to $300	San Joaquin River Exchange Contractors Water Authority	5-yr lease
TX	$30 to $500	Lower Rio Grande	1-yr lease
CA	$20 to $185	Mohave River Basin	1-yr transfer
NE	$100 to $125	Platte Republican Resources Area	10-15 yr lease
NM	$100	Carlsbad Irrigation District	1-yr lease
CA	$70 to $125	Department of Water Resources/Yuba River	1-yr lease
NM	$17 to $100	San Juan Chama Project	various short-term
OR	$30 to $86	Klamath Basin Water Bank	1-yr lease
TX	$75 to $80	Edwards Aquifer Authority	one year?
CO	$10 to $80	Board of Water Works of Pueblo Colorado	1-yr lease
ID	$5 to $39	Magic Valley	1-yr lease
WY	$3 to $40	Boisen Reservoir	1-yr lease
AR	$9	Arkansas Valley	1-yr lease

- Only the Jicarilla-City of Santa Fe contract and the Carlsbad Irrigation District lease approximate that rate of return. The former is due to be reset next year based upon market prices for water rights in the Middle Rio Grande.
- This divergence between market prices for bulk water and market prices for water rights only makes sense, however, if the expectation of market participants is that the price of bulk water will climb substantially in coming years.
- Alternatively, current market prices for water rights may contain a substantial speculative element.

With this empirical background available to us, let's turn now to the implicit question implied by the title of my presentation. Namely, are market prices doing a satisfactory job of measuring the scarcity of water? To get an answer, we turn to the situations in the Middle Rio Grande and Lower Pecos.

Given the new policy of the State Engineer that requires water rights to be acquired in advance of pumping, I think it is fair to say that demand for water rights can no longer be postponed and therefore offers no reason to believe the prevailing price is artificially low. What problems may exist instead occur on the supply side. Three factors stand out. First, in the absence of adjudication there is dispute over the stock of water rights that have been perfected and are therefore available for potential transfer. This dispute encompasses both pre-1907 rights and rights held by the Middle Rio Grande Conservancy District, not to speak of tribal rights. Second, we are currently substituting mined groundwater for renewable surface supply, and there are ample reasons to believe that groundwater is undervalued. Third, according to the most recent analysis of the Middle Rio Grande water budget by S.S. Papadopulos for the New Mexico Interstate Stream Commission,[2] the Middle Rio Grande faces a chronic deficit situation in deliveries under the Rio Grande Compact. To the extent that each of these factors affects the supply of bulk water and water rights, then the price signal emerging from the marketplace misrepresents the scarcity of water.

All three of these problems have existed in the Lower Pecos, so New Mexico's experience in addressing the problems there are instructive, though only by illustration since the parameters of the Lower Pecos are quite different from the Middle Rio Grande. Adjudication in the Lower Pecos is almost complete; the artesian aquifer is reasonably stable, and we appear to be finally resolving our problem of under-delivery under the Pecos Compact. As I reported above, the net result of the first and third solutions is that prices for water rights have about doubled, and prices of bulk water seem to be approximately in line with prices of water rights. Stabilization of the artesian aquifer dates to a much earlier time period, and it would take a more extensive analysis to see what price effect occurred as a result of the formation of the Pecos Valley Artesian Conservancy District and its actions to stabilize the aquifer.

In short summary, it would appear that prices in the Lower Pecos are good measures of water scarcity there, but that we have some work to do before that is the case in the Middle Rio Grande. Comparable analysis would be required for other basins.

[1]Water Strategist, published by Stratecon, Inc., P.O. Box 963, Claremont, CA 91711, www.waterstrategist.com

[2]"Middle Rio Grande Water Supply Study, Phase 3," S.S. Papadopulos & Associates, Inc., November 24, 2004

John Horning *has been with Forest Guardians since 1994 and became the Executive Director in April 2002. During his tenure, he has worked in a variety of positions including grazing program director, watershed protection program director, and conservation director. He has had extensive campaign and litigation experience working on western water, grazing, endangered species, and land-use management issues in addition to his development and administrative responsibilities. The Wilburforce Foundation recently recognized him with its annual outstanding conservation leadership award. A graduate of Colorado College, where he received a B.A. in American history, John has worked as a wilderness ranger for the U.S. Forest Service, as an environmental educator, and as an editorial intern at High County News. Immediately prior to coming to New Mexico, he worked for two and a half years in Washington, D.C., for the National Wildlife Federation on public lands and western resource issues. John loves hiking and skiing, endurance running, and speaking Italian, and assists his wife Terry with horse events.*

A LIVING RIVER FUND

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Thank you. It is good to be here. My name is John Horning, and I am the executive director of Forest Guardians. Forest Guardians is a regional environmental advocacy organization. We are a membership-based organization. We are based here in Santa Fe. Our mission is simply to protect the wild lands, wildlife, and wild rivers in the American West.

For more than a decade now, environmental groups in New Mexico have been working to assert the Rio Grande's rights to its own waters. For years, the only way we sought to meet that goal was to enforce the legal mandate of the Endangered Species Act (ESA). As many of you know, we asserted in federal court that New Mexico's federal water projects, both the San Juan-Chama project and the Middle Rio Grande project, were subject to the ESA's overriding purpose of protecting endangered fish, wildlife, and plants. We argued in many different forms that more water needed to be provided, both to prevent the extinction of the Rio Grande silvery minnow, but also more importantly to ensure that the river's ecosystem would be sustained and eventually recovered. Though those legal efforts – and they are still ongoing of course – have been successful in catalyzing a lot of change in water management on the part of both federal and state agencies and have benefited the river, they have not yet ensured that the Rio Grande has a permanent right

to its own water, and that is really what I want to talk about today.

The Rio Grande silvery minnow litigation has, however, spawned an unusual alliance that creates discomfort in me to this day. It is an alliance that is working to create some new mechanisms to ensure that the river has a permanent right to its own water. In February 2007, the same six environmental groups – including Forest Guardians – that brought the Rio Grande silvery minnow litigation, this time in partnership with both the City of Albuquerque and the Albuquerque-Bernalillo County Water Utility Authority (ABCWUA), announced the creation of what we are calling the Living River Fund. The partners seeded the fund with $250,000. That was $25,000 from the environmental groups and $225,000 from the ABCWUA.

At the moment, the Living River Fund has one purpose. It is to create a pilot agricultural water leasing program in the Middle Rio Grande. The purpose of the program would be to free up more water that can then be allocated to the river when flows are needed most to sustain endangered fish and wildlife, including primarily the Rio Grande silvery minnow. The concept of agricultural forbearance is pretty simple, even if its implementation may be pretty complex. But before returning to the subject of agricultural water forbearance, I would like to explain and provide a little bit of background on how the Living River Fund came about and also describe some other companion mechanisms that are called for and still need to be implemented in order to make this whole thing work.

The ingredients for a Living River Fund are coalescing and coming together. But to be frank, there is a lot more that needs to happen.

Though the long version of this story has a little bit of drama, mostly lots of meetings with John Stomp, who is with the ABCWUA, the short version is that the Living River Fund implements a key component of the April 2005 partial legal settlement between the City of Albuquerque and the environmental plaintiffs. This again is in the still ongoing litigation, The Rio Grande silvery minnow vs. Martinez. In addition to committing the $250,000 to this Living River Fund, the settlement also requires two other actions that are an important component of reclaiming the river's rights to its own water.

The first additional component of this agreement commits up to 30,000 acre-feet of ABCWUA-owned space in Abiquiu Reservoir. This would be for an environmental pool to hold water rights to sustain the river at critical times. We realize, of course, that water without storage is not as valuable as water with storage. That is why storage is a key component of this overall agreement. We have discussed this with the Corps of Engineers, the State Engineer's office, and others. We are engaged in not yet negotiations, but conversations about how to go about authorizing this storage. Of course, it will have to meet both the Rio Grande Compact and any requirements of the State Engineer's permits.

Second, the agreement requires the authority to establish a program that gives residents of Albuquerque and Bernalillo County the choice to add $1 per month to their water bill or more that would be contributed to a Living River Fund. We call this the Living River check off, and that is because people would have to check off on their monthly water bill in order to participate in the program. The check off will certainly go into effect sometime in 2008. With almost 175,000 customers served by the authority, I think the mechanism has some potential to provide a significant and sustained revenue source to acquire water for the river. A similar program has already been implemented here in Santa Fe. Though the participation is not yet super robust, I think additional education and promotion of the program needs to occur. There already is fairly significant participation in the program.

The ingredients for a Living River Fund are coalescing and coming together. But to be frank, there is a lot more that needs to happen. For the Living River Fund to accomplish its goals, there are three additional entities that need to see it as a valuable tool and support it and provide both their political will and their financial capital. Those three entities, of course, are the state of New Mexico, the federal Bureau of Reclamation, and the Middle Rio Grande Conservancy District (MRGCD). Without any one of these players, the initiative of agricultural water forbearance is dead on arrival. We have started some conversations with these entities, and other conversations are planned.

As I have said, one of the key ingredients in the success of this program is additional financial support. The intention of seeding the fund with $250,000 was the hope that that money would act like yeast and attract other funding. With that in mind, we have approached the Interstate Stream Commission and asked them to

allocate funds from the Strategic Water Reserve to supplement the $250,000 currently in the Living River Fund. It is my hope and my belief that if the state provides funding to the program by putting money into a dedicated account that would sit and earn interest until the program is ready to be implemented, then that commitment would likely attract funding from federal agencies. I view that funding as critical to the long-term viability and sustenance of this overall program.

Then the question turns to the MRGCD, and I think to a somewhat lesser extent the Bureau of Reclamation and where they are on agricultural water forbearance. In preparing this talk, I went back and looked at all of the MRGCD's comments on this issue. Forbearance goes back a long way. It has been studied now for about 11 years. This first report on agricultural water forbearance was in the summer of 1997. I looked at press releases from the MRGCD going back to 2003, where studies have been made. There is general interest in exploring and seeing whether or not forbearance can make a difference. My point is that the issue has been well studied. More than anything, it is the political will and to an equal degree the financial capital that are needed in order for this program to be implemented.

I think from our perspective financial incentives can play a key role in providing flows to ensure that a river has a right to its own water. This is especially true as municipalities begin diverting their San Juan-Chama water, and that water is not available for the Bureau of Reclamation to acquire through short-term leases to provide flows to the Rio Grande. I view forbearance as the next possibility of providing flows for the river. My take on forbearance is that though the technical issues are significant, they are not insurmountable. The bottom line, as the saying goes, is that where there is a will, there is a way. If we have the political will, we will find a way to overcome the technical issues and make it one of the tools for providing flows to the Rio Grande.

My presentation is fairly brief, just giving you conceptually what this Living River Fund is all about and how it came about and what its vision is. I would like to close with just a few general thoughts.

First of all, I want to be clear that the environmental community has the same goal today that we had 11 years ago when many of us became involved with the Rio Grande. That goal is to secure the river's rights to its own water. That has not changed, and I suspect it will not. What has changed is that our methods and our approach to securing the river's rights to its own water have evolved and diversified.

Second, my hope and my belief is that the Living River Fund will grow both by establishing other check off programs in other municipalities throughout the Rio Grande basin. I believe that urban constituencies can do a lot of things. One of them is to demonstrate that as we look to the river to sustain, we can take one small step to participate in a mechanism that is about sustaining the river. I also believe over time we should be creative in how we use these funds. In addition to outright leasing for acquiring water, the funds could also be used to increase efficiencies, whether through conveyance or shifts in crop uses that result in freeing up water. The real key is that in all these cases where water is freed up through efficiencies that water is devoted to or dedicated to the river.

...the environmental community has the same goal today that we had 11 years ago...to secure the river's rights to its own water.

Third, my grandfather, who actually celebrated his honeymoon here many, many decades ago, once said to me, "John, don't look a gift horse in the mouth." My point in saying that is I believe this Living River Fund has the potential, if supported by key constituencies out there, to move us beyond some of the conflict that has characterized and undoubtedly will continue to characterize water management in the Middle Rio Grande.

Finally, I just wanted to share what motivates me in all of our work. I have been at this now for 11 years, and it is about a commitment to ensure that future generations have the ability to enjoy the living river just as past generations have. That means that we don't leave those generations with a ghost river. There are many other examples of ghost rivers in the Southwest. I think people involved in those rivers might never have thought that the river that sustained the community and was the original reason for those communities to be established would once go dry and that that state would become permanent. For me, this means basically reclaiming the river's rights to its own water. Of course in my opinion, what is at stake is not just the fate of two or three unfortunately less than charismatic endangered species, but rather ensuring a living Rio Grande that is at the heart of our region's identity.

Again, I think that is what sustains and drives our work amidst what are extremely difficult odds. Thank you.

Question: It seems that you are focusing throwing money at the problem, when the problem is wet water. It seems to me that maybe rather than talking to John Stomp about storage and money, it might have been very productive to talk to the ABCWUA about using that wonderful tool – the drinking water project diversion. If people actually conserve water, they can make a determination for it to go to the river rather than to new uses, so you could actually put wet water in the river. Then the urbanites play a real role in wet water for the river rather than throwing money at it and looking at someone else's water to solve the problem. Why didn't you talk to the city about utilizing that diversion? The urban people could then go down to the river and say, "I put three gallons of water in here."

Horning: I agree completely with the ethic, the principle. In fact, in our negotiations with the city during ongoing litigation, we initially started with that very ethic. That is exactly what we wanted. Quite frankly, it was a very bitter pill for all of us to swallow that we were not able to manifest that ethic in this agreement. I feel like there is still work to be done. I think a lot of people who conserve water do so thinking that it has a connection to something they care about. In fact, you are absolutely right. I think conserved water merely subsidizes the next development. I feel like the next frontier in this campaign is to do just that, to allow people to ensure that their conserved water goes to the river. We were not able to secure that policy through this mechanism.

Question: Well, rather than naming a federal agency, a state agency, and the MRGCD as where you are going next, maybe you should focus on an advertising campaign, because it seems to me that there is a lot of power in creating political will.

Horning: I agree with you.

Question: What did you mean by agricultural forbearance?

Horning: Agricultural forbearance is the basic concept of paying an agricultural water user to forbear the use of the water—that is, not divert that water—to a farm field, so, to put it simply, that water can flow in the river, assuming there is one diversion and one user. It is obviously a lot more complex than that. The idea is to forbear the use of water and be compensated for that forbearance and allow that water to be dedicated to another use, in this case to provide flows for the river. The idea of forbearance is not to acquire the water necessarily, but to lease the water. At least traditionally, the agricultural community has been resistant to out-and-out acquisition, though the previous presenter clearly demonstrated that there are a lot of willing sellers out there. That is the basic concept.

Julie Coonrod *obtained a B.E. in civil engineering from Vanderbilt University in 1987, an M.S. in civil engineering from the University of New Mexico in 1991, and a Ph.D. in environmental and water resources engineering from the University of Texas at Austin in 1998 under Dr. Ed Holley and Dr. David Maidment. Prior to her doctoral work, Julie spent five years working as a consultant with Scanlon & Associates in Albuquerque and Santa Fe, New Mexico. She worked on a variety of civil engineering projects around the state and is a registered professional engineer in the state of New Mexico. Since becoming a faculty member in the Department of Civil Engineering at the University of New Mexico in 1997, Julie's research has focused on issues relating to the Middle Rio Grande. She started a research program with GIS and is teaching a graduate level course that emphasizes the modeling capabilities of GIS. Julie is a member of the American Society of Civil Engineers and the American Water Resources Association. She serves as the faculty advisor for Society of Women Engineers.*

CLIMATE CHANGE AND ITS IMPLICATIONS FOR NEW MEXICO'S WATER RESOURCES AND ECONOMIC OPPORTUNITIES

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ABSTRACT

Social, economic, and environmental systems in water scarce New Mexico and throughout the arid southwest are vulnerable to disruptions in water supplies that are likely to accompany future climate changes. With a particular focus on New Mexico and its potential economic consequences, this paper uses a hydro-economic model of the Rio Grande watershed to integrate plausible changes in climate, hydrologic responses, and water demands within a framework that optimizes water use allocations for the greatest economic benefit. The study uses three climate change scenarios across two future time periods selected to

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represent the range of effects indicted by the outputs across 18 GCMs using the SRES A1B emissions scenario. These six climate change scenarios were then used to model runoff changes using the WATBAL hydrologic model (Yates, 1996), which integrates climate and hydrologic variables, and to change water demand parameters in the hydro-economic model. Primary findings confirm that ecosystems are at greatest risk in New Mexico followed by agricultural water users, as water is increasingly transferred to maintain urban and industrial users with greater economic productivity. While total annual economic losses are estimated in the vicinity of $300 million, under severe climate changes where runoff is reduced by nearly 30%, in actuality, both economic and non-economic losses are likely to be significantly higher. This is due primarily to both the effects of some strongly optimistic model assumptions, e.g., assuming no conflicts over water rights or water transfers, and to several significant and valuable omissions in the analysis, e.g., the environmental and social services that agriculture and the environment provide.

INTRODUCTION

New Mexico has a unique blend of cultures and landscapes, of agrarian values and high-tech economies, of rare ecosystems, fertile valleys, and expansive desert rangelands. It is a place where people have long settled and where growing numbers still long to settle as migration trends illustrate and highlight growing communities praised for their quality of life, climate, and retirement opportunities. The Rio Grande valley, which bi-sects New Mexico, has industry, tourism, residents old and new, and agriculture which all stake claims to water resources. These water resources must also serve the traditions and economic needs of twenty-three Native American tribes and pueblos, and which also flow through traditional acequias – i.e., canals – felt by many to be the 'lifeblood' of four hundred year-old Hispanic communities. The Rio Grande is also home to endangered silvery minnows where is found the last remnant of their historical habitat, and where flocks of migrating cranes and geese gather in vast numbers to rest and find refuge in riparian bosques – i.e., woodlands.

The Rio Grande, and the subterranean aquifers that it feeds in some regions, are the principal – and often only – water sources for cities and farms from Southern Colorado through New Mexico and into far West Texas, as shown in Figure 1. The vulnerability that these water users face together – especially in light of potential climatic and hydrologic changes – is not only indicated by this high level of dependence on a sole source of supply, but by the oversubscribed nature and exhaustive use of this source (Hurd et al., 1999; Hurd et al., 2006). The level of use is so exhaustive of surface supplies that after the thirst is satisfied it is, in fact, normal for the Rio Grande to trickle with salt-laden return flows and summer storm runoff for 180 miles until its confluence with Mexico's Rio Conchos – just above Big Bend National Park near Presidio, Texas – where, newly reconstituted, it continues its remaining 1,100 mile journey to the Gulf of Mexico.

Figure 1. The Upper Rio Grande Watershed and Study Area

The future health of New Mexico's economy, traditions and cultures, and riparian ecosystems is so tightly hinged, in the long run, to the flows of the Rio Grande that it may not be even necessary, as is the aim of this study, to monetize the economic consequences as distinct from the hydrologic consequences of potential climate change. And, as highlighted throughout this paper, there are many limitations in the capability to measure and express even the economic consequences from changes that

affect the regional character and economy in such profound ways.

The paper begins with a discussion of New Mexico's climate and the approaches used to model and identify appropriate scenarios of climate change. Next, the State's hydrologic situation is described, reviewing key studies that have tried to understand the climate influences on the State's rivers, and describing the hydrologic modeling used to examine the climate change scenarios and estimate streamflow changes. This is followed by a description of the economic approach used to estimate impacts. In estimating these consequences, a hydro-economic model of the Rio Grande watershed is used that optimizes the allocation of available water, and as necessary, readjusts water-use patterns such that economic losses are minimized during, for example, a long-run downturn in streamflow. The final sections of the paper present and discuss key findings and conclusions.

CLIMATE VARIABILITY AND CHANGE IN NEW MEXICO

Tree-ring analysis indicates that New Mexico has a long and highly variable history of precipitation and streamflow that is punctuated with periods of high runoff and drought. Nearly five hundred years of Rio Grande streamflow has been reconstructed and is shown in Figure 2. This reconstruction is long enough to illustrate that the period of recorded streamflow, roughly 100 years, does not fully account for the natural range of extremes. For example, neither the recent drought from 2001-2005 nor the 1950s drought – the most severe in recent memory – match the severity of 8 or 9 previous drought episodes within this reconstructed record. Some anthropologists speculate that droughts, in periods even earlier than shown in the Figure, were severe enough in this region to cause the collapse of early pre-Columbian civilizations in the region (Plog, 1997).[1] Such observations indicate that significant climate anomalies are not unprecedented in this region; and, that it is entirely plausible that with continued greenhouse gas forcing of the atmosphere, and its rising effects on the earth's energy balance, there can be a reasonable expectation of exceeding these natural extremes in the future (IPCC, 2007).

In assessing climate change impacts, selected scenarios should be based on climate models that reflect the range of plausible regional outcomes. By choosing across the available range, uncertainty about the regional climate change is conveyed more accurately than would be if selections were narrowly targeted. For example, use of only model outcomes estimating precipitation increases would be misleading if some models project a decrease. Differences across climate models tend to indicate the minimum uncertainty concerning possible regional climate change. Therefore, to capture the plausible range of climate outcomes associated with continued atmospheric forcing, Smith and Wagoner (2006) – with guidance and technical assistance from scientists at the National Center for Atmospheric Research (NCAR) – selected three climate models, from the 18 used in the IPCC's Fourth Assessment report (IPCC, 2007), that were most representative of the range of precipitation response

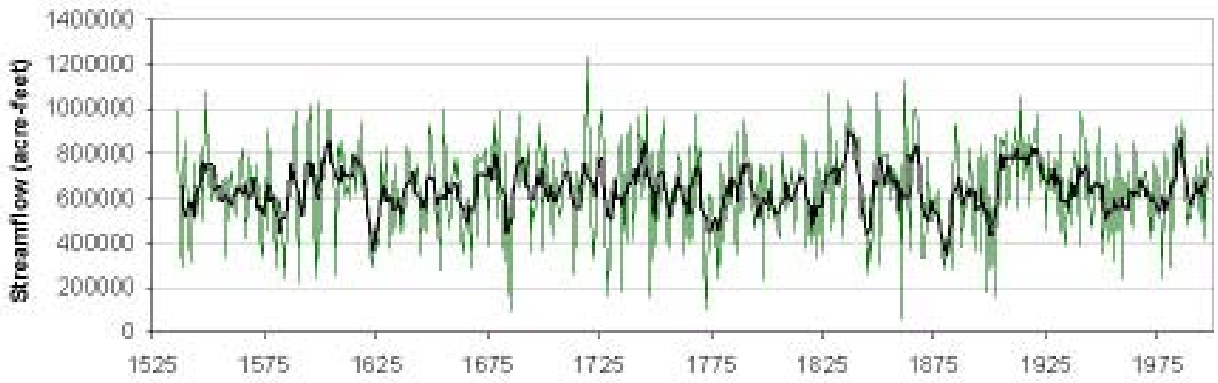

Figure 2. Long-run Tree-ring Reconstructed Streamflow of the Rio Grande near Del Norte (Source: National Climate Data Center, NOAA, http://www.ncdc.noaa.gov/paleo/streamflow/riogrande.html Accessed: February 10, 2007)

from relatively wet to relatively dry with one approximating the median. In this comparison each climate model used the same underlying greenhouse gas emissions scenario, the Intergovernmental Panel on Climate Change (IPCC) emission scenario referred to as 'A1B'.[2] This emissions scenario is generally regarded as "neither too optimistic nor pessimistic," and is commonly associated with 'business as usual' economic activity levels. Furthermore, the spatial resolution of climate model output is coarse relative to the regional scales most of interest, with grid cell sizes covering approximately 5.6° in latitude and longitude, i.e., very large areas of approximately 300 miles across, as shown in Figure 3 for the New Mexico. This limitation means that local differences in climate change, for example, by altitude or on the leeward and windward side of mountain ranges is not well represented and contributes uncertainty to the model results.

Based on this process, the following three climate models were selected to represent the range of outcomes projected for New Mexico:

1. **Wet:** Hadley Centre for Climate Prediction and Research Met Office (hadcm3)
2. **Middle:** Atmospheric Research Australia (CSIRO)

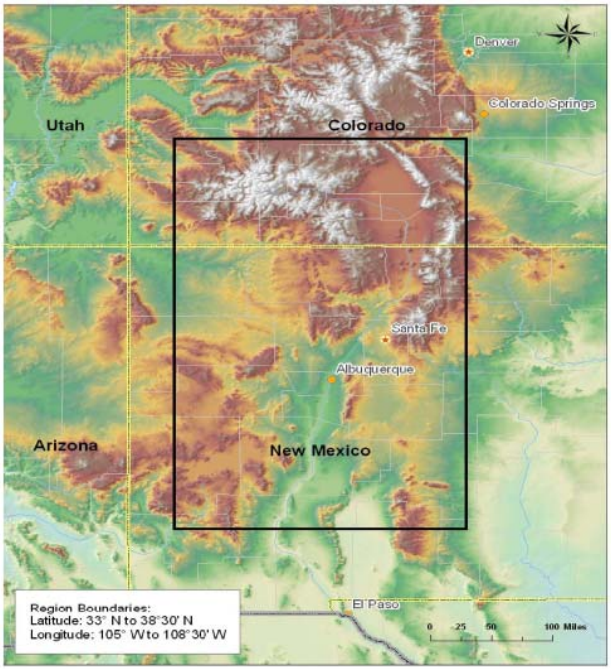

Figure 3. Approximate Location of the GCM Grid Cell Used to Estimate Temperature and Precipitation Changes for the New Mexico Climate Change Scenarios

3. **Dry:** U.S. Department of Commerce (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL0)

Using the temperature and precipitation outcomes estimated by each of these three models, Smith and Wagner (2006) develop six climate change scenarios, a Wet, Middle, and Dry scenario for each of two future time periods, a closer time frame, simulating years 2020-2039, and one further, simulating years 2070-2089, referred to as "2030" and "2080" scenarios in the analysis, respectively. Figure 4 (panels 'A' through 'D') illustrate the estimated temperature and precipitation changes for New Mexico for each of the six scenarios.

CONSTRUCTING SCENARIOS FOR SOCIO-ECONOMIC TRENDS AND BASELINE CHANGES

Economies develop, technologies advance, and populations grow and change, together altering the socio-economic setting in which the future climate is realized. In the future, will New Mexico residents, industries, and cultural traditions be more or less vulnerable to a changing climate? Population growth, for example, in New Mexico cities – and throughout the cities of the southwestern U.S. – has been significant and appears not to be slowing. Studies suggest that this growth amplifies exposure and the vulnerability of these communities to risks from severe droughts and flash floods (Hurd et al., 2006, 1999). As Frank Pinto, the Executive Director for the UNDP's Global Environment Facility, writes in his forward to a UNDP handbook on developing socio-economic scenarios:

> *Developing socioeconomic scenarios of the future is important because socioeconomic changes may substantially increase or decrease vulnerability to climate change. For example, as populations grow, human activities that pollute may increase and habitats may be fragmented. Together, these changes may increase the vulnerability of some aspects of human welfare. If the economy grows and technologies can be developed, vulnerability may be reduced in some sectors but possibly increased in others. These interactive changes can be explored (although not predicted) through the development of alternative socioeconomic scenarios of the future (Malone et al., 2004, p. 5).*

Figure 4. Temperature and Precipitation Change Scenarios for New Mexico (Source: Smith, M.B. and C. Wagner. 2006. Scenarios for the National Commission on Energy Policy. Memorandum to Brian Hurd from Stratus Consulting Inc., Boulder, CO. August 1.)

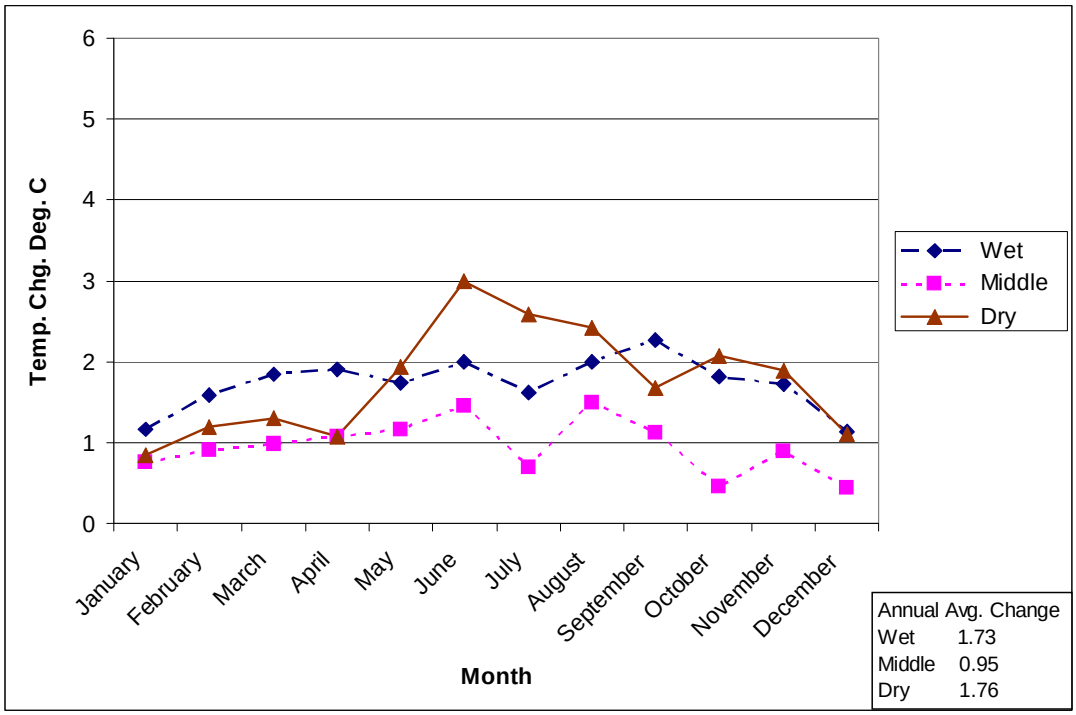

Figure 4a. Temperature Change in 2030

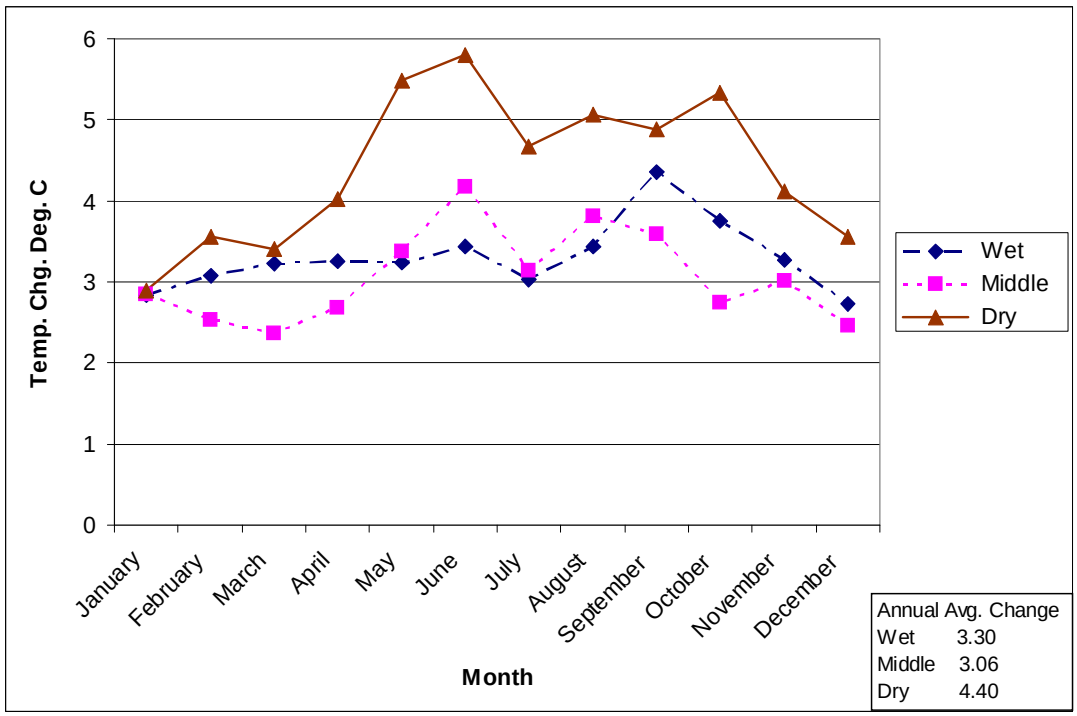

Figure 4b. Temperature Change in 2080

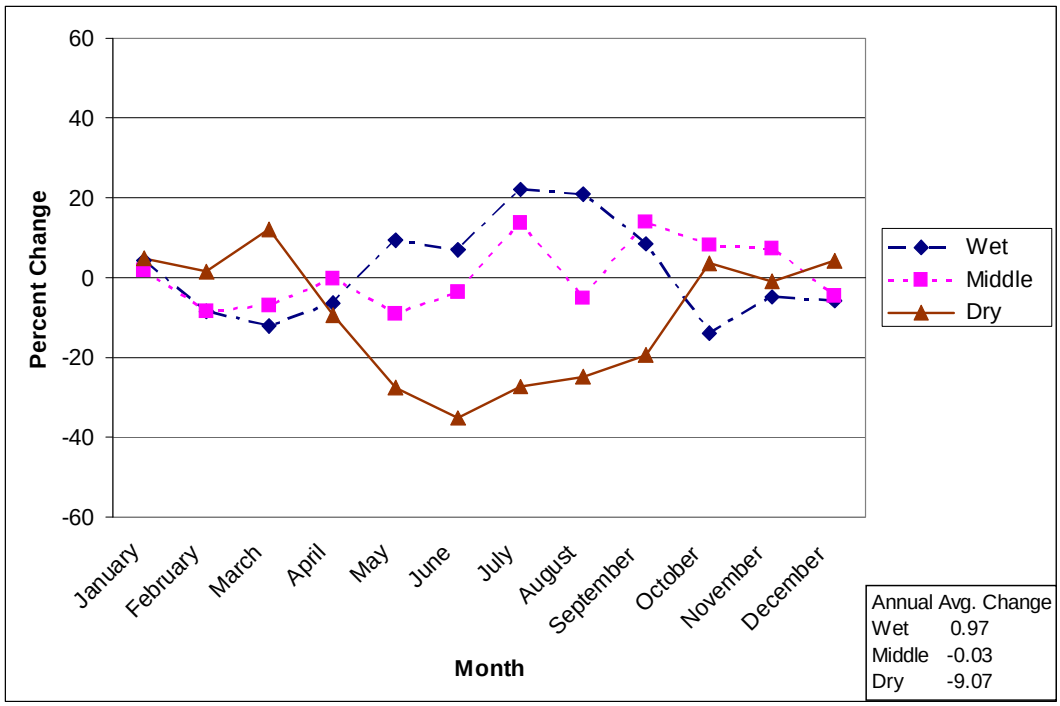

Figure 4c. Precipitation Change in 2030

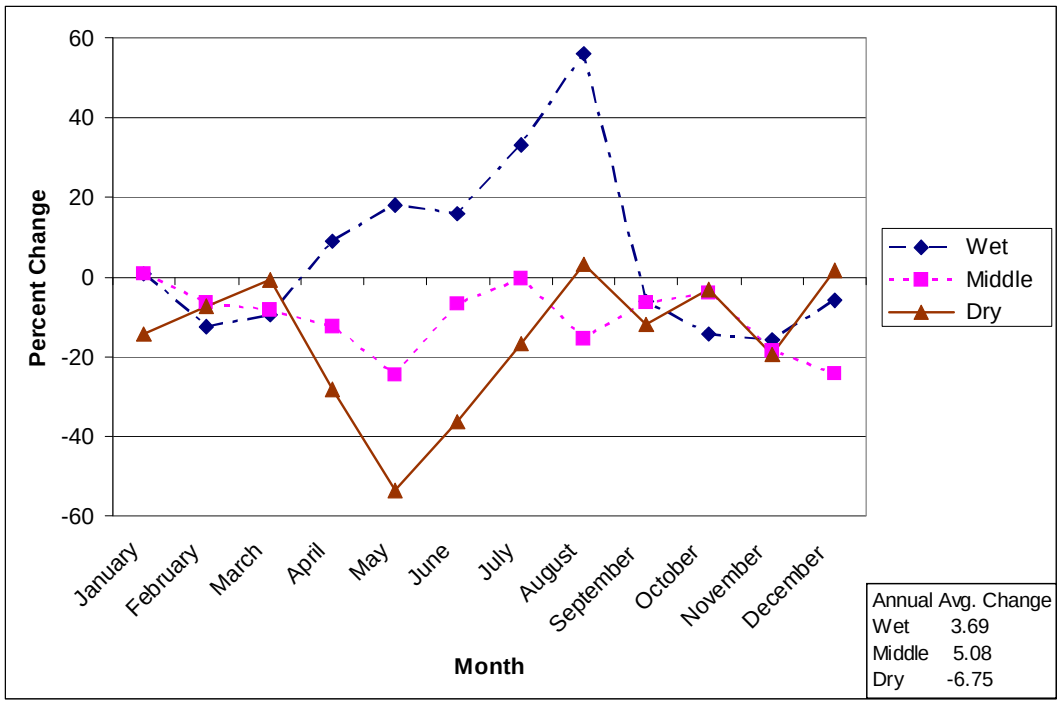

Figure 4d. Precipitation Change in 2080

Impacts from future climate changes are best performed against baseline estimates of expected socio-economic conditions in the relevant future timeframe. In other words, it would not be consistent to measure impacts by comparing conditions expected 20 or 70 years in the future to those that currently exist. To construct socio-economic baseline scenarios, Smith and Wagner (2006) collected demographic trend data on population and income growth for New Mexico from the U.S. Census, to which was added additional data from the New Mexico Bureau of Business and Economic Research (NM BBER, 2004) on population growth trends within the counties of the Rio Grande watershed.

Using county-level population growth rate projections developed by NM BBER (2004) for five-year incremental periods out to 2030, annual population growth rates for the counties in the Rio Grande watershed were estimated. The population growth trend was further extrapolated to 2080 by fitting a quadratic trend to the data. The results show that population growth in the Rio Grande corridor is projected to decline fairly steadily over the study period, falling from current annual rates just under 2% to approximately 1% in 2030 and 0.5% by 2080, as shown in Figure 5. To insure consistency of the population estimates with the SRES A1B scenario used in developing the climate change scenarios, the estimates were compared to those developed by Smith and Wagoner (2006) – which were SRES A1B rescaled U.S. Census estimates – and were found nearly identical at the State level. Figure 6 shows the estimated population in these counties for the years 2000, 2030 and 2080 using the extrapolated growth rates.

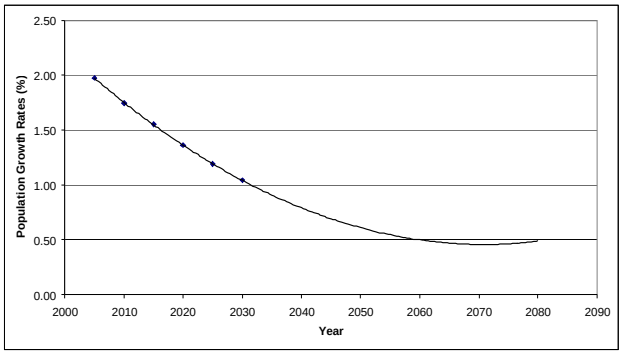

Figure 5. Projected Growth Rates of Rio Grande Watershed Counties in New Mexico (Source: NM Bureau of Business and Economic Research, rev. 2004. Counties include: Bernalillo, Doña Ana, Los Alamos, Rio Arriba, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, and Valencia)

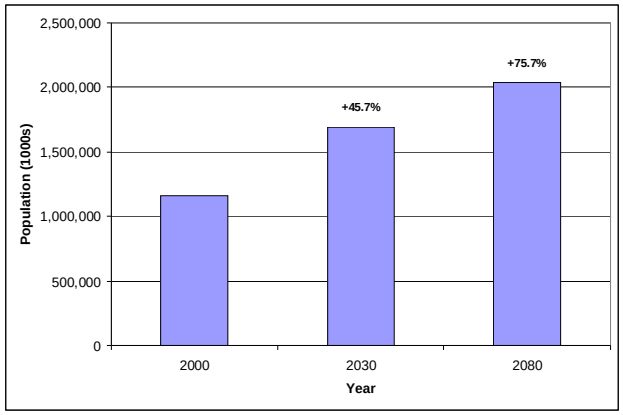

Figure 6. Projected Populations of Rio Grande Watershed Counties in New Mexico (Source: NM Bureau of Business and Economic Research, rev. 2004. Counties include: Bernalillo, Doña Ana, Los Alamos, Rio Arriba, Sandoval, Santa Fe, Sierra, Socorro, Taos, Torrance, and Valencia)

Estimated population change is the primary driver used to shift aggregate urban water demand in the analysis and to provide an appropriate baseline against which future climate change impacts can be compared. Although per capita income and regional economic development are also expected to increase and contribute to wealth formation over the relevant timeframe, their effect on aggregate municipal and industrial water demand is much less clear than those from population changes. Household water demands can rise with income reflecting, for example, an increase in the size of homes. However, estimated income elasticities are generally quite low and to a significant degree are expected to be offset by improvements in household water-use efficiency.

ESTIMATING THE HYDROLOGIC AND STREAM-FLOW CHANGES UNDER CLIMATE CHANGE

Estimating changes in streamflow and water available is the result of hydrologic simulation of the climate change scenarios. These simulations are run using the conceptual rainfall-runoff model called WATBAL that simulates changes in soil moisture and runoff as a result of changes in temperature and

precipitation (Yates, 1996, 1997). WATBAL is conceptualized as a one-dimensional water balance model comprised of two elements. First is a water balance component that describes water movement into and out of a basin consisting of three sub-processes describing i) surface runoff, ii) sub-surface flow and iii) maximum catchment water-holding capacity. The second models the system energy balance and uses the Blaney-Criddle relationship to simulate evapotranspiration (FAO, 1992) and to model the snow storage and runoff. Parameters in WATBAL include the size of catchment areas, and the rate water additions and removals, which are based on historical runoff relationships, calibrated changes, physical characteristics, and input data such as monthly rainfall and temperature. Water is added by precipitation, can be accumulated to some extent, and is removed by evapotranspiration, surface runoff or sub-surface runoff.

The simplified representation of soil moisture dynamics has been shown to adequately represent runoff changes due to climate fluctuations (Yates and Strzepek, 1994; Yates, 1996, 1997). WATBAL was applied to each catchment area in the Rio Grande watershed to simulate runoff and streamflow such that it is spatially and temporally consistent with the hydro-economic model described in the next section.

For each watershed corresponding to the hydro-economic model (see Figure 7), historical monthly values for stream flow, precipitation, and temperature were required. Monthly stream flow values are available from the USGS (waterdata.usgs.gov). Historical precipitation and temperature grids (4 km grid cells) are available for the contiguous United States from the PRISM group (www.ocs.orst.edu/prism). The historical 30-year climatic period of 1971 to 2000 was chosen. This period of time contains some of the wettest years on record. However, this period of time also has the most complete record. Any 30-year climate period will contain sufficient variability to calibrate WATBAL, but the calibrated models for the same basin will differ based on the climate period selected.

Downloading stream flow data is straight forward as the data correspond to a single point. Conversely, precipitation and temperature are spatially distributed across the watersheds that drain to the gage locations. From the PRISM website, 1,080 monthly data files were extracted: 360 precipitation, 360 maximum temperature, and 360 minimum temperature files for 1971-2000. Each file contained data for the entire contiguous United States. ArcGIS™ was used to create watershed zones based on the contributing areas of the gages selected to be modeled. These zones were then used with ArcGIS™ to spatially average the precipitation and temperature over the watershed for each gage. As this procedure was required for each of the 1080 files, the process was automated by writing a Python script that could be used in ArcGIS to convert the PRISM file grids to rasters, clip the rasters to the watershed zones, and calculate average values across the watersheds. The ArcToolbox>Spatial Analyst Tools>Extraction>Sample tool was then used to extract a .dbf table of the attributes for each of the spatially averaged grids. Using Excel, the ArcGIS output files were arranged and consolidated by watershed. The average monthly temperature was calculated by averaging the maximum temperature and minimum temperature for every month. This method was validated by researchers at the University of Dayton, who studied 53,004 daily temperature records (www.engr.udayton.edu/weather/source.htm).

WATBAL was calibrated for each individual watershed using the historical data (monthly values for stream flow, spatially averaged precipitation, and spatially averaged temperature). The future climate change scenarios were applied to each watershed to obtain possible 30-year scenarios of monthly values for precipitation and temperature for each watershed. WATBAL was then used to estimate the corresponding monthly values of stream flow associated with each climate scenario for each watershed.

A HYDRO-ECONOMIC MODEL OF THE RIO GRANDE

Modeled runoff and streamflow, the principal outputs from the hydrologic model, are key drivers in estimating changes in water use and allocation, aquifer and reservoir storage, and changes in economic welfare. To estimate these changes, a river basin-scale hydro-economic model (RBHE) of the Rio Grande watershed is used, which simulates the management of water systems from watershed-wide perspective. The model optimizes the allocation, use, storage, and management of available water such that the greatest long-run economic benefits are achieved within the legal boundaries of river compacts and treaties, and with available resources, technologies, and infrastructure.

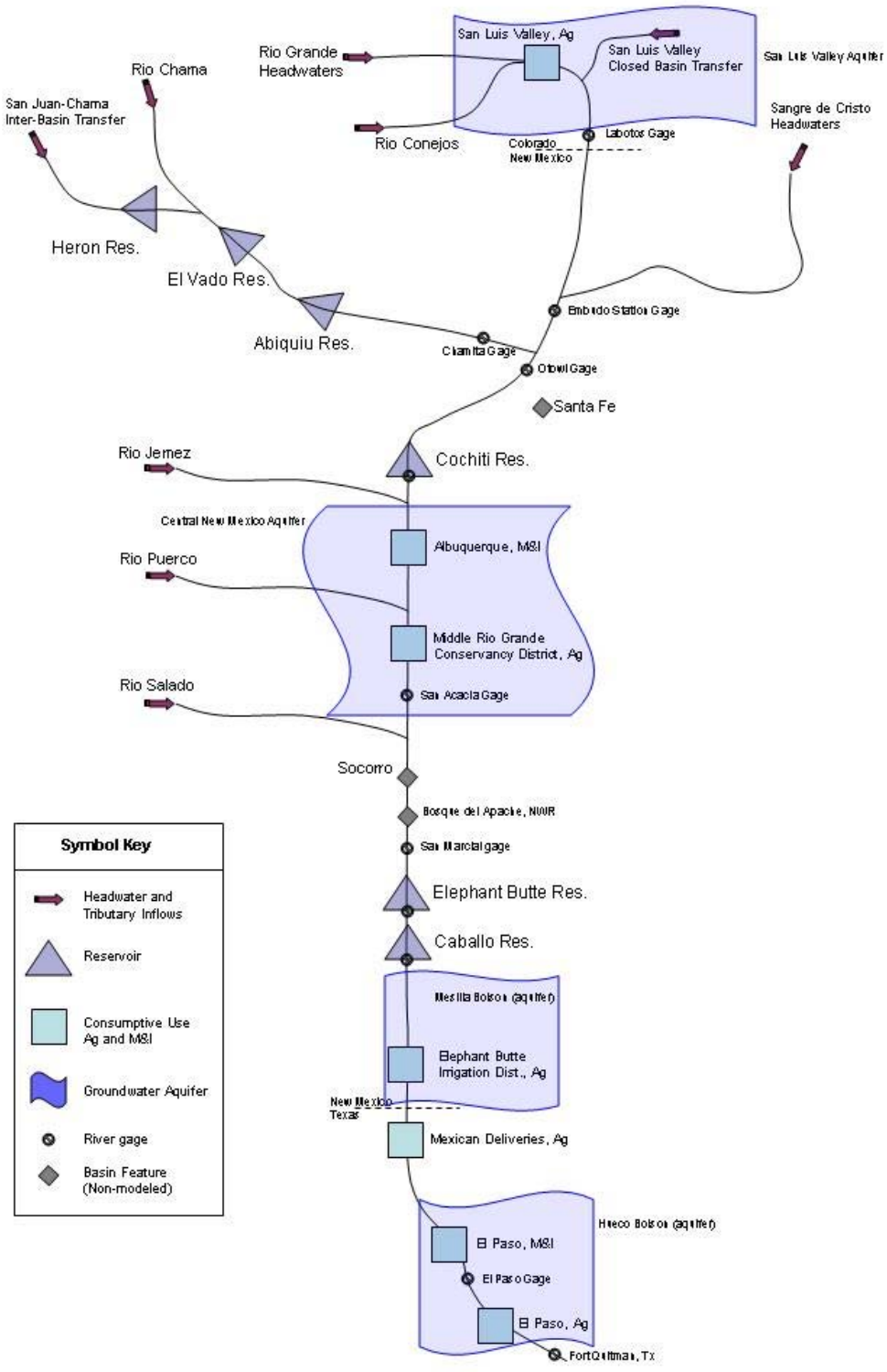

Figure 7. Schematic Diagram of the Rio Grande Hydro-Economic Model

One of the key aspects of the RBHE model is the explicit treatment of the underlying value of water, often represented as mathematical functions that relate the marginal economic value of water to the quantity of water use, i.e., 'water demand functions.' By specifying this relationship, the modeler is implicitly specifying the flexibility of the particular water user to changes in water prices. Economists often refer to this as the 'price elasticity of demand' – in other words how the quantity of water use changes in percentage terms to a percentage change in price. As climate change interacts with economic markets by affecting resource supplies and demands, ultimately resource prices are altered and signal to water users that a change in water use is indicated – providing that institutions and policies permit the direct and transparent relay of these implicit prices to water users. Adaptation to a water shortage, for example, occurs as some water users that are less tolerant of price increases begin to curtail their use.

Hydro-economic models have several advantages for long-term planning and assessment over alternative water budget and system simulation type models. First, by using an optimization framework RBHE models replicate an active decision environment that explicitly recognizes the opportunity costs and economic tradeoffs inherent in any given water allocation and storage decision. Second, simulation and water budget models use a "what if" perspective to assess the consequences that would follow from a given allocation decision; however, only an optimization framework can systematically sift through all the permutations of possible allocation decisions and identify those that are potentially 'best' and worthy of more closer scrutiny. This is a distinct advantage when examining and comparing the effects of large-scale, system-wide changes, especially if behavior within the system is dynamic and roughly follows the optimization objectives. Third, RBHE models provide explicit information regarding the value of water, how it is affected by water supply changes, how it varies both temporally and spatially, and how it is altered by physical limitations and institutional constraints. As a result, RBHE models excel in their capacity to identify strategies that can improve water-use efficiency, infrastructure designs, investment decisions, and institutional arrangements.

Vaux and Howitt (1984) pioneered the development and use of RBHE models for regional water assessment in examining water transfer issues in California. Booker and Young (1991, 1994) extended the approach by more realistically capturing the extensive network characteristics of a watershed in their study of the Colorado River basin. More recently, climate change impacts have been assessed using the approach by Hurd et al. (1999, Hurd and Harrod 2001, 2004), and in California by Tanaka et al. (2006). And in the upper Rio Grande basin, Ward et al. (2001) developed an RBHE model and used it to examine the consequences of sustained drought, which was further extended by Ward et al. (2006) to assess the combined effects of drought and endangered species protection on the water economy of the Rio Grande. Descriptions of the conceptual foundations and use of RBHE can be found in Hurd (1999, 2004), Null and Lund (2006), JWRPM (2006), Draper et al. (2003), Jenkins et al., (2004), and in Cai et al. (2003).

This study builds on the Rio Grande hydro-economic (RGHE) model of Ward et al. (2001) by making several important modifications, the most important of which is the reduction in time-step from annual to monthly. By increasing the temporal resolution to monthly, the RGHE is better able to capture the effects of an expected shift in the streamflow hydrograph toward an earlier snowmelt and peak runoff as a result of climate change. This extension also improves the model's capability to simulate changes in seasonal water use patterns, instream flow requirements for endangered species, and recreational use patterns at reservoirs.

As with all hydro-economic models, the RGHE model is oriented towards economizing available water resources by identifying the most valued use and storage, conveyance, and water quality decisions possible within the existing physical, institutional and infrastructure limitations. In addition, two important behavioral assumptions are implicit in the modeling framework that can significantly affect the nature and interpretation of the results. First, competition between water users is assumed, and furthermore, these water users aim to maximize their expected net economic returns. This implies that water is freely transferable across uses with no restrictions or transaction costs, and subject only to the physical and institutional restraints of the system (i.e., logical mass-balance relationships must be satisfied between the flows of water from upstream to downstream locations and between adjacent time-periods in storage conditions). By ignoring the significant transactions costs of water transfers and, indeed, some of the underpinnings of the institution of prior appropriation in defining water

rights, the model understates the economic costs of adjustment and adaptation to changing water supplies. Another artifact of this assumption is that the optimization framework is not necessarily a 'good' predictor of current and actual patterns of water use. This limitation, however, does not detract from the insightful and useful results that focus less on the absolute level of economic output and instead focus on the magnitude of change – a measure that is likely to be more robust (Draper et al., 2003; Tanaka et al., 2006).

Second, the model design allows for 'perfect foresight' across the 30 year sequence of runoff and streamflow conditions. By assuming away future uncertainty in runoff and streamflow, adjustments and adaptations – in the form of storage and use decisions – are optimally executed without errors in the amount or timing of adjustment. As a result, this assumption contributes further to the model tendency to understate economic adjustment costs and hence the economic impacts of water supply changes under climate change.

A conceptual diagram of the model is given in Figure 7, which depicts key physical characteristics of the watershed, including tributaries, inflows from the hydrologic model outputs, return flows from users, diversion points, and reservoirs. The model is developed and executed using the General Algebraic Modeling System (GAMS, Brooke et al. 1988). In summary, the model consists of:

1. A nonlinear objective function that aggregates all the sources of economic value and cost in the watershed as a function of water use and reservoir storage, including the cost of pumped groundwater, the benefits associated with reservoir recreation, and the shifting water demands due to population and climate changes. Figures 8a and 8b illustrate the urban sector aggregate and household benefit functions, respectively. Figures 8c and 8d show examples of the aggregate and per acre functions for the agricultural sector. And Figure 8e shows net economic benefits for flatwater recreation on reservoirs as a function of storage level.
2. A system of linear constraints that characterize:
   - Spatial network and streamflow continuity of monthly runoff into the basin, main stem and tributary streamflow, surface water diversions, and sub-basin water transfers, i.e., where water enters the system, how it travels and is distributed, where it is used, and how it leaves the system.
   - Inter-temporal balances in reservoirs and aquifers between adjacent time periods (i.e., months), and mass-balances within each time period that balance additions and extractions, including storage releases and evaporation losses.[3]
   - Institutional limitations of compacts, treaties and intergovernmental agreements, for example, the Rio Grande Compact between Colorado, New Mexico and Texas; the 1906 Treaty with the Republic of Mexico requiring the annual delivery of 60 kaf/yr; and operational rules between the Elephant Butte Irrigation District (EBID) and the El Paso Water Conservancy District #1 (EPWCD#1). See Ward et al. (2001) for details.

Incorporating the Climate Change and Socio-Economic Baseline Scenarios into the Rio Grande Hydro-Economic Model (RGHE)

In modeling the climate change and socio-economic baseline scenarios previously described, several key changes in the model inputs and parameters are highlighted that coincide with changes in scenarios and, in the process, introduce the scenario terminology that is used subsequently to report the key results and findings.

A total of nine scenarios were run using the RGHE model. Three baseline scenarios were modeled without the effects of climate change but with the projected changes in population and its attendant shift in urban water demand, referred to as: 2000 Baseline, 2030 Baseline, and 2080 Baseline. In addition, six climate change scenarios were run, one for each of the combinations of the three representative climate change patterns and the two time periods, referred to as: 2030 Dry, 2030 Middle, 2030 Wet, 2080 Dry, 2080 Middle, and 2080 Wet. In presenting the results, the relative effect of each climate change scenario is compared against the appropriate baseline time period, for example, all 2030 climate scenarios are compared against the 2030 Baseline using the same population change assumptions.

Key changes in model inputs and parameters across the climate change and socio-economic baseline scenarios are summarized as follows:

Figure 8. Examples of Economic Benefit Functions in the RGHE Model

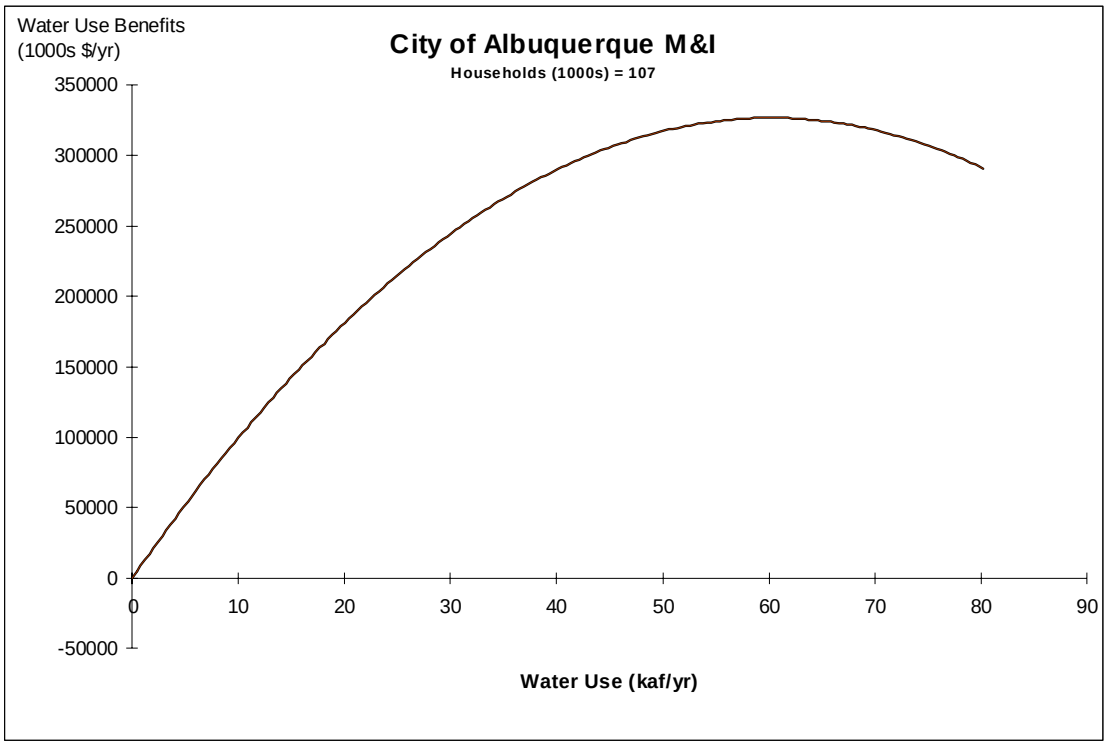

Figure 8a. Example of a Municipal and Industrial (M & I) Aggregate Benefit Function

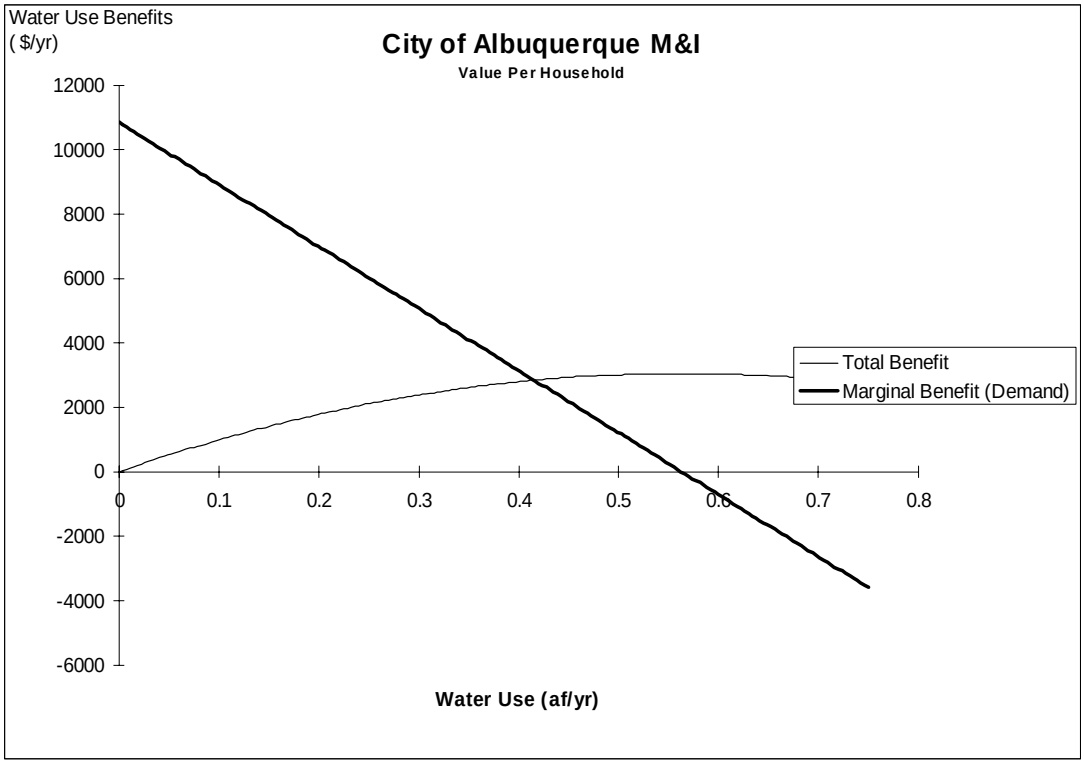

Figure 8b. Example of Annual Household Water Demand and Total Net Benefits

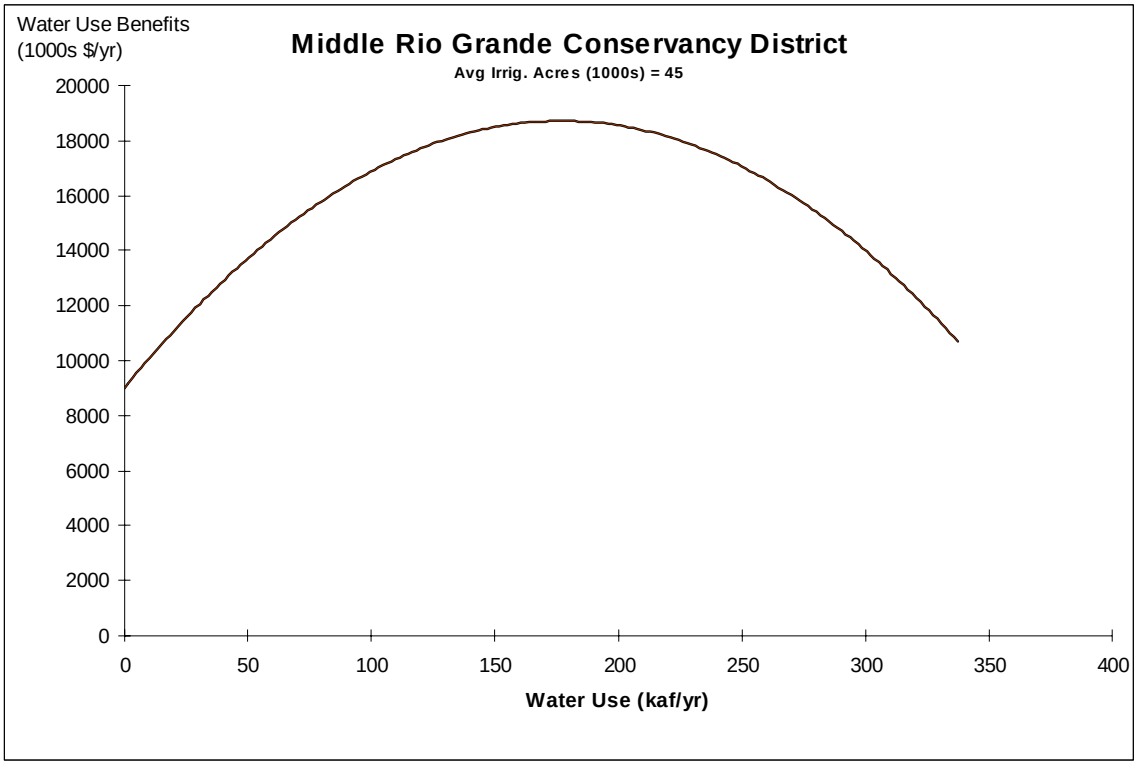

Figure 8c. Example of an Agricultural Aggregate Benefit Function

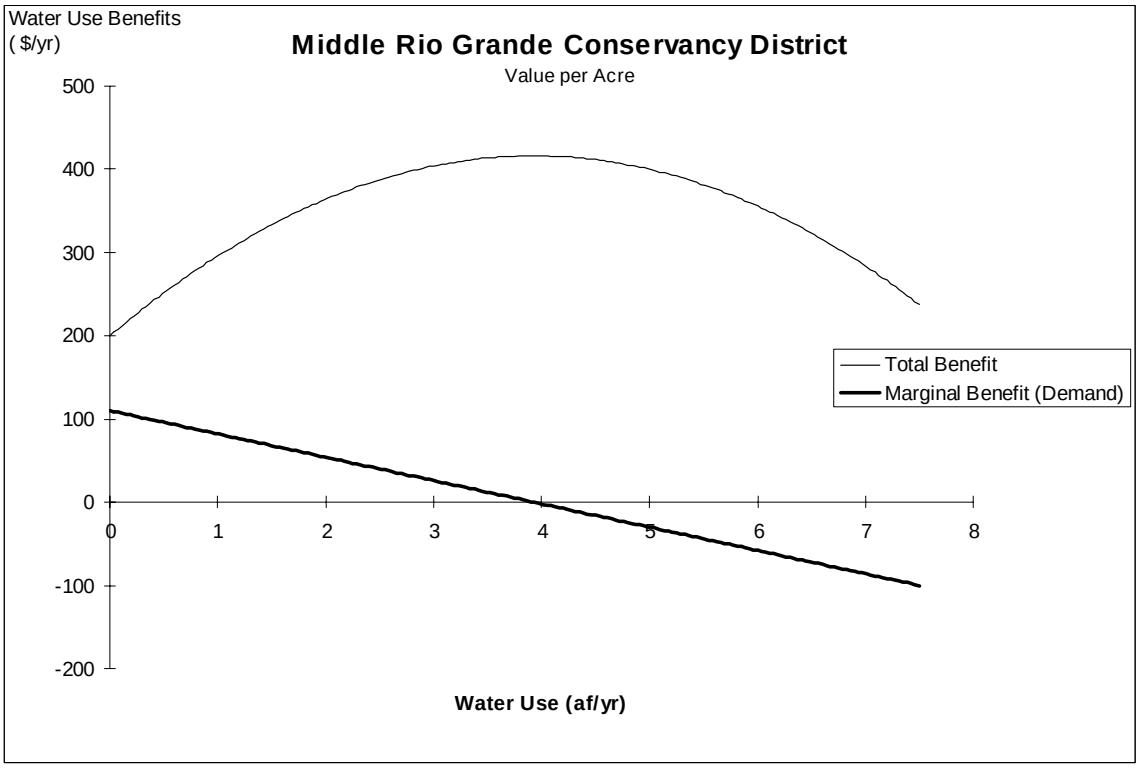

Figure 8d. Example of Annual Agricultural Water Demand and Total Net Benefits per Acre

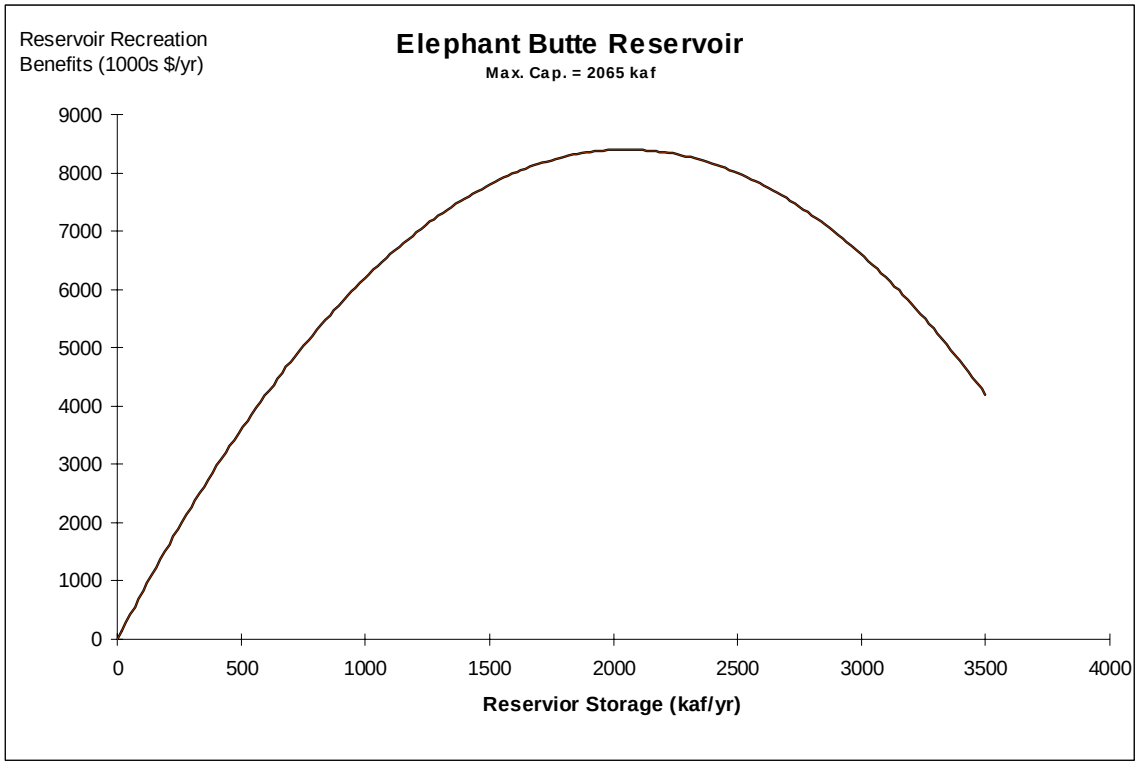

Figure 8e. Example of Total Benefits from Reservoir Flat-Water Recreation

1. **Streamflow and runoff input is altered.** Using the output from the hydrologic simulations, the 30 year sequence of monthly runoff for each inflow point is modified according to the selected climate change scenario.[4]
2. **Reservoir evaporation rates are changed.** Using estimated changes in potential evapotranspiration rates from simulating the energy-balance changes in the WATBAL hydrologic model, adjustments are made to the monthly water losses for each reservoir in the upper, middle, and lower watershed, respectively, for under each climate change scenario, as shown in Figures 9a through 9f.
3. **Agricultural consumptive water use is shifted.** Reflecting the increased irrigation requirements associated with higher temperatures, consumptive agricultural water demands are raised consistent with agronomic needs but without implying an increase in net economic benefits.[5] The assessment implicitly assumes changes in the mix of crops grown – consistent with current crop technologies. There are many changes in New Mexico agriculture that are plausible over the next 50 years, including changes in genetic technologies and crop yields, incidence of pests and diseases, and loss of arable land due to urban development. Each of these changes could alter the agricultural demand and value of water, however, owing to the speculative nature of these changes they are not included in the present analysis.
4. **Urban water demands shift in response to population changes.** Population change is accounted for in each scenario that is run in a future time period, either for the 2030's or 2080's. These changes result in an increase in aggregate household water demand and, hence, in the estimated value of economic services generated. Although landscape irrigation requirements for non-native grasses would be expected to rise similar with agricultural demands, these increases would be expected to be offset by improvements in household water-use efficiency and in continued trends of reduced turf landscapes.[6] Therefore, in the present analysis, household water demand is assumed to be invariant to climate changes. It should be noted that there are many issues related to urban water use

Figure 9. Relative Change in Regional Monthly Reservoir Evaporation across the Six Climate Change Scenarios

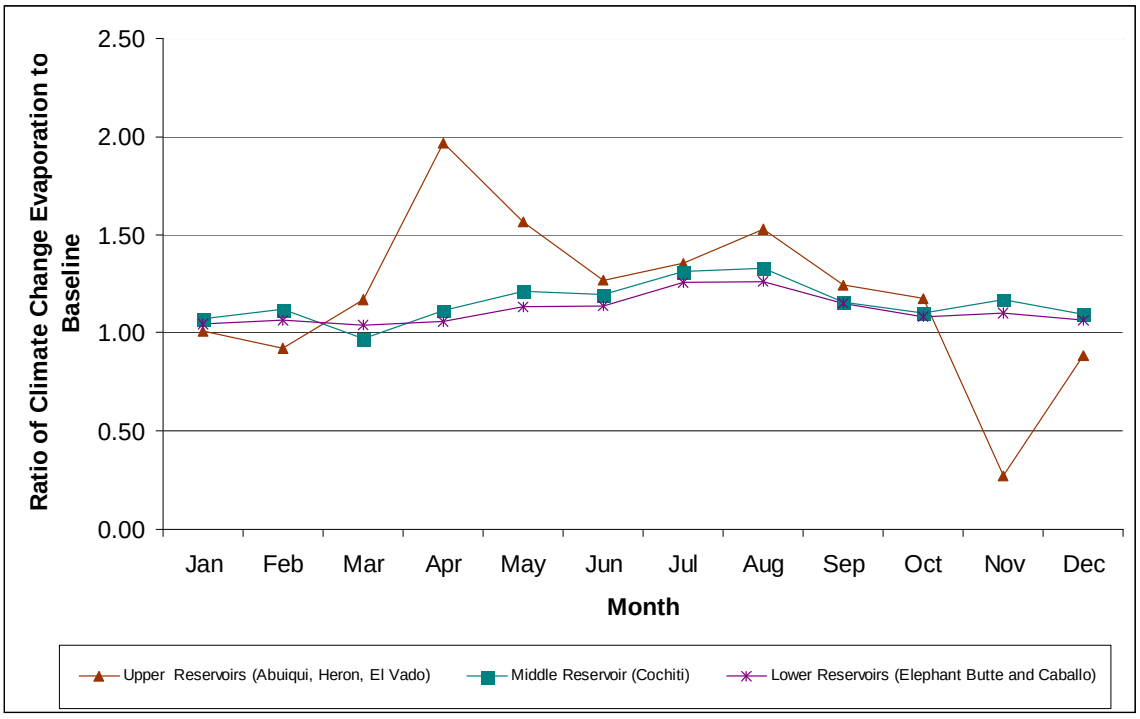

Figure 9a. 2030 Dry

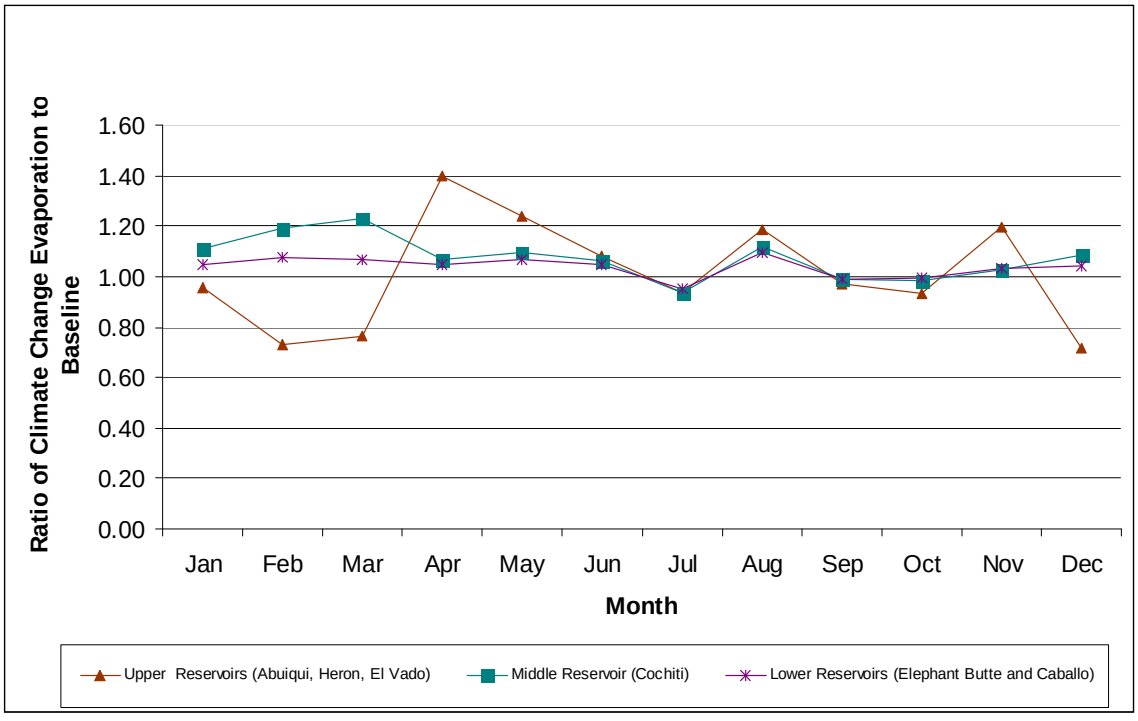

Figure 9b. 2030 Middle

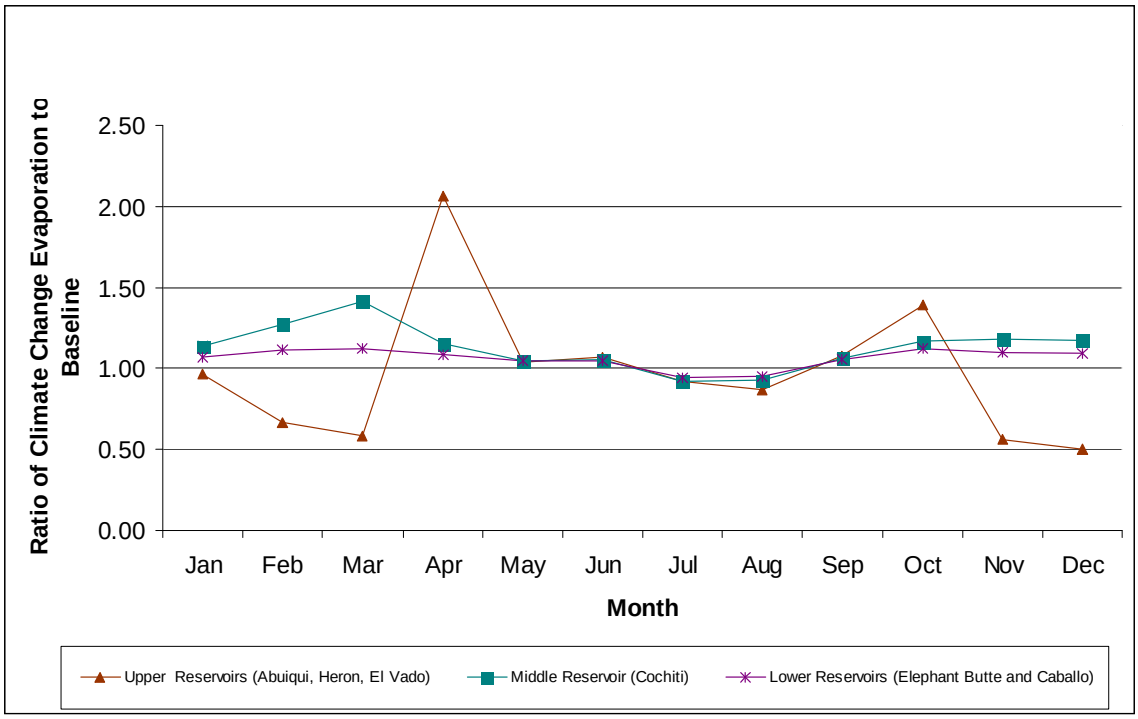

Figure 9c. 2030 Wet

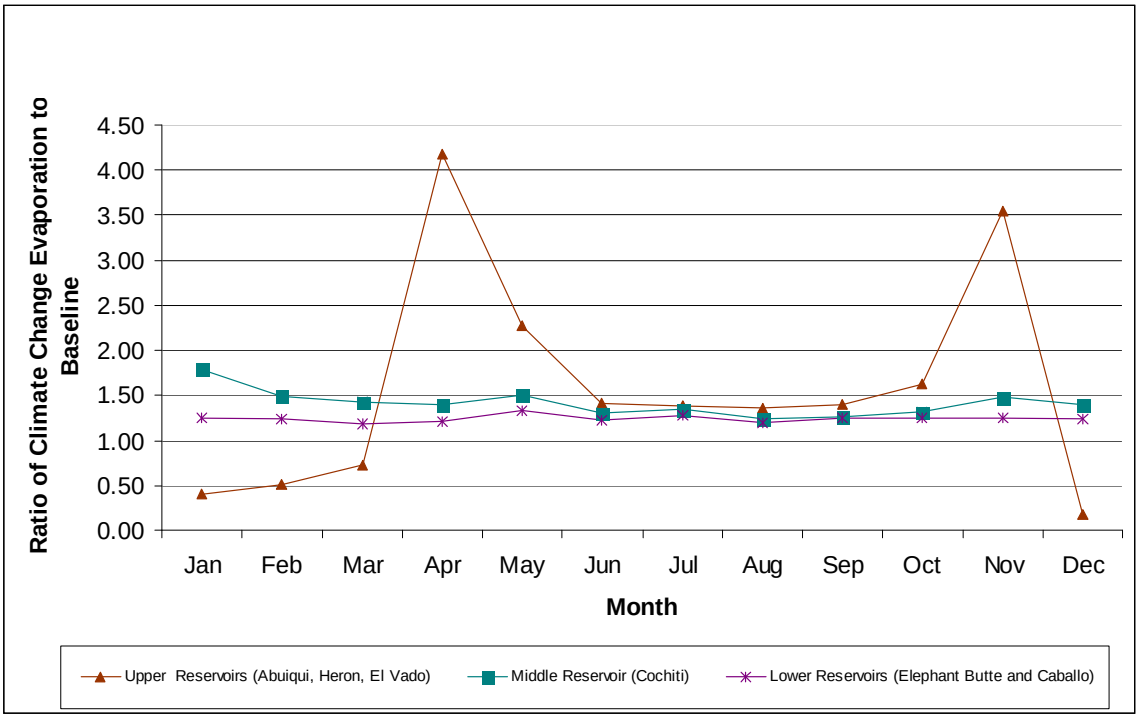

Figure 9d. 2080 Dry

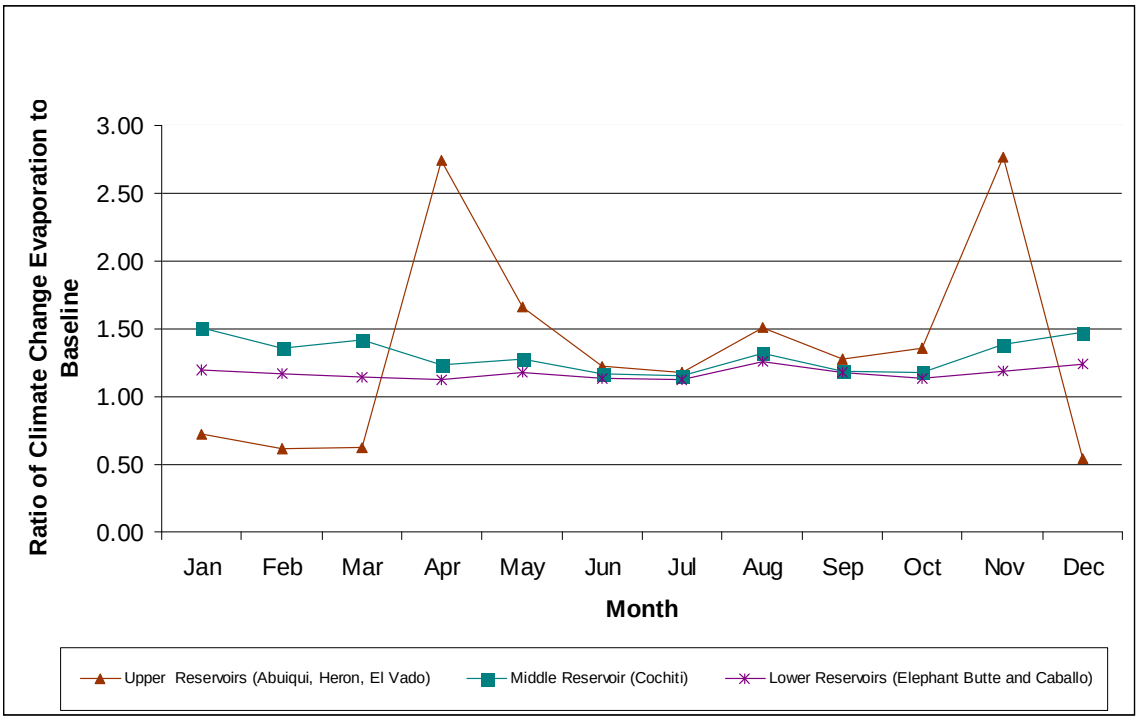

Figure 9e. 2080 Middle

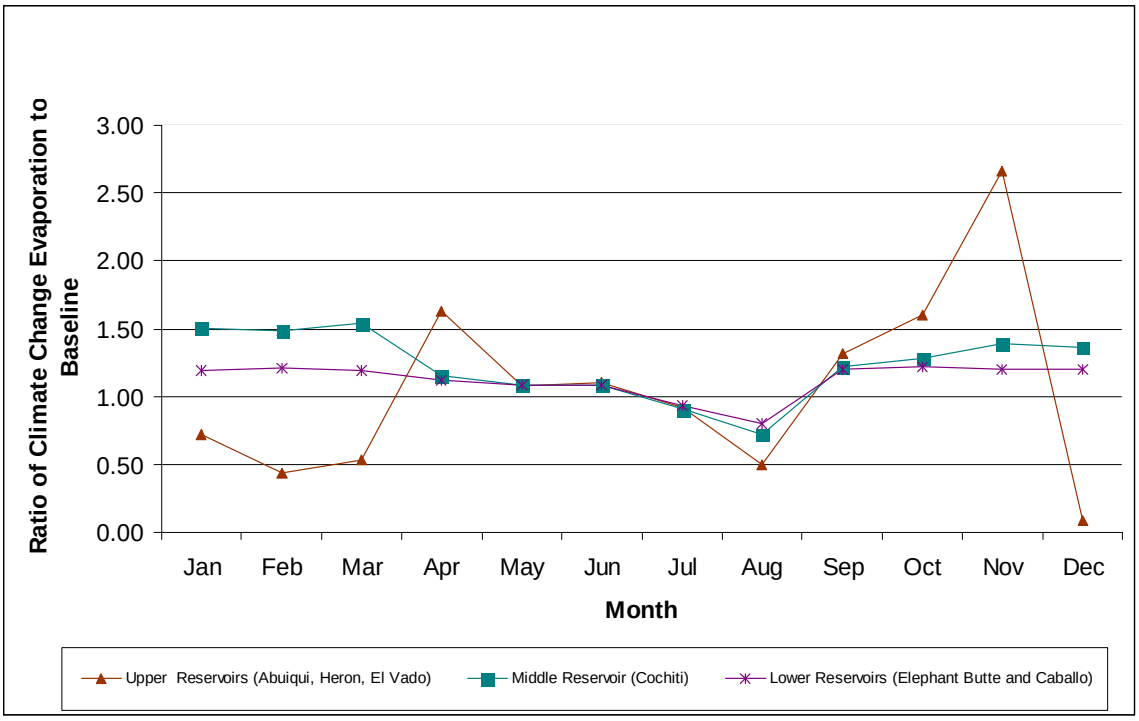

Figure 9f. 2080 Wet

that can be expected to affect urban water demands and values over the coming 50 years, such as water re-use and recycling, availability of alternative water supplies from, for example, desalination of extensive brackish aquifer resources. These changes, which would be increasingly used as water prices rise, are included in the present assessment, and would, if included most likely reduce some of the net economic impacts.

Endangered Species Concerns

The Rio Grande, especially the Middle region between Cochiti and Elephant Butte Reservoirs, is the last remaining habitat for the endangered Silvery Minnow. As a result, the U.S. Fish and Wildlife Service (USFWS) has determined that a minimum instream flow of 50 cfs is necessary at the San Acacia gauge for species protection. Aggregating this flow level into a monthly estimate and using a 100% safety factor to account for daily variability results in a streamflow minimum of 6 kaf/month. This constraint is maintained in the analysis all model runs.

ASSESSMENT RESULTS AND FINDINGS

WATBAL and the RGHE model were run to simulate and optimize the management of a 30-year sequence of monthly streamflows for each of three baseline scenarios (Base 2000, Base 2030, and Base 2080) and for each of the six climate change scenarios (2030 Dry, 2030 Mid, 2030 Wet, 2080 Dry, 2080 Mid, and 2080 Wet). Model results are presented and described in the first two sections below. This is followed by a section summarizing the possible effects of model assumptions, uncertainties, and notable omissions all of which caution against the unqualified use of the estimated impacts from the models alone.

Streamflow and Hydrologic Assessment

Consistent with the RGHE model schematic shown in Figure 7, WATBAL modeled streamflows for each of seven tributary inflows within the Rio Grande watershed (in addition, two inter-basin transfer inflows are also included but are not assumed to vary as described earlier in endnote 6). The most important tributary inflow to the Rio Grande is the mainstem headwaters coming from the San Juan Mountains of southern Colorado and passing the river gage at Del Norte, accounting for more than 35% of annual streamflow. The relative contribution of each of the seven modeled tributaries is shown in Figure 10, which also highlights the peak streamflow months of May and June under current climate. Most of the flow in the Rio Grande is the result of snowmelt in the higher elevations during late spring. Flow from the Rio Puerco and Rio Salado are mostly driven by July and August monsoons. These rivers are perennial and quite erratic in nature. A monthly time step cannot adequately represent perennial streams as flow is event driven, yet monthly time does account for the time periods when the Puerco and Salado have been responsible for consistent increased Rio Grande flows.

To see how climate change might affect the streamflow hydrograph, average monthly streamflows for each tributary were aggregated and plotted for each scenario as shown in Figure 11. Two results show clearly in this figure. First, peak flow and total streamflow declines for all of the climate change scenarios, whether or not they are relatively 'wet'. The apparent robustness of this result could have important implications for the management of water resources in the region. Although, there is a potential for summer monsoonal activity to increase, as suggested by the 2080 Wet scenario, this is not likely, according to the model results, to offset the losses from diminished snowpack levels in the headwater regions. Second, there is a pronounced shift in later periods (i.e., 2080s time frame) in the peak runoff month by about 30 days. In all of the 2080 period runs, the peak occurs in April and, perhaps, equally as important, there is a significant increase in late winter runoff compared to current conditions.

To further illustrate potential changes in the relative likelihood of basin streamflow, Figure 12 presents the total runoff data for each scenario in the form of a cumulative probability function. This figure shows, for example, the substantial change in the distribution of runoff between present and changed climates. The severe dryness of the 2080 Dry scenario is apparent in the figure where median runoff drops by nearly 1/3, from approximately 1.6 maf/yr to less than 1.1 maf/yr.[7]

With the hydrograph shift indicating lower runoff totals and a shift toward a greater share of runoff occurring earlier, i.e., reflecting both an earlier snowmelt and lower snowfall totals, water availability during peak use periods is likely to be significantly more dependent on stored water management in reservoirs and aquifers than at present. Further implications of these possible

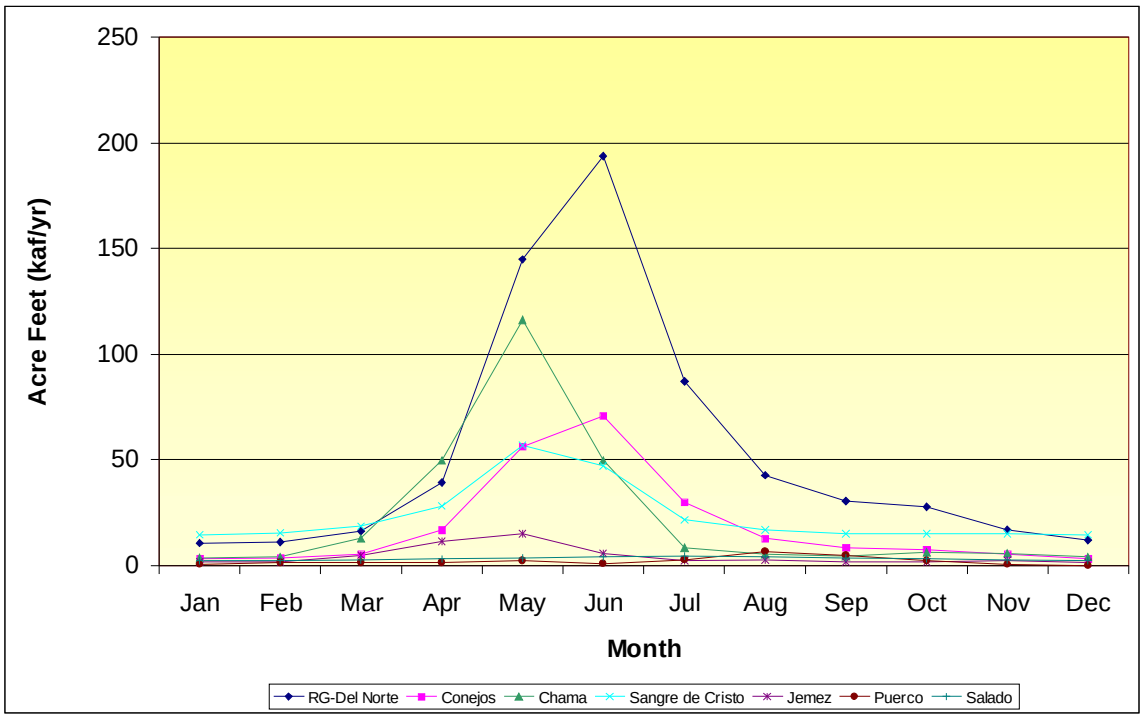

Figure 10. Average Monthly Streamflow for the Upper Rio Grande Basin Tributaries under Baseline Conditions (historical period: 1971-2000)

changes in water availability are found in the results of the RGHE model below.

Assessment of Water Use and Economic Impacts

As illustrated by the changes in both the amount and timing of annual snowmelt and runoff, there is a significant potential for climate change to disrupt the current allocation and management of New Mexico's water resources. How these changes might affect current and future water users is the primary focus of the hydro-economic model, and its capacity to highlight adaptive changes in allocation and storage – within the existing infrastructure and technology – to minimize disruption and economic losses to the region as a whole. The assessment results are presented in two sections. First modeled changes in consumptive use are described, highlighting shifts in allocation between agriculture and urban use by scenario. The second section presents the estimated economic effects of these changes in allocations and patterns of use by scenario.

Changes in Water Use and Allocation

As might be expected for water use in a basin that exhausts even the present water supply in normal years, any reduction in long-run, average supply necessarily leads to a reduction in long-run average use. Figure 13 shows the modeled changes in aggregate water use across the scenarios. Heavily influenced by the pattern of agricultural irrigation that peaks in June, the figure shows how total water use is curtailed as total supplies diminish with the severity of climate change. The dry scenarios lead to declines in total water use of nearly 10% and over 25% for the respective periods of 2030 and 2080. Declines of 2% and 18% accompany the middle scenarios, respectively; and for the wet scenarios water use declines of nearly 4% and 6.3% are projected, respectively. Note that the 'middle' scenario is wetter than the 'wet' scenario in the earlier 2030 time period, thus explaining the estimated higher loss of 4% for the wet scenario compared with the middle scenario.

As stated earlier, hydro-economic models are very adaptively efficient – they anticipate water supply changes perfectly and execute allocative changes with perfect timing and efficiency. As a result, the modeled changes in water use by sector will strongly reflect differences in the relative economic value of water in each sector. These differences are most strongly evidenced in Figure 14, which shows the modeled changes in streamflow, agricultural sector, and urban sector allocated use, by climate change scenario. For all but the two most severe scenarios, reductions in modeled water allocation and use are less than

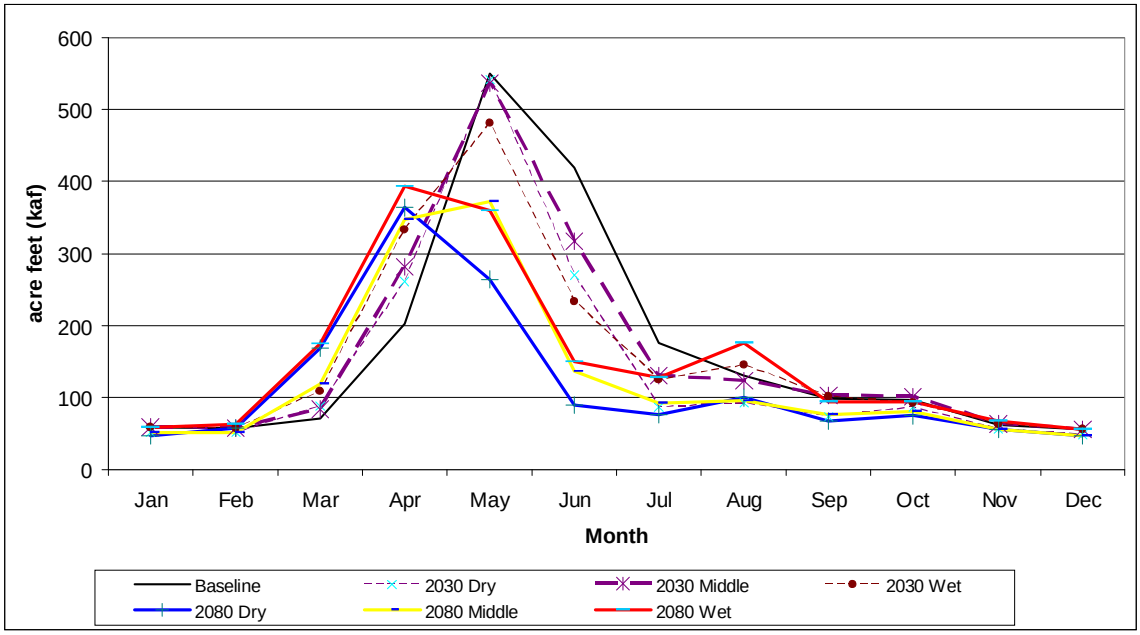

Figure 11. Average Aggregate Streamflow by Month for Each Climate Change Scenario

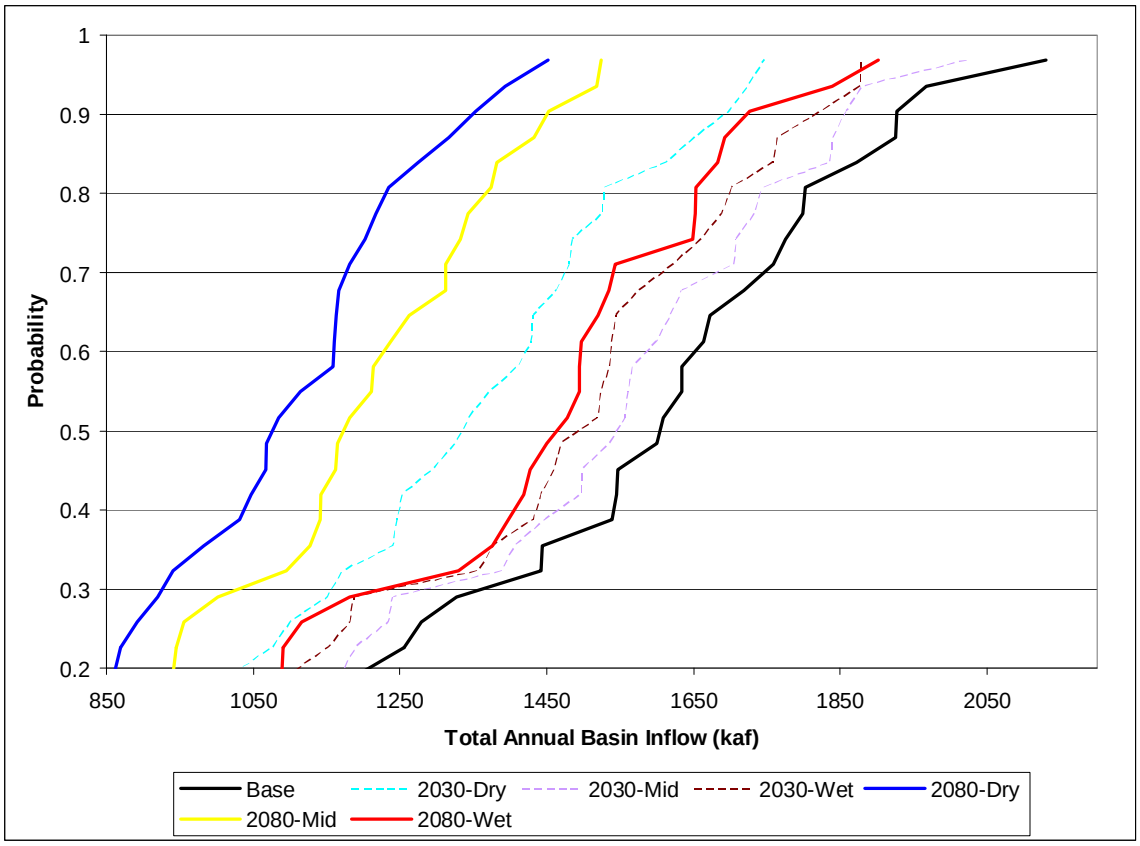

Figure 12. Cumulative Distributions of Total Basin Streamflow across the Climate Change Scenarios

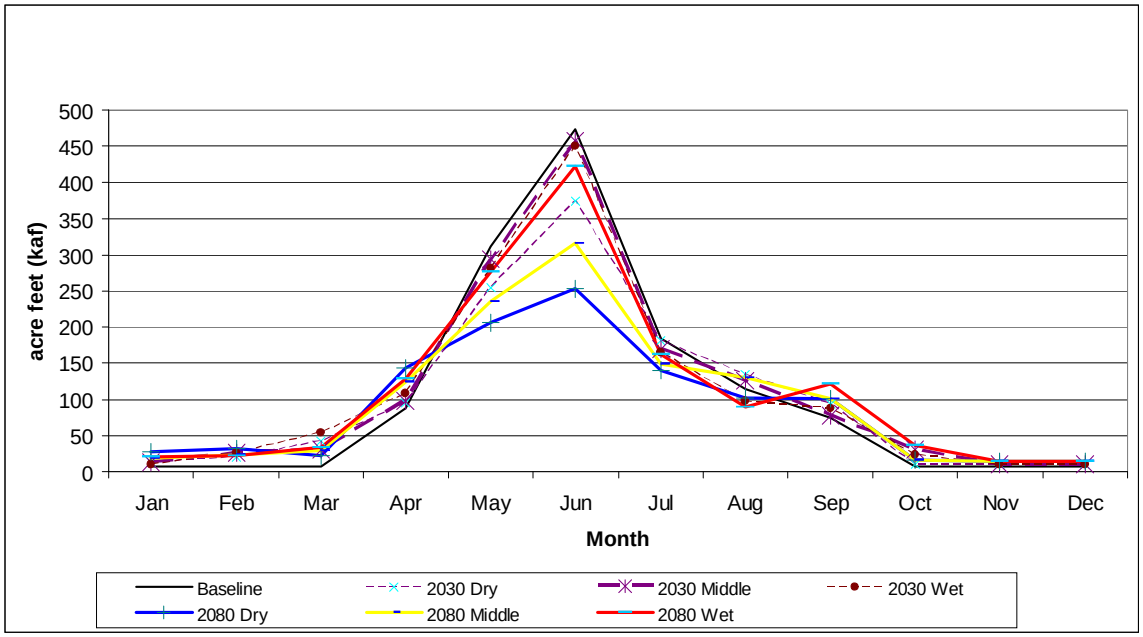

Figure 13. Average Monthly Aggregate Water Use for Each Climate Chnage Scenario

reductions in streamflow. For example, in the 2030 dry scenario, streamflow falls by nearly 14%, which leads to a drop in agricultural use of 12% and 0.3% in urban water use, respectively. Each of the wetter scenarios – i.e., 2030 middle, 2030 wet, and 2080 wet – result in virtually no allocated reductions to the urban sectors, with agriculture absorbing the reduction in runoff nearly entirely. Each of the two drier scenarios – i.e., 2080 middle and 2080 dry – show quite significant reductions in agriculture and to some degree in urban water use.

As expected, these results illustrate the relatively high modeled demand for urban water as compared to agricultural water, as evidenced by the example demand curves shown by Figures 8b and 8d, respectively, and the high share of agricultural water use in the Rio Grande basin, approximately 87.5% in the modeled baseline year of 2000.

Reductions in modeled runoff and water supply are *not* equally shared across water users. Rather, by considering the relative economic contribution, reductions are allocated to minimize long-run, expected losses to total regional economic production. In other words, the optimization framework used here enables the system to avert potentially much greater economic losses that would follow if water use reductions were necessary in other non-agricultural economic sectors.

Estimated Changes in the Marginal Value of Water

From an economic perspective, a rising price is the clearest signal of increasing relative scarcity. Water resources in New Mexico are increasingly scarce as a result of two processes, increasing demands from growing populations and, potentially, falling water supplies given the estimated effects of climate change. Both effects are evidenced in Table 1, which shows the change in the marginal value (i.e., modeled price) of water at two points in the watershed, the Rio Grande headwaters in Del Norte, Colorado and the Sangre de Cristo headwaters in Northern New Mexico. The estimated values for Colorado are much higher than for New Mexico as a result of the Rio Grande Compact and the relatively high value of agricultural production in the San Luis Valley. For New Mexico, the Sangre de Cristo values are much more representative of the marginal value of water, which is primarily measured by the marginal value for agricultural uses.

The pronounced effect of population increases on the marginal value of water in New Mexico is clearly shown in Table 1. For example, as population alone grows by 45.7% and 75.7% for 2030 and 2080, respectively, the implicit price of raw, untreated, and undelivered water is seen to rise by 47% and 81%, respectively. This shows, in effect, the necessary price rise for bidding water away from agriculture and into municipal service.

Climate change introduces water supply changes – in these cases, reductions – that exacerbate relative scarcity and result in even larger price increases in order to induce water transfers from agriculture to urban water users. Table 1 shows the effects on

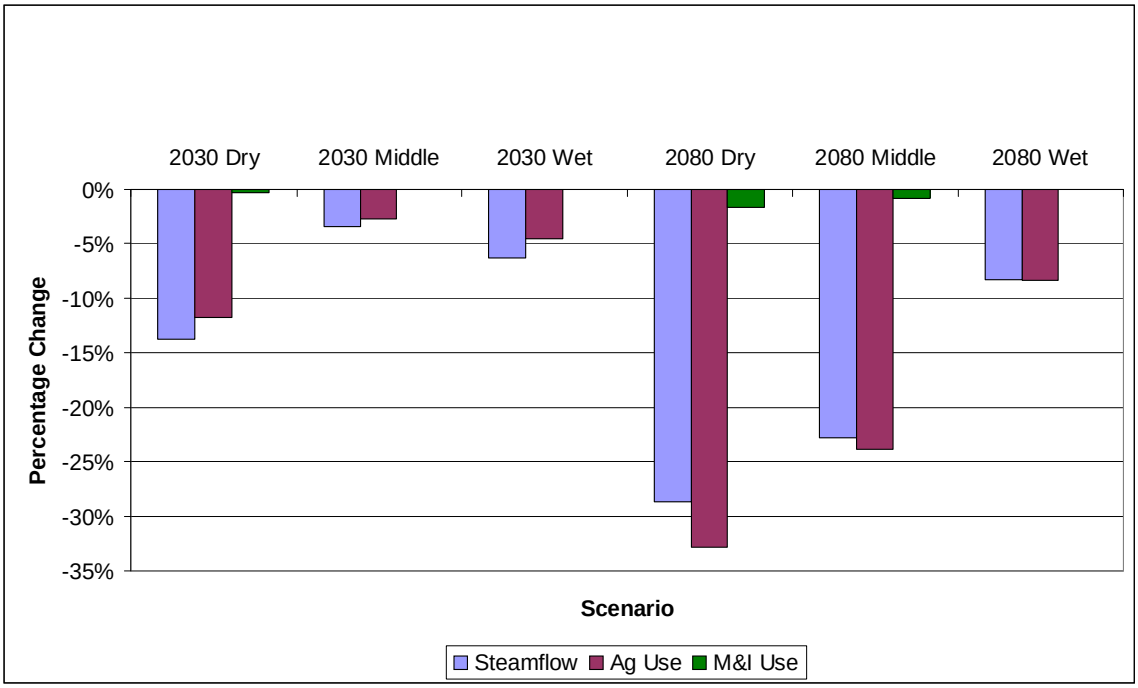

Figure 14. Streamflow and Water Use Changes by Sector and Scenario

marginal values (or implicit model prices – not necessarily observed 'market prices') across the climate change scenarios relative to the appropriate baseline scenario.[8] For example, projecting climate change into the decade of the 2030s, results in estimated price changes ranging from 15% to 60%, with the marginal value of raw water rising from an estimated $25/af to between $30/af and $40/af. Projections to the decade of the 2080's finds still greater potential scarcity with price increases ranging from 11% under 'wet' conditions to nearly 200% under 'dry.'

Direct Changes in Economic Productivity

Water is important to the economy of New Mexico by providing drinking water to residents and supporting commercial, industrial, and recreational activities. In 2006, the total gross domestic product of New Mexico was estimated at $76 billion (NMBBER, 2006), roughly one-half of one percent of the $13,000 billion GDP of the United States in 2006. The largest contributors to New Mexico's economy include government (18.4%), manufacturing (13.8%), retail and wholesale trade (11.2%), real estate (10.6%), mining (8.2%), and forestry and agriculture (1.7%). Within the agricultural sector, crop production accounts for approximately 20% of total cash receipts while dairy and livestock production accounting for nearly 40% each (NMDA, 2005).

In considering the economic impacts of population and water supply changes on New Mexico's economy, it is useful to address both direct and indirect (or secondary) changes. Direct effects result from changes in economic output as a result of changes in operating conditions, for example, diminished water supply. Indirect effects reflect the consequences for related economic activities and services, and are described in greater detail in the next section.

Modeling the baseline water use and economy for the year 2000, RGHE generates $387 million in direct agricultural sector benefits (which includes some agriculture outside of New Mexico but within the Rio Grande watershed, including agriculture in Colorado's San Luis Valley, and agriculture in far West Texas). Even including agricultural income generated in Colorado and Texas, this amounts to less than 0.8% of New Mexico's GDP, a slim slice of the economy that uses more than 87% of the water.

Consistent with the expectations of the model, continued population growth must necessarily compete with existing water users for available supplies. With the estimated increases in population for 2030, and 2080, the future baseline scenarios show decreases in agricultural water use and economic production of 1.3% and 2.5%, respectively. Agriculture is and will be in the future the overwhelming source for this continued population and economic growth.

With climatic change and the expected decrease in available runoff shown above across all the scenarios – even the relatively 'wet' ones – the competition for water will be exacerbated and the pressure to increase water transfers from agriculture further heightened. Figure 15 shows, in percentage terms, and Table 2 in estimated direct economic losses (in 2000$), the relative distribution of economic impacts among agriculture, municipal, and recreational users across the climate change scenarios.

Under the most extreme scenario (2080 Dry), for example, average agricultural water use declines by 33% and results in an average economic reduction of $82.6 million (22%) compared to the population adjusted 2080 baseline run; whereas, water use in the urban sector falls less than 2%, with estimated economic losses of $12 million (0.6%) from a baseline value of $2.1 billion. Add to this estimated losses of $6.1 million for reservoir recreation, and total modeled economic losses under this severe scenario reach nearly $101 million (2000$) – approximately 4% of the estimated total $2.5 billion in water generated direct economic benefits.

Table 1. Estimated Value of Rio Grande Water by Climate Change Scenario

Climate Change Scenario	**% Change in Average Annual Runoff**	**Marginal Value of Water in Rio Grande Headwaters**[#] $ per acre foot (% difference from baseline)	
		Rio Grande Del Norte (Colorado)	**Sangre de Cristo** (New Mexico)
2000 Baseline		$66.82 (0%)	$17.23 (0%)
2030 Baseline	(0%)	$67.40 (0.9%)	$25.38 (47%)
2080 Baseline		$67.77 (1.4%)	$31.25 (81%)
2030 Dry	-13.7%	$101.43 (50%)	$40.66 (60%)
2030 Mid	-3.5%	$72.56 (8%)	$29.22 (15%)
2030 Wet	-6.3%	$73.76 (9%)	$30.78 (21%)
2080 Dry	-28.7%	$129.02 (90%)	$93.18 (198%)
2080 Mid	-22.8%	$106.78 (58%)	$63.37 (103%)
2080 Wet	-8.3%	$74.46 (10%)	$34.79 (11%)

[#]Estimates based on the Rio Grande Hydro-Economic model shadow values averaged for water for primary tributary inflows to the Rio Grande at Del Norte and from Sangre de Cristo headwaters. Differences in the estimated marginal value of water at these two locations in the watershed highlight the effects of the Rio Grande Compact requiring water deliveries to New Mexico and the relatively high marginal value of agriculture in the San Luis Valley of Colorado.

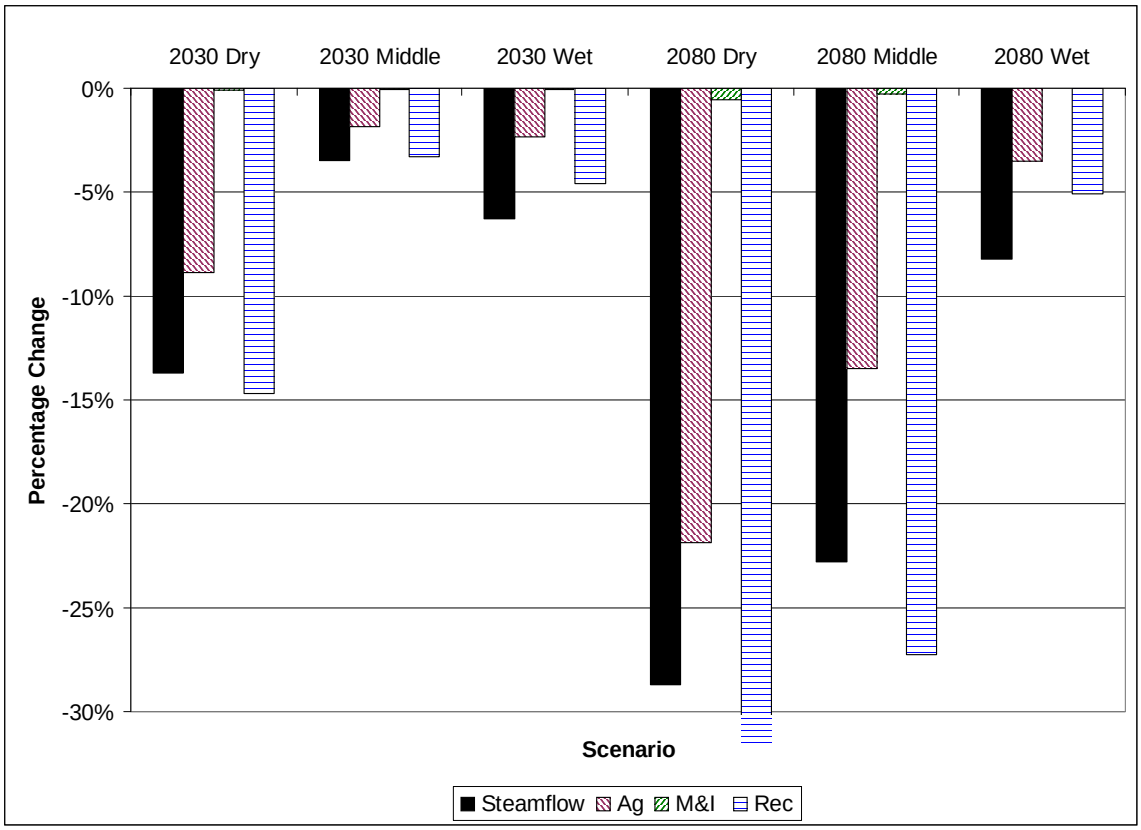

Figure 15. Streamflow and Economic Output Changes by Sector and Climate Change Scenario

Though direct economic losses to the agricultural sector are potentially substantial, there may be considerable economic consequences that follow from these potential changes in the character and composition of New Mexico's economy, and are the subject of indirect and secondary effects.

Indirect and Secondary Economic Effects

Indirect and secondary impacts take the form, for example, of 'losses' in income or employment in agricultural-related industries and locations, and of 'gains' in industries and locations to where water is transferred. For example, water that leaves agriculture and reduces irrigated acreage not only reduces farm incomes (i.e., the direct effect) but also reduces the demand for supporting economic services, including upstream activities such as farm machinery and repair, seed and chemical inputs, and labor, and downstream activities such as farm product processing and manufacturing. This can generate significant economic hardship and dislocation.

Although many economists consider an indirect (or secondary) economic effect to be the result of economic restructuring that merely shifts or transfers economic activities – i.e., changes in the types or location of jobs with no measurable effect on overall economic performance and, therefore, of no net economic consequence – rather, there are many reasons why these effects should not be readily dismissed. First, though population changes may propel water transfers to urban areas with perhaps a shift in potential employment opportunities from the farm to the city, climate change induced water transfers are fundamentally concerned with an absolute reduction in water supply, not simply relocating an economic activity. Second, as Howe (1997) points out in describing inter-basin water transfers, there are likely to be severe and lasting economic repercussions in the regions where water is leaving. People are not so easily uprooted and retrained. It is likely to require substantial transition costs to provide the needed 'safety net' of support to rural economies that must adapt to reductions or loss of agriculture. Many rural communities in New Mexico include disadvantaged native and Hispanic communities that are likely to suffer disproportionately in attempting to adjust to the loss of income and a lack of viable alternatives for economic development and employment.

Such indirect effects are difficult to measure and to account for accurately. Most often, these effects are estimated as economic multipliers to the estimated direct effects. Hall and Skaggs (2003), for example, estimate an economic output multiplier of 1.61 for vegetable production in Southern New Mexico. In other words, for each $1 of vegetables produced, an additional $0.61 is contributed to the economy by upstream and downstream economic activities. Lillywhite et al. (2007a, 2007b) estimate multipliers for other agricultural industries ranging from 1.55 to 1.8. Allowing for a bit wider range in economic impacts and dislocation e.g., a range in multiplier effects from 1.5 to 3, Table 3 shows estimated direct, indirect, and total economic effects of climate change on New Mexico's water resources. These impacts range from a loss of $15 million to $114 million in the 2030's to as much as $302 million in the 2080's under the relatively severe, 2080 'Dry' scenario.

Assumptions, Uncertainties, Omissions and Other Potential Biases

The presentation of the estimated potential economic consequences from climate change closes with a discussion and concern for the unaccounted for effects that flow from model assumptions, uncertainties, and omissions. Here, are highlighted – at least qualitatively – the nature of some significant additional concerns that condition the quantitative assessment. The following may not exhaust all the potential concerns but, highlight key areas and limitations.

The costs of water transfers, respect for 'property rights,' and the potential costs of conflict are not represented well at all. This is perhaps the most contentious and undervalued of all the 'omissions' in the assessment. The modeling framework assumes neatly organized and efficiently functioning water markets in which buyers and sellers behave rationally and cooperatively with perfect information, foresight, and knowledge. In actuality, the potential for significant

Table 2. Estimated Changes in Direct Economic Output by Sector and by Climate Change Scenario

Climate Change Scenario	**% Change in Average Annual Runoff**	**Economic Sector** millions of 2000$ (% of sector total)			
		Agriculture	**Municipal/ Industrial**	**Reservoir Recreation**	**Total***
2030 Dry	-13.7%	-33.8 (-8.9%)	-1.3 (-0.1%)	-3.0 (-14.7%)	-38.1 (-2.0%)
2030 Mid	-3.5%	-7.1 (-1.9%)	-0.6 (-0.04%)	-0.7 (-3.3%)	-8.4 (-0.4%)
2030 Wet	-6.3%	-8.8 (-2.3%)	-0.6 (-0.04%)	-0.9 (-4.6%)	-10.3 (-0.5%)
2080 Dry	-28.7%	-82.6 (-21.9%)	-12.0 (-0.6%)	-6.1 (-31.7%)	-100.7 (-4.0%)
2080 Mid	-22.8%	-50.9 (-13.5%)	-5.5 (-0.3%)	-5.3 (-27.3%)	-61.7 (-2.4%)
2080 Wet	-8.3%	-13.2 (-3.5%)	0.0 (0%)	-1.0 (-5.1%)	-14.2 (-0.6%)

*In 2006, New Mexico's total gross domestic product was estimated at $76 billion (NMBBER, 2006), and therefore, even estimated direct losses greater than $100 million are less than 1/2 of the 1% of the regional economic output.

Table 3. Impact of Climate Change on the Direct and Indirect Economic Output of New Mexico

Climate Change Scenario	**% Change in Average Annual Runoff**	**Direct and Indirect Economic Impacts** millions of 2000$		
		Direct Impacts	**Indirect Impacts[#]**	**Total Impacts[*]**
2030 Dry	-13.7%	-38.1	-19.1 to -76.2	-57.2 to -114.3
2030 Mid	-3.5%	-8.4	-4.2 to -16.8	-12.6 to -25.2
2030 Wet	-6.3%	-10.3	-5.2 to -20.6	-15.5 to -30.9
2080 Dry	-28.7%	-100.7	-50.4 to -201.4	-151.1 to -302.1
2080 Mid	-22.8%	-61.7	-30.9 to -123.4	-92.6 to -185.1
2080 Wet	-8.3%	-14.2	-7.1 to -28.4	-21.3 to -42.6

[#]Indirect economic impacts are estimated at 0.5 to 2.0 of the direct impacts. This is arrived at by subtracting the direct impacts from estimates of total output impacts using a range of total output impact multipliers from 1.5 to 3.0 based on available studies and incorporating a margin of safety. For example, Hall and Skaggs (2003) estimate a total output impact multiplier of 1.61 for vegetable production in Southern New Mexico, Lillywhite et al. (2007) estimate an impact multiplier of 1.55 for the New Mexico dairy industry and an estimate of 1.80 for the state's pecan industry (Lillywhite et al., 2007)

[*]In 2006, New Mexico's total gross domestic product was estimated at $76 billion (NMBBER, 2006), and therefore, even estimated total economic losses greater than $300 million are less than 1% of the regional economic output.

economic and legal conflict is not only real but likely unavoidable and very difficult to measure a priori. Absent a publicly and politically acceptable form of eminent domain and an accepted framework for 'compensable takings' there will likely be long, protracted litigation that will make water transfers from agriculture to municipal users anything but 'frictionless' as the model assumes. Consider, for example, the tens of millions of dollars spent to date in attempting to accommodate stakeholder concerns in a 'cooperative, consensus building exercise' to address the water problems of the San Francisco Bay-Delta in California. Without any promise of resolution – after more than twelve years of trying – the so-called 'Cal-Fed' process is, like most western water issues, more and more likely to resort to litigation. Unresolved water rights' issues flourish in the Rio Grande. Adjudication of water rights is long and contentious, and not likely to be clearly resolved in the foreseeable future. Add to this the 'prior and paramount' water rights reserved under the 'Winter's Doctrine' for the many tribes and pueblos of the Rio Grande region and there are legal knots within knots that will add to water transfer costs – perhaps by many multiples.

Agriculture provides many valuable but uncompensated – and often unrecognized – services that will also be lost as water is transferred. Farms scattered throughout the Rio Grande region create green, open spaces enjoyed for their scenic beauty and by flocks of birds and other wildlife that migrate and traverse the arid rangelands of New Mexico in search of food, water, and refuge. Farming and agriculture are natural-based activities that are consistent with core public values such as stewardship of the land and water. Pastoral activities and landscapes are valuable for their ability to stimulate imagination, calm anxiety, restore connections to nature, and remind people of their long-enduring connection to the land and to the food it provides. Withering the agricultural lands of the Rio Grande will have unmeasured costs as land fragments into other uses or reverts to desert rangeland.

Adequacy and reliability of expected inter-basin transfers is called into question by recent studies and

reports. For example, the 94,200 acre-feet of annual deliveries to the San Juan Chama system – accounting for 5% and 7.3% of native tributary inflow under current 'baseline' and '2080 Dry' scenarios, respectively – might be overly optimistic of available future flows (Christensen et al., 2004; NRC, 2007). After investing $275 million directly for its construction and making it a principal source of municipal water supply, the city of Albuquerque is, for example, particularly vulnerable to a reduction in this diversion. Replacing reductions in San Juan Chama water will exacerbate the conflicts and costs with agricultural users and potentially with nearby pueblos and tribes.

The effects of increased flooding are not addressed and could be a very important and damaging feature of climate change. As the 'wet' scenarios show and as indicated by both other climate change research and even recent experience, there is a measurable likelihood that summer precipitation associated with monsoonal flow and thunderstorm activity could increase across the Southwest and in the Rio Grande basin, in particular.[9] The year 2006, for example, was the worst year in recent history for flooding and flood damages in the Southern Rio Grande of New Mexico and the El Paso, Texas region. The Rio Grande not only left its banks but breached the levee in some areas causing millions in flood damages in El Paso and near Hatch, New Mexico. Recent assessments by the Federal Emergency Management Agency (FEMA) indicate that aging levee and flood control infrastructure is degrading in the region and provides much less flood protection than previously indicated by 100 year flood-plain maps. With increasing numbers of both people and economic assets at risk, climatic changes that increase the frequency and intensity of summer monsoonal storms in the Southwest are surely to exacerbate the severity and frequency of flood damages in the region.

Maintaining water quality is likely to be more difficult under climate change. Reduced streamflow lowers assimilative capacity for both point and non-point pollutants. In non-attainment reaches of the river lower TMDLs (total maximum daily load) might be expected and could raise control costs. Climate change might also lead some river reaches to fall out of attainment and require TMDLs and higher pollution control costs. Salinity is of particular concern in Southern New Mexico. Salinity concentrations continually rise as the Rio Grande journeys south, picking up loadings not only from urban wastewater and agricultural return flows but from upwelling of salt concentrated spring waters. With lower streamflow and runoff to dilute salinity concentrations could be expected to rise. Currently, salinity is damaging only in the extreme southern part of the watershed, particularly near El Paso where concentrations in excess of 2000 ppm are common. But without sufficient irrigation water to leach and resist the buildup of salts, salinity problems could become more common and severe for New Mexico water users in the future. For example, each acre of irrigated farmland in Southern New Mexico can expect to receive 2-3 tons of salt each year from surface irrigation water (presently containing concentrations between 500 ppm and 800 ppm). If salinity concentrations rise as a result of reduced flows, additional irrigation water for salt leaching would be needed to maintain agriculturally productive soils.

Climate change will affect New Mexico in significant ways beyond dewatering rivers and streams. Increased drying of soils and significant reductions in soil moisture are likely with climate change as potential evapotranspiration rises with increasing temperatures (Wang, 2005).[10] These effects will compound the adverse effects of changes in the hydrology of runoff and water availability throughout New Mexico. Such changes will affect the quality and condition of New Mexico's significant range- and forest-lands, which is likely to accelerate the severity and extent of forest fires but will likely diminish forage production on rangelands that will adversely impact livestock and wildlife across the region (Hurd et al., 2007). Such changes in range productivity and livestock production due to climate change will likely add to the estimated agricultural sector impacts in New Mexico by damaging its most important agricultural activity, beef cattle, accounting for about 40% of agricultural income, or $2 billion in cash receipts (NMDA, 2005).

Additional impacts of climate change on New Mexico's people and resources are found in two recent assessments of climate change.[11] Watkins (2006) surveys the literature on climate change, hydrology, and water-related impacts and their potential inferences for New Mexico. Her findings are substantially consistent with those in this study, for example, she finds a consensus on the likelihood for rising temperatures and resulting hotter summers and milder winters. Regarding snowpack and snowmelt, she observes that snowpack would be less enduring of rising winter temperatures leading to earlier snowmelt and earlier peak runoff by 4 to 6 weeks, and a relative

shift from snow to rain. Furthermore, her findings confirm the likelihood of increased evaporation losses from streams, soils, and reservoirs, and increased evapotranspiration. Finally, she even finds support for the increased likelihood of more frequent and severe extreme events – both floods and droughts.

Ecological and cultural impacts are uncounted in the assessment. Substantial changes in the natural hydrograph and intensification of managed uses will severely disrupt stream ecology and health, which may have additional implications for managing the endangered Rio Grande Silvery Minnow (Meyer, 1997). Additionally, long-standing Hispanic acequias communities will likely be early targets of water transfers – causing local economic dislocation and increased poverty (Rivera, 1996; Selcraig, 2002). Those communities that resist water transfers – either due to restrictions that the State Engineer might place on their water rights – for example, under New Mexico water statutes that require consideration of the 'public welfare' when a water transfer is permitted (Bokum, 1991), or owing to a particularly powerful degree of cooperation among farmers, may also suffer as a result of a hydrographic shift. Because of a lack of storage infrastructure and vulnerable delivery systems, earlier and higher peak runoff could inundate acequias systems and fields early in the season and provide insufficient water during peak growing needs.

Additional related industries could also be negatively affected by climate changes and the loss of agriculture, ecosystem health, and damages to cultural resources. For example, tourism, arts, and recreation, which together contribute $360 million to New Mexico's economy, might decline as the States' unique landscapes, environment, and scenic opportunities are potentially degraded by changes in riparian ecosystems and agrarian land use (Rivera, 1996).

Each of these concerns taken individually adds considerably to the expected economic impacts from climate change. Taken together, there is sizable uncertainty in the extent to which economic damages, quality of life, ecosystem effects, and the overall severity of potential harm are unaccounted for by the model results. At least on a qualitative basis, there is significant cause for concern about the nature and magnitude of potential changes to New Mexico's economy, landscape, and quality of life as a result of climatic change.

FINDINGS AND CONCLUSIONS

Ultimately, water is used by people, plants and animals – either directly consumed or indirectly used in growing food and providing economic and ecological services.

Under current climate there is virtually no spare water in New Mexico. Imagine a very plausible future, as this study attempts, of significantly less water and at the same time significantly more people. Though improvements in water-use efficiency will be increasingly important to adopt and use – and which will likely be further stimulated by economic prices that are allowed to signal increasing scarcity – this assessment puts light on the likely need to reorganize patterns of water use or else risk significant disruption in some of the important services provided by the State's water resources.

A particular strength of the hydro-economic approach is its capacity to identify where and to what extent significant reorganizing of water uses will be potentially most rewarding from a watershed perspective. In this case, the results indicate the most expedient and least economically disruptive adaptation is to transfer water from agriculture as it is needed to maintain urban uses, growth, and economic development. In some ways these results highlight the obvious, there is a lot of water in New Mexico – 87% or more if lawns, parks and golf courses are included – that is consumed by plants. Plants that no doubt provide food for people, for dairy cows, and for other livestock, but nonetheless plants; and the food they provide can almost surely be replaced by purchases from other places. Of course, if water transfers from agriculture are not as forthcoming as the hydro-economic model assumes, there could be significantly more economic dislocation in other sectors of the economy.

As described previously, agriculture's real value – and potentially the real loss New Mexico's residents, tourists, and wildlife may experience – may not be so much in the market value of its agricultural produce but in the auxiliary services that agriculture provides to the environment and quality of life. Losses and transfers – amounting to perhaps more than 30% of current water use levels – will dramatically and deleteriously affect agricultural systems, communities, and environments across the region. Therefore, in our view, such losses as must be accommodated should be regarded with both respect and regret, and

fundamentally matched with an equal regard and effort to eliminate and guard against wasteful and capricious uses by urban and industrial water users. Absent this sentiment and action, farmers and rural communities – along with their political allies and representatives – will most certainly fight to defend their way of life and their legal and constitutional rights to use and control water for their benefit. And if farmers and rural communities adopt this perspective, all the more likely that it will also emanate from the pueblos, tribes, and acequias as well.

The following summarizes most of the key points developed in this assessment:

- Climate change scenarios result in less snowpack, earlier snow melt, and higher evaporative demands. The resulting change in runoff will affect vegetative cover in the watershed and habitat for various species.
- Substantial and transformational disruption to New Mexico's agricultural and rural economy can be expected in the future as climate changes. Under the best economic and institutional assumptions, direct economic losses of up to $100 million are estimated and largely suffered in the agricultural sector under relatively severe climate changes by 2080, with an additional $200 million in indirect economic losses anticipated.
- These economic estimates almost surely understate the severity and extent of economic, social, and ecological disruption that is likely to result from moderate to severe changes in climate. For example, water transfers are likely to entail significant transactions costs because of unsettled water right issues, including protracted litigation, water right adjudication, and transfer approval procedures that must protect against adverse effects on third-parties and the 'public welfare.'
- In addition, many sources of value and that are potentially at risk under climate change have not been captured in the analysis. Examples of values that are not reflected include, the expansive ecological and social services that agriculture provides, additional ecological and environmental services by flowing water in riparian systems, and further erosion and loss of cultural values and services from historical acequias and community irrigation systems.

The research findings suggest, particularly so when the limitations are given consideration, that New Mexico's social, economic, and environmental systems are highly vulnerable to changes and disruptions to water supplies potentially caused by climate change. Thus, the need is highlighted for water users, communities, organizations, and institutions in New Mexico at every level and in every sector to begin considering possible adaptive strategies for making better use of their water resources.

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ENDNOTES

[1]A growing consensus among anthropologists attributes the regional collapse of indigenous settlements prior to European arrival to multiple factors, among which importantly include climatic extremes (Plog, 1997). Peoples such as the Anasazi, Hohokam and

Mogollon abandoned long-held settlements during a period that tree-ring analysis has identified as 'the Great Drought' at the end of the 13th century.

[2]The Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emissions Scenarios (SRES, Nakicenovic et al. 2000), which consisted of four families of emissions scenarios that ranged from very low population and very high economic growth (A1), to very high population and somewhat low economic growth (A2), to somewhat low economic growth and moderate population (B2), and to moderate economic growth and low population (B1). Of these, the A1B scenario comes closest to U.S. government projections for population and income growth and to the 'business as usual' emissions projection, known as IS92a. Note, however, that the A1B scenario also has the highest emissions of sulfate aerosols of all the SRES scenarios, with a peak in 2030 and rapid decline thereafter.

[3]In addition to the limitations and assumptions previously discussed, the RGHE model uses a simplified representation of groundwater and aquifer storage and its connectivity to surface water systems. For example, Albuquerque currently relies on groundwater for its public water supply system. However, the hydrologic connectivity of surface- and ground-water systems is well recognized, including the requirement that future groundwater development requires offsetting retirement of surface water rights. The model assumes that over the long-run, water use is constrained by available surface water supplies. To implement this perspective, in the model groundwater and aquifer use must be offset such that by the terminal model time period (i.e., after 30 years) aquifer volumes are returned to their initial storage volumes.

[4]Exception is made for the managed transfers from the Closed Basin Project (CBP) and from the San Juan Chama (SJC) trans-basin diversion. For the CBP and SJC, annual deliveries of 21 kaf/yr and 94.2 kaf/yr are assumed (the latter is based on average importations since 1970; however, 110 kaf/yr is authorized). Imported water is distributed across months in approximate proportion to system water demands. Furthermore, imports are assumed not to vary with climate change. According to recent research on the effects of climate change on the Colorado River (NRC, 2007; Christensen et al., 2004) – the source of the SJC water – it may be a strong assumption that this amount of water will be available in the event of significant climate change. The potential reduction or loss of this water will have a significant impact on Albuquerque water users.

[5]This stands in contrast to earlier studies (e.g., Hurd et al. 1999) where the modeled shift in agricultural demand resulted in an expansion of so-called producers' surplus. Here, the value of agricultural production is maintained on the condition that the necessary water is supplied to meet the change in irrigation requirements. As water is then reduced, so then is the generated economic value. It is also assumed that relative agricultural prices are NOT affected by climate changes – a strong assumption that depends on sector-wide market effects that are beyond the present scope of analysis.

[6]See Hurd (2006) for discussion of current trends in New Mexico residential landscapes.

[7]The slopes of the curves in Figure 12 are relatively constant. This constancy reflects the assumed absence of changes in streamflow variability, and the primary focus of the present analysis on changes in average conditions. There is quite significant natural variability in the Rio Grande watershed, variability that is captured in the current analysis. Climate change, however, could change runoff variability and, if increased, further exacerbate the relative likelihood of drought and/or flood events. Changes that increase runoff variability would result, for example, in a relative flattening of the scenario curves shown in Figure 12.

[8]Implicit model prices are the marginal values that are estimated by observing the 'shadow price' on water supply constraints in the model. Though these 'values' are illustrative of the relative values under different population and water supply conditions, they are not necessarily indicative of actual market prices that are a complex function of many factors affecting local water demand and water supply conditions, including speculative development. These estimated values are most reflective of the marginal value of water in agriculture and not indicative of the willingness to pay for water by, for example, municipal and industrial water users.

[9]Nohara et al. (2006) examine the effects of climate change using 19 GCMs simulating the SRES A1B scenarios (just as in this study) on the hydrology and river discharge of 24 of the world's most

important river basins, including the entire Rio Grande system. Results for the Rio Grande show wide divergence in seasonal runoff across the GCMs, with several showing pronounced summer runoff that is most closely associated with intense summer storms and the likelihood of regional flash floods.

[10]Wang (2005) examines changes in soil moisture conditions across 15 GCMs and finds substantial consistency across the models in projecting significant reductions in soil moisture in all seasons for the southwestern United States.

[11]These assessments were initiated under Governor Richardson's Climate Change and Greenhouse Gas Reduction Executive Order (05-033) and were conducted by New Mexico's Office of the State Engineer on potential impacts on the water resources (Watkins, 2006) and by the New Mexico Environment Department (ATWG, 2005).

PANEL DISCUSSION

THE FEDERAL PERSPECTIVE AND INITIATIVES ON WATER

Moderator

Karl Wood *was named director of the New Mexico Water Resources Research Institute in June 2000. He joined the NMSU faculty in 1979. Prior to his tenure at the WRRI, Karl was assistant department head and range coordinator for NMSU's Department of Animal and Range Sciences. Much of his research over the years has been related to water resources, and for 20 years, he was a member of the Range Improvement Task Force, which provides scientific expertise to help resolve disputes over management of water and other natural resources. Karl completed a B.S. in 1974 in forestry and range management and an M.S. in 1976 in range science with field emphasis on soils and range improvements both from the University of Nevada/Reno. In 1978, Karl received a Ph.D. in range science with field emphasis on watershed management from Texas A&M. Karl has nearly 150 journal articles, research bulletins, special reports, and conference proceedings publications to his credit, mainly in the areas of range hydrology, range vegetation and soil assessment, and rangeland management, including reclamation of disturbed lands, range improvement techniques, grazing systems, and management of rare and endangered species. At the WRRI he has represented NMSU as chair of the Lower Rio Grande Water Users Organization, co-chair of the New Mexico-Texas Water Commission, and chair of the regional Paso del Norte Water Task Force.*

Mike Connor *works for Senator Jeff Bingaman, the Chairman of the Energy and Natural Resources Committee in the United States Senate. He is Majority Counsel to the Committee and is responsible for all issues before the Water and Power subcommittee as well as Native American issues that are within the Energy Committee's jurisdiction. Prior to joining the US Senate, Mike was with the US Department of the Interior (DOI) where he served as Director of the Secretary's Indian Water Rights Office (1998-2001), representing the Secretary of the Interior in negotiations with Indian tribes, state representatives, and private water users to secure water rights settlements consistent with the federal trust responsibility to tribes. Before joining the Secretary's Office, he was employed with the DOI Solicitor's Office in Washington, DC, and Albuquerque, New Mexico. Mike received his J.D. from the University of Colorado School of Law and is admitted to the bars of Colorado and New Mexico. He previously received a B.S. in chemical engineering from New Mexico State University and worked for GE.*

Zane Vaughn *is a Legislative Assistant for Senator Domenici (Ranking Member, Committee on Energy and Natural Resources and Energy and Water Development Appropriations Subcommittee) focusing on issues related to the federal budget, judiciary, government affairs, taxes, environment and public works, agriculture, CERCLA and Superfund issues, water and related litigation, and endangered species and related litigation. Zane is a native of Las Cruces and received a B.S. from Texas Tech University, an M.S. from North Carolina State University, and a J.D. from Texas Tech University School of Law. Prior to joining Senator Domenici's staff, Zane was a trial attorney with a private firm in Texas focusing on complex and commercial litigation.*

Ron Morsbach *has been a Field Representative for Congressman Steve Pearce working out of Socorro since 2003. He handles economic development issues for the Socorro area. He was the President of the Ramah Water and Sanitation District for 25 years, Chairman of the North West New Mexico Council of Governments for four terms, and Chairman of the New Mexico Association of Regional Councils for two terms.*

Johanna Polsenberg *is the Senior Legislative Assistant for Representative Tom Udall, a member of the House Appropriations Committee. Johanna's portfolio includes environment, agriculture, science, and natural resources issues such as forests, public lands, water, wildlife, and oceans. Prior to joining Udall's staff in early 2004, Johanna spent a year as a research faculty member developing an interdisciplinary coral reef study and management project at the University of Miami. She also studied coral reef diversity and marine reserve design in Sulawesi, Indonesia, and mangrove ecology in North Queensland, Australia; rehabilitated marine mammals at the Marine Mammal Animal Hospital in Marin, California; researched mangrove diversity and resource use in Samoa, Fiji, and Micronesia; and contributed to the development of a drug targeted against breast cancer that is now in clinical use. She received a B.S. in biochemistry and chemistry from the University of Vermont, an M.B.A. from the University of Maryland, and a Ph.D. in ecosystem ecology from Stanford University.*

Tito Madrid *was appointed by Governor Gary Johnson as Director of Field Operations for the New Mexico Environment Department from 1993-2000. He worked for Representative Wilson from 2003 until the end of 2006, when he left to work for the Greater Albuquerque Chamber of Commerce. There, he became the Senior Director of Regional & Local Public Policy and Government Relations. Tito rejoined the staff of Representative Wilson in October 2007 in the Albuquerque District Office. He has 27 total years experience with the Environment Department working in various positions including Underground Storage Tank Bureau Chief, District Manager, Health Program Manager, and Environmentalist.*

THE FEDERAL PERSPECTIVE AND INITIATIVES ON WATER

Mike Connor for Senator Jeff Bingaman
Zane Vaughn for Senator Pete Domenici
Ron Morsbach for Congressman Steve Pearce
Johanna Polsenberg for Congressman Tom Udall
Tito Madrid for Congresswoman Heather Wilson

Mike Connor: I guess it is unfortunate that I get to go first, because the things that I am going to talk about are things that I am sure everyone else on the panel will talk about. I think for the most part we are pretty united as a delegation on water issues. Certainly on the Senate side we are, because Zane and I work together almost on a daily basis when he is not working on the farm bill or some of his other projects. I guess I kind of specialize in water a little bit more. Whether it is Zane or his predecessors, Senator Bingaman and Senator Domenici decided a long time ago that water was not in any way, shape, or form a partisan issue and that it is something to work together on because the state has many challenges, and they need to put together their efforts to deal with those challenges. Even with their standing in the Senate, it is tough to get done all that we think we need to get done for New Mexico.

From my standpoint with Senator Bingaman, I have two sets of responsibilities with respect to initiatives that we have been working on. Certainly and always on Senator Bingaman's mind are his responsibilities for dealing with water issues in the state, so I will talk a little bit about that. He is also the chairman of the Energy and Natural Resources Committee, so we have a bunch of nationally weighted issues that we are trying

to deal with also. Let me go through those very quickly. I am not a fast talking easterner. I am from Las Cruces originally, so my fast talking is just related to trying to let everyone else have a chance to talk.

I think with respect to state-based initiatives, obviously what we are working on, as you have heard from others, are the Indian water rights settlements that have been signed by the state and several tribes here, whether it be the Navajo settlement in the San Juan basin, the Aamodt settlement on the Nambe-Pojoaque-Tesuque stream system, or the Taos settlement involving that pueblo. We spent a great deal of our time trying to work with the settlements that have been agreed to between the state and the tribes. We are trying to deal now with some of the policy issues that we see as a delegation so that we can move those forward. For the Navajo settlement, we have already introduced legislation. We have put together a concept for paying for the Navajo settlement, and I think right now we are doing the same thing with the other two settlements. The key thing is paying for those settlements. We are kind of working behind the scenes right now trying to find a way to guarantee funding to implement those settlements, so that if we enact them, they will get funded, they will get implemented, and those claims will be resolved for the benefit of everybody in those basins.

The next thing I will mention is the eastern New Mexico pipeline project. We have historically introduced the legislation, and there has been a ripeness issue from the Bureau of Reclamation's perspective. There is also a funding issue from the Bureau of Reclamation's perspective, but the ripeness one is one that we have been working on with those folks in eastern New Mexico. I think they are just about done, and we are ready to introduce that legislation again early next year.

The Middle Rio Grande is an issue that is constantly taking up the entire delegation's time. Along those lines most recently, the Water Resources Development Act was passed in Congress, and there were a number of initiatives in the Act related to the Rio Grande that the entire delegation worked on and supported. There was the Rio Grande Environmental Management program, the Middle Rio Grande Restoration program, and a cooperative agreement of authority. All of these authorizations have to do with bringing the Corps into the basin with a much more active role in addressing some of the problems that exist in the Rio Grande. The cooperative agreement of authority is a little thing, but it is probably one of the most important because it will allow them to cooperate with the Cochiti Pueblo to look at some of the reoperation scenarios, which I think are key to addressing some of the long-term Endangered Species Act (ESA) problems.

The transboundary aquifer assessment bill that Senator Bingaman and Senator Domenici cosponsored was enacted last year. We very much are looking into trying to maintain the funding to get that off of the ground. You may have seen some of the reports recently about the grand opening of a water project for groundwater development in Juarez in the Mesilla aquifer. It is those types of international issues that we want to avoid having joint studies on both sides of the border. That is pretty important from our perspective.

On the national stage, I want to mention three things that we are working on in the committee. As Bob Hirsch mentioned this morning, Senator Bingaman and Senator Domenici put together something called the Secure Water Act. It is basically a science-based initiative intended to ensure that we have better data, whether it be stream gaging, groundwater data, or data about water use and availability. Those three items are promoted as part of that bill. We want to strengthen the National Streamflow Information Program that Bob talked about this morning. The idea is that better science leads to better data, and that leads to better management. We are also dealing with the issue of climate change and the impact on water supply and trying to get a better understanding of the implications of that. We are looking at more refined models, downscaling atmospheric models to understand what may happen basin by basin in that area, and then finally a bill for conservation efficiency. No matter what water challenges we face, whether drought or some other change, such as population increases or environmental demands, conservation efficiency is going to be the key to addressing those challenges.

Aging infrastructure I think is very much a problem. With respect to the infrastructure we put in place, a lot of it was done 100 years ago, and it is deteriorating. We need to do upkeep on it, and we are seeing more of that issue come to the surface.

Finally, water reuse projects have been talked a lot about lately. There are some reuse projects in New Mexico that have been in place, certainly with respect to Albuquerque and some other community planning. Reuse is a huge thing in California in particular. There are reuse projects everywhere in the state of California, which I think reflects progressive water management,

but also the realization that even a state like California, which is the eighth largest economy in the world even on its own, needs a little bit of federal assistance.

Those are the kind of initiatives, the major issues that I see comprising the funding issues concerning water. Unfortunately, water resource programs have not been in favor over the last seven or eight years. If you look at it from an inflation standpoint, they have actually decreased anywhere from 11 percent through 2007. If you look at the President's budget from 2001 to 2008, those water resource programs have been reduced by 20 percent. Water issues are just hitting us everywhere, not just in the West but also in the East as you heard a bit ago. That is the biggest issue we have to grapple with. We need somehow to find the balance where there is an effective federal partnership with state and local communities and get back to where we are a responsible partner in that effort.

Zane Vaughn: For those of you who I haven't met, my name is Zane Vaughn. I am also, like Mike, a native of Las Cruces. I work for Senator Domenici. Mike and I kid each other that we have to be bipartisan, because Mike's mom was actually my first grade teacher, and I don't want him to tell her on me, because I know she will get me in a heap of trouble. I think Mike hit on a lot of the stuff that both Senator Domenici and Senator Bingaman have been working on. Some of those areas both senators have been working on for quite some time. I won't go back through it and rehash any of that. I think Mike did a good job of that. I will tell you that—I am sure most of you know this, I hope that you know this—Senator Domenici will be retiring at the end of this Congress, so we have about 13 more months left on his tenure to try to figure out what he can and can't do for the state of New Mexico in relation to water.

We have tried to prioritize certain initiatives for the Senator to let him look at and pick through and see exactly what it is he wants to do. I will tell you one of the critical issues right now that he is faced with is one that he and Senator Bingaman are working on, which is again the Indian water rights settlements, particularly how to find enough money inside the federal government to come up with the federal cost share. I think that is a very difficult prospect inside any time frame, especially 13 months. It is also made more difficult by the way the administration has been positioning itself. It is something that we are going to try to work through. It is something that Senator Domenici would like to see happen before he leaves office.

One of the things that is on the horizon for us is a bill that is going to come out maybe at the end of this session or the beginning of next year that Senator Domenici has been working on, in some form or fashion, since the early 1980s. Basically the focus of that bill is the interdependence between energy and water. A couple of the critical aspects of that will be that this piece of legislation will call on the federal government to look within each of the agencies to determine what their roles are regarding water and how to get those agencies to work with one another in order to better meet the water needs all across the United States. That has a significant impact.

I think a lot of people lose focus on the broader picture. For example, if you take the current farm bill that we are looking at right now with all of the corn subsidies and the energy incentives contained in it, there are not many people looking at that in regard to what kind of water consumption it will take. Why would a producer in New Mexico change his farm plans to start planting corn and sorghum? What does that do to our water allocations that are currently out there? I think what Senator Domenici is going to try to do through that legislation is address some of those more global concerns. I think that after the OPEQ oil embargo quite some time ago, you saw a national initiative to try to look at some of these, but it died off. As drought becomes more persistent and more strains are placed on federal dollars on the federal level, I think this is going to be a critical component as to how the federal government reacts and helps each individual state with its water needs and with the energy needs that we are faced with right now.

Johanna Polsenberg: I am Johanna Polsenberg, and I work with Representative Tom Udall. It is nice to be out here again. I am in D.C., and I come out to the state occasionally, but almost every single year I've been able to come for this water conference. It is just a clear indication of how important water is for us. On the top of my notes, I have scribbled a line that says, "Water is the most bipartisan issue," and we have heard that reflected so far. It is very true. We work together on many, many water issues.

I'd like to say that there are both the national and state perspectives that we have to take as federal lawmakers; however, the national issues are pretty much writ large in the Southwest and especially in New

Mexico. I have the bumper sticker behind my desk that reads, "If you think we have bad fights over oil, wait until we start fighting over water." We hope at meetings like this that we will not come to that point.

Mike, Zane, and I all mentioned the water settlements. Mike also mentioned the Ute pipeline. We have the northern district, and we have all three of the water settlements and the Ute pipeline in our district. When you total the amount, we are looking at over $2 billion that would have to come to the northern part of the state to address these water issues that are all pressing and urgent. The portion of the Ogallala that extends into New Mexico is expected to be unviable in 15 years. These are on the order of month to years problems now. We are not talking on the scale of a century. We are talking short lifetimes right now, so these are very large issues.

One of the focuses that we are taking is on climate change. I think Julie's presentation really laid the blueprint for a lot of what we are trying to focus on. While some climate change predictions are uncertain, there is a strong consensus across most of the models, if not all, that the Southwest is going to get drier. I refer now to a study that was done in the Sierra Nevadas. Global warming over the last 40 years by less than one degree has led in the Sierra Nevada Mountains largely in the California area to an average of about 28 to 30 fewer frost free days each year. We are seeing effects from relatively small temperature changes magnifying to rather large indirect effects. That small difference in warming has led to about a fourfold increase in wildfires. After this last wildfire season, you probably have to update that. When you look at these large-scale warming trends—one degree, two degrees—what will that mean on the ground? That is the point Julie brought up that the Congressman is really focusing on. It has been brought to his attention sitting on the appropriations committee and the authorizing subcommittee on the interior. As you know, appropriations is the committee that sets the budget.

Julie mentioned the lack of data. It is astonishing for us to learn this first year on the appropriations committee that, particularly over the last seven years, the funding has created some holes in our data, such as the USGS stream gauge that Mike and Julie mentioned. It is not now adequately able to monitor and see, if we have this one degree change, what it means on the ground. Can we get an early warning to see these magnified indirect effects from small global changes? We are trying to address inadequacy of monitoring and data collection through the appropriations process.

Another thing that has been brought to the Congressman's attention, both by his tenure on the resources committee and also now on the appropriations committee, is the fractionation of various land management agencies. The Forest Service is managing their piece, and BLM and national parks have their pieces. There are all these pieces in contiguous areas managed by different agencies. Another example is the Bureau of Reclamation, when looking at water. Their efforts are not necessarily being coordinated. It is necessary to manage each of these pieces for multiple uses, which the Congressman has always recognized; for example, forests can be water factories in watersheds and need to be protected. Perhaps other land uses can be used for other reasons. We are focusing in and getting the agencies there and asking, "How are you working together? How are you looking at connectivity between all the various pieces that you are managing?"

Again, the Congressman has a long-term focus on the watershed role of forests not only for water yield, but also for the prevention of fire hazard. Just to wrap up and reflect again the efforts Mike and Zane were talking about on conservation. I want to reiterate that we have so much water to gain from simple conservation; it is relatively simple to talk about, but very difficult to carry out. Our focus now and in the near future is to create greater efficiency, whether it is irrigation efficiency, water use, or putting money to research to get the technologies that have been discussed for water reuse, water use efficiency. The Congressman always likes to relate a statistic, and I hope you all know it better, about the water use, say, of a citizen in Albuquerque versus a citizen in Santa Fe versus a citizen in Las Vegas. The Las Vegans are very, very conservative in their water use and those in Albuquerque, not so much. He recognizes that if they can do it in Las Vegas, we can do it elsewhere in this state, and he is trying to find ways that we can enhance that conservation. Thank you very much.

Tito Madrid: Good afternoon. My name is Tito Madrid, and I have the honor of representing Congresswoman Heather Wilson's office. I'm not from Las Cruces. I can finish my talk with what has already been said. When I joined the Congresswoman's staff, I saw the unity of the entire delegation in their work on water issues. I am from the district office in

Albuquerque, so I get to go out and see where all of these water projects are, the need for them, and the work that has been done. The delegation works really hard in Washington, D.C. We get to see down in the district the projects for which they have worked so hard. To both of the senators and Congressman Udall, thank you for all of your work on behalf of the constituents in at least Congresswoman Wilson's district.

I don't want this to be a campaign speech, so I am not going to list everything the Congresswoman has done. She has worked very hard on water issues, and that is where a lot of her projects have come from. She has helped communities with flooding and with water to providing drinking water wells and so on. One of the issues I think she is working on and struggling with for the future is how to balance the needs of our district and the state, between farmers; agriculture; the Endangered Species Act (ESA), for example, and threatened species; development in our cities, jobs; and so on. That will be the biggest issue that she sees coming out in the next couple of years. How do we do this balance? Water is scarce. Everyone is talking about the cliché—you know that it is going to be a war for water out West. It might possibly be. With all of the requirements put on water from the cities, from the farmers, from the ESA, there are just a lot of demands on water, and they are not making any more water, folks. Congresswoman Wilson is looking at what she has called the New Mexico Aquifer Assessment act. It is kind of a forward-thinking act to look at the water in the deep aquifers, say 3,000 feet or deeper. There is some water there that we can possibly use. She has introduced legislation that would take a look at the salinity of this water, the availability of the water in certain aquifers, and how susceptible the aquifers are to contamination. It is basically looking at other sources of water supply.

The Congresswoman is also very interested in conservation credits. For example, if you are a farmer and you laser level your field and are not using all of the water you are allotted, there is a possibility that you could get some kind of credit put into a water bank or you could lease the saved water out. The idea is to reward conservation efforts. That may create a source of water there. It is always a balancing act for the Congresswoman, trying to balance the needs of her district and state and make sure everyone has water. Water is important for our future. I thank you and the delegation for their help.

Ron Morsbach: My name is Ron Morsbach. I work out of the Socorro district office for Congressman Steve Pearce. Tim Charters from our Washington office was supposed to be here, but he could not make it and he asked me to pinch hit for him. As mentioned earlier by previous speakers, the delegation works very closely together on water issues. Conservation is a very important part of our water resource solution, but it cannot ultimately be the final solution to water needs for our state in the future. It is a big part of it, but there are other things that are just as important for us to work on.

The Congressman is very cognizant of how important it is to keep as much of New Mexico water in New Mexico as possible. He worked with the Senate side on the Arizona Water Settlement Act, which is on the Gila. Hopefully a resolution can come to pass that will allow New Mexico to retain the acre-feet there and not make all of the Arizona developers happy by letting it go to Arizona.

Desalination of brackish water is very important. We need to continue to fund and work on technology to make the process more economical. Retention of water in the state is important, so we need to continue to look at the areas where water can be retained and released to protect not only the urban areas, but the farming and ranching industry, which is the largest industry in the state of New Mexico. We need to continue to work on eliminating and reducing the invasive species of salt cedar and the Russian olive plants along the rivers in New Mexico. We need to continue to try to fund that effort. Sometimes funding becomes a difficult issue, but working on these issues is very important for the water resources of the state. It is very important to protect endangered species, but it must be done in a reasonable manner so that all interested parties can work together to make that happen and still maintain the water usage that is used for consumption. We continually need to work on restoring the watersheds and have better management on our national forests, which generate a lot of water in the state by using better management. Right now, unfortunately, we have too many trees in the forest sucking up a lot of the water that could flow.

I personally visited, as Tito did, some of the areas where we used to have flowing rivers and what have you, but they do not exist anymore because the water can't get into those rivers. They are dry as they can be, yet some of the farmers and ranchers who have been in that area for a long time can remember when

they were fishing in those rivers. Now they are dry. Those are the issues that the Congressman will work on with the delegation to continue to improve the scenario to have reasonable water resources in our area, not only for urban areas but also for our rural and farming communities as well.

Question: This is a question for Johanna. You said that in 15 years the Ogallala, I guess you are referring to the aquifer, would be unviable. Are you referring just to the New Mexico part of it?
Polsenberg: That's my understanding of it, the New Mexico part of it, from where they are drawing water.

Question: Anyone can respond. It seems to me the philosophy of the Bureau of Reclamation is to move water too often in the West to municipalities, perhaps because of money, power, votes, whatever at the expense of drying up entire states. I am wondering if maybe with global warming we should pause and take a look at this kind of force. It is really important. This actually happens globally too. The entire planet is drying up, and we are moving water into municipalities in places like India and China. We are doing it in our own state. I actually think in the next 15 years the Rio Grande will be kind of attacked the way the Colorado River was in the last century. We have an opportunity to keep our diversity in this state and do things differently and perhaps be a model federally for keeping an area that might be healthier in terms of the planet naturally.
Connor: I'll answer that just to acknowledge the problem more so than to offer a solution. My sense is that your concern is with ongoing urbanization and drying up of our agricultural areas. I do not necessarily agree that it is driven from the federal level. I think it is driven from market forces and local realities more so than anything else. I don't think there is any silver bullet to protect water uses across the board, but I also don't think we have gone nearly to where we need to go with conservation efficiency and that includes managing our reservoirs and water operations or reusing water or looking to new supplies, such as desalination, and dealing with the energy costs involved with that. The bottom line is that we are trying to address water issues in many ways to try and promote all those things that deal with immediate water needs and that may provide some water for new uses and to protect existing uses. From Senator Bingaman's perspective, water drives everything we do dealing with the economic needs of a growing state and protecting the culture of our state. While New Mexico is not in the top ten, it is certainly in the top half or top third of growing states. We want to have agricultural areas. We don't want to just dry them up as a way to foment our economic growth in the future. All that is just to say that we look at this from any number of different potential solutions to help alleviate water needs, to help avoid water crises, and to look at the long-term by putting in a suite of tools and authorities and funding that we need to keep everybody balanced in all those different sectors of New Mexico.

Question: How is the New Mexico delegation going to deal with the Oberstar-Feingold bill that is out right now? I think it is called the Clean Water Restoration Act. That bill constricts, confines, and limits the ability for us to use our water resources in the future. How is the New Mexico delegation going to handle that?
Vaughn: I am not divulging any official position on that. I have seen that bill, and I know exactly what you are talking about. It is the reauthorization of the Clean Water Act. One of the significant obstacles in front of that piece of legislation at least in the Senate is that it has been authored by one of the most polarized members of the body and cannot garner the 60 votes necessary to clear out of our chamber. I don't think it is going to go anywhere. What happens after this Congress though if the body were to shift in such a way to where 60 votes could be garnered in favor of the Democratic party, then I think something like that could be on the horizon. As far as in the near future, I do not think that is going to happen on our side.

Question: Texas and New Mexico have recently started some interesting efforts pertaining to salinity and looking at salinity projects with both budgets on the Rio Grande, especially the lower Rio Grande. Maybe we can look at these with an interstate approach. I would like to suggest that maybe in the Secure Water Act that the Senator has introduced we can include something to help us address salinity issues for the Rio Grande and the Pecos. Instead of finding new water, we could clean up the supplies that we have, and that would make a significant difference to our water availability.
Connor: I think the question deals with advocating for salinity issues on the Rio Grande and the Pecos, maybe similar to what has been done on the Colorado River and maybe what we could do as part of the Secure Water Act to initiate that activity. I think part

of the problem is understanding the issue and then doing something about it. I think with respect to the salinity issues not just in the Rio Grande basin but in other areas, we should incorporate as part of the Secure Water Act building this database of information about our water supplies and water quality data. Salinity would be fundamental to understanding the problem. I think to move to a solution similar to the Colorado River salinity program, you will need to follow the process that those folks followed getting that program established. They got all of the states together, which is always the most effective way to deal with these issues—to bring the states, local, and federal government together and say, "You've got to help us do something." That is what they did in the Colorado River basin. The salinity program was one of those win-win situations for everybody. Yes it costs money, but when you bring stakeholders from Colorado, Texas, and New Mexico all to the table as well as local effective communities, I think that will be very helpful to get a Rio Grande basin salinity control program.

Question: Currently the climate change models all predict that most of the very heavy impacts will be in the areas where the tribes are located. These are also people who are the least stable to deal with these impacts in terms of technology, research, infrastructure, and so forth. This question is for Zane, because I was very intrigued when you said that Domenici was interested in the connection between energy and water. As you know, on the Navajo Nation, there are very rich energy resources. There has also been a very high price for the Navajo Nation with those energy resources. Now with climate change impacts predicted to be quite severe, especially in the New Mexico corner of the Navajo Nation and energy development using so much water, I would like to hear a little bit more about that connection and Domenici's interest between energy development and water resource use in an area where there is already not enough water.

Vaughn: I will tell you one of the things that I didn't mention as a component inside the bill that he is working on right now. There is a climate change component in that bill that allows the federal government to look into the impacts that climate change is going to have and how to specifically try to address the issue. I don't think Senator Domenici has gone too far out there on climate change, but suffice it to say he knows the impacts are significant in New Mexico, especially concerning more drought. I think that question has a lot to do with 1) supplying the appropriate amount of federal funding for the Navajo settlement, and 2) finding a way to get the federal government on board in relation to climate change and to start developing initiatives in order to assist impacted communities in particular areas. I think that is a very important area and one that does dovetail into that bill that I was talking about.

Question: As far as the forest thinning in our area, with the RS 2477 road closures possible, we need as many of those road open so that we can economically get in there and clean those forests. We need your help. How do the senators stand on closing those roads?

Vaughn: I have seen a little bit about this but not much. I have turned part of that over to the appropriate staffer in Senator Domenici's office. I will tell you right now though that Senator Domenici is supportive of forest thinning in an effort to prevent fire. I believe right now from the latest I have seen in our office internally he is opposed to those road closures.

Polsenberg: I think this is an example of the pitched battle that you sometimes hear out there. Each of the sides stake their claims, but the reality of it is a lot closer to the middle. My understanding is that in some cases clearly road closures are beneficial to the forests for keeping the forests and the ecosystem intact, keeping access away when there shouldn't be access. In most cases, however, the recognition of the damage of overgrown forests is there. As we go about determining road closures, I think it will be done in a way to make sure we can get the work done that we need with the access that we have before just closing it off. I think it is just an example of how you see the two sides staking their positions extremely, but then really working it out in the middle.

Morsbach: When you look at some of the plans that the Forest Service has with regard to road closures, it has been evident that many of the roads in the forests are not on the Forest Service maps. This is especially true in the area that I am coming from, which is the Gila. It is important that people in that area go look at the proposed roads so that when the road program is actually implemented, they know where all of the roads are. They are encouraging farmers and ranchers to look at the particular roads to make sure that the road to their tank and what have you isn't closed because it isn't on the Forest Service map. When the roads are closed, I think there is the possibility that after a year, this issue will be reviewed again regarding the opening

of lanes for fire protection and for ranchers. It is important that they look at the plans to make sure that roads that are important to them remain open.

Question: What do you think it will take to get two New Mexico senators back on the Energy and Natural Resources committee? Will that ever occur again?
Connor: I don't know. We are not going to do much better than we are right now, with a chairman and a ranked member. I always joked during the last election in 2006 that New Mexico was going to have a chairman and a ranking member. It didn't much matter. Our chief council researched this, and that is the first time that has happened on a committee—that one state had both the chairman and the ranking member. Except for appropriations, there are very few committees that are as important as Energy and Natural Resources. Even getting two senators again on the same committee would be a little tough quite frankly. I think Senator Domenici is going to leave a huge hole. That is an obvious understatement, probably the biggest one today. EPW is just as important with respect to the core. Obviously the appropriations committee is where we would like to see another New Mexico senator. It is going to be tough with respect to Energy and Natural Resources.
Vaughn: Senator Domenici shared with me a story one time. He said, "You know when I first got on the Energy and Natural Resources committee, I wanted to do everything my way and I couldn't get it all done. Having Senator Bingaman there to go to and say, 'Hey, is there some common ground here where we can meet and try to get some legislation passed?' was key." I think both of them combined have more seniority as a delegation, as a pair, than in any other state. It is not only on energy, but they have the bulk of a lot of the other committees covered. Senator Domenici is senior on budget. Senator Bingaman is senior on finance. Senator Domenici sits as an appropriator on the energy committee. You cannot pull too much over on two senior members who have that kind of weight to push around. As a freshman senator coming in, he or she would ask to be on every committee but it's just potluck at the end of the day. It would be very difficult for them to get on what is called a Class A committee, like energy or budget or finance or appropriations. You will see a stronger likelihood that there will be another member on Indian affairs or maybe EPW or another similar committee.

Connor: I just want to put a quick plug in for both senators. I think people ought to be proud of this. Next week, we are going to go back into session, and we are going to try to get some major energy legislation enacted. If we do, it will be because of New Mexico's two senators. The legislation deals with fuel efficiency and a lot of things within the committee's jurisdiction and some not, but the senators are both leaders in energy policy, and I think they are both being relied on by the leadership to pull something together that can get 60 votes in the Senate and move to the House. This is something that everyone should be aware of. It is not just for New Mexico, because these guys are major players in the national stage.

Question: About two months ago I had the privilege to attend an event where Senator Bingaman was the keynote speaker. In a forty-minute speech, he went through all of the things important to our nation, including the Iraq war, healthcare, and education. He didn't mention water once, and I was surprised he didn't. I asked during the question and answer session, "What is the thought in Washington on western water problems?" He looked at me a minute and said, "We kind of have a tendency to leave that up to the states." Again, that kind of surprised me. If you take a look at New Mexico alone, a federal agency like the Bureau of Reclamation controls one heck of a lot of water in New Mexico. Nine western states and now three eastern states have a great problem with water resources. The states that have water like Washington, Michigan, and Illinois are trying to get ours, why isn't this on the national scene?
Connor: I've heard Senator Bingaman say this a number of times, and it applies to water. With respect to climate change or something like that, he said, "The public and the community in some cases are way ahead of the Congress." I think his view on water issues is that that is true too. There is no resounding human cry within Washington, D.C., about water issues. They are fundamental to basic life issues, but obviously economic enterprises everywhere in the West are based on access and availability of water. I hear it in the water and power subcommittee and the issues I deal with everyday of strong concerns at a minimum and extreme concerns from every western state represented on our committee. Now we are getting it in the southeast. We are quietly, methodically trying to put in place tools for when people do wake up with respect to water issues. I don't want to make this a partisan speech at

all, but this administration has neglected water resource issues without a doubt. It is reflected in their budgets and their priorities. I think what we are doing right now is going for the next administration—whoever it is, because I think whoever it is is going to have to pay a lot more attention to water—so we are methodically working on items like the Secure Water Act and getting the fundamentals in place. Senator Bingaman and Senator Domenici last year passed the Rural Water Supply Program Act. We couldn't get any funding in the budget. Maybe Congress can write in $1 million or so to get that program up and going, but it is a tool that is going to be in place for those administrations that want to use it. When there are enough impacts nationwide for the Congress to realize we need to be investing more money in these programs, from basic science to infrastructure to river restoration programs and so on, they are going to warrant that. We just haven't quite caught up with the public yet.

The reality is that the water resource programs across the board are about $10 billion. That includes the Corps of Engineers, EPA, Bureau of Reclamation, USGS, USDS, USDA rural utilities programs—those are about $10.1 billion. That is 0.2 percent of the overall budget. You ask these folks what they can do, not just the federal agencies but partnering with state and local agencies, if you increase that budget by 20 percent. You wouldn't even recognize that in the federal budget, and it can have a major impact on a lot of things going on. There is going to be some crisis that is going to bring it to the table. The reality is that it is not that expensive to deal with, quite frankly.

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CLIMATE RESEARCH AND APPLICATIONS NEEDS IN SUPPORT OF CLIMATE SERVICES

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"*If we are not careful we will end up where we are going*."

The year 2007 was a record breaking season: Salt Lake City and Las Vegas experienced their hottest June through August temperatures; Phoenix had 32 days of temperatures above 110 degrees; Utah had their largest fire in history with 618,679 acres burned during the fire season; record high and maximum low temperatures were recorded in Missoula, Montana, and the Southeast experienced their worst drought in 100 years. Los Angeles received 3.21 inches of rain from July 1, 2006 to June 30, 2007. This is nearly one foot or 11.93 inches below normal during the same period, or just 21 percent of normal. This was the driest since records began some 130 years ago in 1877. It was a rough year.

Climate services of the National Oceanic and Atmospheric Administration provide "The timely production and delivery of useful climate data, information, and knowledge to decision makers." More specifically, we ask what should we do with our lessons? We have a network of activities that maintains well-structured paths from observations, modeling, and research to usable information.

Why do we need a National Climate Service? There is a growing awareness within research and resources management communities that climate

variability and climate change are affecting natural and socioeconomic systems. These impacts vary from region to region given variations in climate patterns and natural/socioeconomic systems. There is a recognized need (and demand) for spatially relevant research on climate and climate impacts and a need for reliable and responsive technical support for the resource management community (if we are going to get a broader use of forecasts) for climate-ecosystem impacts, trends, and changes.

We need to get local data down to where it is needed and to help in having the data understandable. Currently, there are a couple of bipartisan bills that address this need: the Global Change Research Improvement Act, which directs NOAA—only as the lead agency, not the only one—to develop a National Climate Service. NOAA is not doing this on its own; there are folks telling us what we ought to be doing. The Udall-Inglis bill is another bipartisan bill, the Global Climate Change Research, Data, and Management Act. All these bills direct us to ask what we should be doing to adapt to climate change. I am taking a position that the climate is changing, and we need to figure out what are we going to do about it.

There are other things being asked of us. I love the National Academy and have sat on several of their panels. They are great at coming to you and telling you what you ought to do. Recommendations from academia are useful but what they are really telling us is that they have been trying to evaluate what we have been doing regarding global change science for the last 20 years, and even where regular scientific progress is being made, the use of knowledge to support decision making is proceeding too slowly. The Government Accountability Office released a report, Climate Change 2007, The Physical Science Basis, basically saying, "Good. We are good at the science, but so what?" It is not getting us to where we can actually use the science.

I wanted to make a couple of comments concerning the Intergovernmental Panel on Climate Change (IPCC) and to make a clear distinction of which few people are aware. For international agreements like Kyoto and others, climate change is defined only as human activity produced. For the ICPP, climate change refers to both natural variability and whatever might be attributed to human activity. So keep in mind when you hear about the IPCC that we are considering both of these factors, not just the human-induced piece. The question is what you do about it.

Warming is here. We have the data, folks. We can't avoid this. It is not just some model imagined into the future telling us what is happening. This is actually what is going on. What do we see? In the West, we have seen one to four weeks earlier peak streamflow due to earlier warming-driven snowmelt. A portion of precipitation falling as snow is declining. The duration and extent of snow cover is declining over most of North America. Water temperature of lakes is going up (0.1 to 1.5 degrees C) over most of North America. Annual precipitation is decreasing over the central Rockies and southwestern U.S. Dry days and timing between rainfall events are increasing over most of North America. The mountain snow water equivalent is falling over western North America, and periods of drought are increasing over the Western U.S. and southern Canada. These things are happening. Those are the trends. We see this in the data, it is not guesswork. Remember the old saying, "If you want to make God laugh, you tell him your plans for the future." But this is really what is happening.

What are the gaps? Where should we be paying attention? We need to look at regional climate models that have variability. Most of the models that we have right now only include temperature. They need to incorporate variability, like El Niño events, for example. We need to fill gaps in hydrological monitoring with gridded data sets. We need to look at water budgets and the impacts climate change has on groundwater. We need monitoring sites especially for soil and moisture content, which are very little understood in the West. What piece of this is anthropogenic? What piece isn't? What are the climate-related management triggers? How do we use them to design criteria? Where are the limits and thresholds in ecosystems? Some really good work is being done out here on the pinyon trees. We need to know the cost of these impacts, whether they are third party costs or water transfer costs.

How do you develop a collaborative framework for research and management? We have seen the template for research, development, prototyping, and services that includes identifying user requirements, conducting research, developing applications, integrating knowledge and products, delivering products, disseminating information, and controlling data quality. We've been talking about this process and what we need for over the last 50 years. The question is why we haven't done anything about it. Well, we have done some things. The issue is why we don't have a better collaborative framework for

research and management. That is the essence of the Climate Service. If it is so easy, why is it so hard? Why do we still have this problem? I always like talking to people in other agencies and states. They tell me, "We're doing everything." So then, you don't have problems with drought and everything? And they say, "Well, yeah." Okay, something is missing between what we are doing and the resulting outcomes. Everyone asks us to be proactive. I say, "You first." What are the incentives for strategic and long-term thinking? Do we actually need it? Can we just adapt and adjust our way through this?

The challenge is to link research, development, the experiments we have, and the services. I am going to talk about why it is important to delivering products. Most of you in this room are familiar with the map in Figure 1. Note the dark blue areas that represent where our water comes from. Those areas are a small percent of the entire U.S., and minor changes in these areas affect the entire country dramatically. What we have are basically small areas that supply water for all of us. Small changes in temperature and in wind impact these areas a great deal. Why does this matter? If we look at the Colorado River and talk about climate impacts we have to talk about the short-term, year-to-year, and decade-to-century periods. Each of these periods has different decision timeframes on the Colorado River. In the short-term we consider power and irrigation. On a year-to-year timeframe, we are concerned with balancing Lake Mead and Lake Powell, deliveries to Mexico, and lower basin requirements. Each of these areas requires different kinds of information. Each of these has different degrees of uncertainty. When we talk about climate change, it is not just about 2050 or 2100. We need to know how to get from one period to another over time.

Figure 1. Average Inches of Annual Precipitation in the United States 1961-1990

Figure 2 shows Lower Colorado Basin mean annual temperature from 1895 to 2006. As some of you know, it has been much warmer during the more recent droughts than it was during earlier droughts at the beginning of the century. Where is that warming signal in the U.S. that we are seeing?

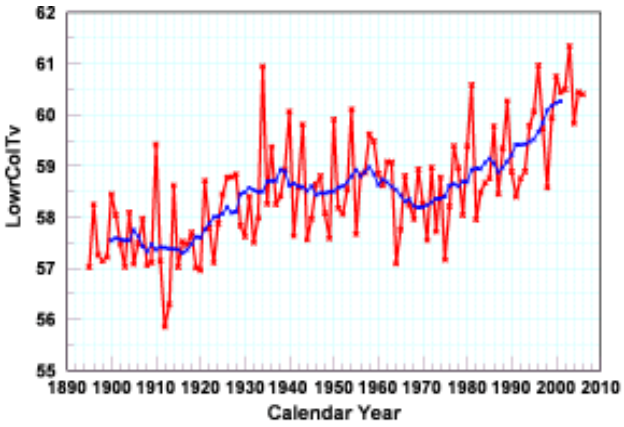

Figure 2. Lower Colorado Basin Mean Annual Temperature 1895-2006

What is the current thinking on projections? The models used by the IPCC and a bunch of other folks with whom we are working show that we are moving toward increasing aridity, not just drought, but increasing aridity. A more recent study by Seager and others (2007) shows virtually the same thing for our region. Even worse, the same study indicated that evapotranspiration rates in the Colorado Basin increased by 3 to 4 inches in the last 50 years.

What makes this so difficult is that we are trying to make decisions about our future based on what the models are telling us—and the models are beginning to agree—but we are not sure that this is actually going to happen. So how do you make a decision that incorporates what the models are telling us with the possibility that maybe this won't happen?

What are the estimated effects of climate change on Colorado River streamflow? Christensen and Lettenmaier (2007) think it will be a small decrease (0-8 percent by mid-century); Hoerling and Eischeid (2007) think we will see a large decrease (up to 40 percent); and Seager and others (2007) think we'll see a moderate decrease (in between). None of the studies show the streamflow increase. Any decrease is a source of concern, and it is a big concern. Ten percent is a major change. We must resolve these differences. The paleo-record says our average flow on the Colorado

River is 13.2 million acre-feet. We use more than that already.

You may be familiar with the vanishing snowpacks recorded in 2004 in Arizona, Colorado, Montana, and New Mexico (Figure 3). Let's take New Mexico. It had an 80 percent state-wide average the first of March 2004, and it went down to a 37 percent state-wide average on the first of April; this is strictly temperature related, not precipitation related. During 2005, we received 105 percent of the snowpack we needed in Colorado. We lost 25 percent of that, though strictly because of soil moisture and warmer January to June temperatures, not because precipitation declined. We can experience big changes simply because of temperature changes.

to kill outbreaks and that will affect forest hydrology and wildfires. Since 1986, the fire season has been extended by 78 days in parts of the West. Dust storms threaten snowpacks with snowmelt occurring up to three weeks earlier if there is significant dust. What do you do with this information?

One of the things we have to remember is that the anthropogenic piece, plus the decadal, plus the ENSO, plus the regional and local variability add up to one thing: surprise. The drought of 2002 was not projected in any climate model. It was a complete surprise. It was outside the realm of everything we were projecting including climate change. There are surprises in the system that we have to try to account for. That is the problem with creating a service that has a high degree

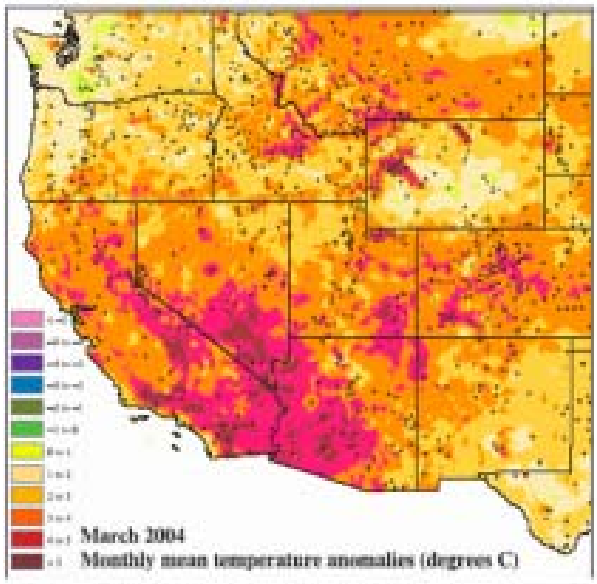

Table 1. Summary of Mountain Snowpack (Snow Water Equivalent) Changes Between 1 March and 1 April 2004.

State/Area	*Statewide % of Average, 1 March 2004*	*Statewide % of Average, 1 April 2004*	*Statewide % of Average, Change*
Arizona	74	22	-51
Sierra/Tahoe	113	70	-35
Colorado	90	64	-26
Idaho	105	81	-25
Montana	93	78	-16
Nevada	118	64	-54
New Mexico	80	37	-43
Oregon	126	96	-30
Utah	109	70	-39
Washington	93	86	-7
Wyoming	91	71	-19

Figure 3. 2004 Snowpack Vanishing Act (Pagano, Pasteris, Redmond, Dettinger, EOS)

So what do you do with this information? Is the current Southwest drought a once-or- twice-a-century drought like those of the past 500 years? In other words, will we come out of it? Is it more important now because we are here? Or is the drought a harbinger of things to come, a new type of drought that we haven't observed before? Is the jet stream actually moving north a little bit more permanently? That is part of the question.

And what do we do about this? There are wildcards like the pine beetles. We haven't had enough cold nights

of uncertainty. Uncertainty doesn't mean that we don't know anything. As a famous philosopher by the name of Satchel Paige once said, "Uncertainty is not what you don't know. It is what you know that isn't so." If anybody tells you, "Oh no. It is not going to change," then they are being as certain as the person who tells you it will change. We have to ask the question of what is in between that. If so, so what? How do you develop a system and a service that incorporates this information?

Well, that is why we collaborate and we have a history of working together. The environment is up there saying basically, "I don't know if we are exceeding the design specs." But you know, we are all in the room and we're talking.

We have multiple competing values and multiple competing objectives. We have a social and economic context that is changing. For example, the population is changing on the Colorado front range. Population is increasing, but we have ways of managing water use at the same time. It is not necessarily the case that population increases always lead to an increase in water use.

There are paradoxes in our planning. We want decentralization, but we are also asking for better coordination. We are reducing smaller floods and droughts, but is that increasing our vulnerability to larger events? What do I mean by that? Everything that we put in place in New Orleans reduced the risk from flooding for a long time, but what we did of course was to induce people to live in places of higher risk. We have to ask why the city of Phoenix is where it is – it's because of planning. We only plan after a crisis or focusing event. Lessons are available on particular events but not on gradual changes or abrupt regime shifts. I have looked at the details of the drought plans post-1977. They look exactly like the ones we have now. Why is that the case? We must ask how better to use those lessons, not just say, "Oh. Here's my latest study, and it says we should all coordinate and work together." We've been saying that for a long time, and some of it is working. We have to ask how to draw on those lessons.

Another paradox has to do with Integrated River Basin Management. We want that, but we have national, state, and borderland priorities. We ask to develop procedural and participatory mechanisms, but as all of you know—those who have worked at this scale—you have individuals even at the local level. You do not want to go back to the time when the sheriff and the mayor were brothers-in-law. We want to figure out how to work together to have maximum participation and to learn what is needed at this scale. There are paradoxes in our system—while we may ask for one thing, we need to balance unintended consequences. It is not as simple as choosing one or the other. We are asking to reduce these risks, but we may be increasing our vulnerability. How do we deal with these questions?

Planning depends on a stable climate and baselines. As I pointed out, small mountainous areas drive runoff. We see some change going on in the system already. Given our observed values, regardless if whether we stop producing CO_2 today, we are still going to experience change to some extent, and you must add variability on top of that. Most climate studies suggest that in the near future, droughts may be more common in the Colorado Basin even if precipitation stays the same. We need a full investigation of the potential yield from increased storage. Is increased storage actually going to help us in a drier environment? We must figure out how much increased storage will help us.

What has worked in the West in the past, and how do we take advantage of that for developing a Climate Service? We have found that the following elements make a difference: a strong focusing event that concentrates public and private interests like a drought, close federal/state/tribal and local partnerships, personal attention of key leaders, and strong support for collaboration between research and management. Every local, state, or federal partnership that we have identified to have been successful has had these four elements in them. That has been our experience.

One of our initiatives is the National Integrated Drought Information System (NIDIS), the regional implementation of an early drought warning system. The first experiment is going to be on the Colorado River Basin. You can find out more about this effort on www.drought.gov. This initiative is an example of how we are trying to use some of our systems. We need this to be a coordinated effort. We know states need to have drought plans, but we need to talk about what pieces of those plans need to go on this scale of the watershed. We have research on monitoring and predictions, and we've done some work on applications, but they are very idealized applications, using, for example, ideal farmers and a cost/benefit analysis that we don't know how to use in practice. We will be working on integrated tools for planning, mitigation, and adaptation.

Let's get back to why we need a National Climate Service? What regional functions should it perform? Who are the regional and local partners, and how should they be engaged (public, private, and tribal)? What information services should it provide? How can a framework for research and management be adopted and supported? How do we know that it is working? How should it be designed? We are now working with

the states to put into place a regional assessment program to improve our monitoring.

So if the products we have today are good but still not helping local decision makers on most of their local scale items with drought, then what is needed above what we have today? What we need is to continue our understanding of climate issues and to understand what causes changes in the climate. Although we are quite good at forecasting weather on a day-to-day basis, we need to be able to do the same with climate over longer periods of time. We also need a more integrated national and regional approach that can provide localized information in the real time. NIDIS is NOAA moving toward what we need tomorrow and over the long-term.

Where are we now? We have all of these elements being put together: research, development, prototyping, and services. We need to find out from groups such as yours how to work better with the professional associations and groups on delivering the services. That is the plea I make today. Thank you very much.

Question: This is something that I brought up yesterday, and I keep bringing it up. I may be the only one in the world who ever talks about it, but I don't care. There always has to be a component of growth management and those related things thrown into any talk like this. It has to be with carrying capacity—population and area—in mind. The answer yesterday was that it takes local public will. My experience has been that local politicians don't seem to have the clout. The president can make a decision on the national level. Local politicians often make decisions based on not wanting to step on their friends' toes. That is the social aspect, in my view, of all this science.

Pulwarty: I want to point out that half of my talk was on the social aspects of this issue. One of the things that we need to address is the issue of growth. It was off the table in Georgia and Alabama. There is no legal requirement to restrict growth in a lot of instances. The issue, to me, is a state issue. Now that is not passing the buck. The other thing to remember before we get away from the carrying capacity idea is that carrying capacity works really well with ecosystems and organisms that don't modify their environment on the scale that we do. I don't know that there is a limit to how much we can put into one place. Look at places like Phoenix and so on. If carrying capacity were a limitation, Phoenix shouldn't be there. We move water from one place to the next pretty easily. But if the place that you are moving water from is also tending toward dryness, you have a problem. If the adaptation strategies that we have used in the past, such as interbasin transfer, are themselves vulnerable, then you have a problem. As Pat Mulroy from the city of Las Vegas, Nevada, keeps telling me, growth will happen. The question is how we manage it. How do you want growth to happen? I think our role is to provide better climate products and information services, including how to use them, for people making decisions about growth. I don't want to pass the buck here, but it really is a state issue. Political will should come from the people that vote. Remember I talked about a focusing event. If enough of your population doesn't think that growth is a problem, then we don't make changes. Remember the four things we talked about that led us to change our minds? That is the nature of the beast. It is how we make agreements.

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GOVERNOR'S TASK FORCE REPORT ON CLIMATE CHANGE

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Well, Roger just told you that no one can make forecasts. But I am one of these academic guys who think that my job is to start talking about uncertain forecasts. By way of background, a couple of years ago after one of the driest summers ever reported, I gave a talk on drought down at the Sevilleta Long-term Ecological Research site. That day turned out to be the wettest recorded day in the history of the Sevilleta. My talk was interrupted at one point because the rain was falling so hard on the roof that people couldn't hear. I am here to tell you today principally about decreasing snowpack. Would anyone care to make a forecast for this evening based on that little piece of background? In case you didn't know, you are supposed to get four to six inches of snow tonight. Nevertheless, that is a weather forecast, not a climate prediction.

Over the past couple of years, I have worked with some other people to make some regional assessments that bring the global-scale perspective of organizations like the IPCC and down-scope them somewhat to the Southwest and New Mexico. Let me point out over the next couple of minutes some of the principal results that are contained in a number of reports, several of which have been published by the state. "Potential Effects of Climate Change on New Mexico" is a very nicely written overview (not written by me) put out by the state almost two years ago now, on the general

effects of climate change. I did help write a subsequent report, "The Impact of Climate Change on New Mexico's Water Supply and Ability to Manage Water Resources," which came out in the summer of 2006. More recently, I wrote a short article entitled "Climate Change and Water Resources in New Mexico" for a publication called Earth Matters, put out by New Mexico Tech. Each of these reports is online.

To begin, Figure 1 is a version of the global average temperature time series that Roger has already shown you. I am sure you all have seen versions of this before. It shows the instrumental record of global temperature change, plus temperature curves that isolate ocean or land components. We see the familiar story that the observed global warming over the 20th century was about one degree Fahrenheit. All the warmest years in the record over the past decade or so are—just in case you didn't get the message—plotted in red at the end of the time series. As Roger mentioned, the consensus wisdom of the scientific community that has parsed this time-series in just about every way you could possibly imagine is that there is simply no way to explain the temperature increase in the latter part of the 20th century other than by recourse to human forcing in the form of greenhouse gas emissions.

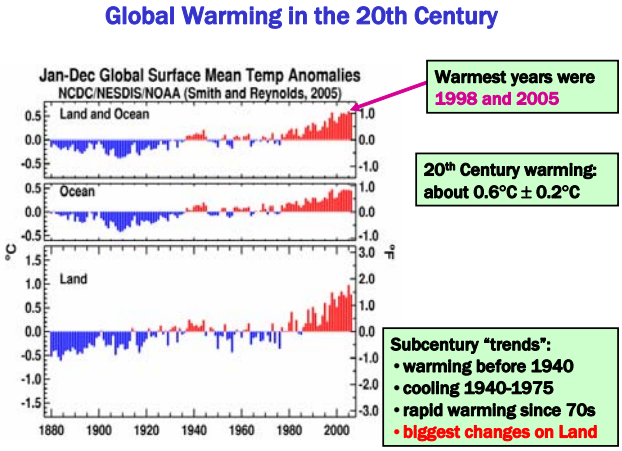

Figure 1. Global Warming in the 20th Century

If we want to down-scope that result to New Mexico, Figure 2 shows what it looks like. For this plot I have defined the "warm season" as the six months each year ending in September (By the way, you can make this plot online yourself at the Western Regional Climate Center website). There are three main points to make here:

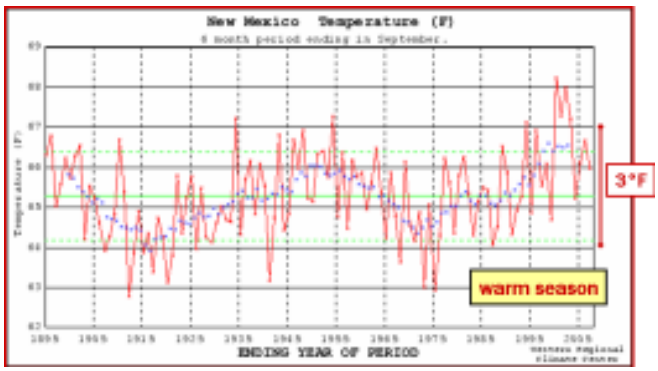

Figure 2. 20th Century Temperature Variability New Mexico Statewide

1) The principal ups and downs here basically parallel what we see in the global average. Global warming matters locally, because what we see locally in a very broad sense is parallel to the New Mexico record. We see some warming early in the 20th century, turning around in the middle part of the century, and then a rapid temperature increase in the latter part of the 20th century, with most of the warmest years in the record recently.
2) Anytime you down-scope things to a regional scale, you get way more ups and downs on an interannual basis. The climate variability from year to year, and for that matter decade to decade, is bigger on a local scale. That is true anywhere.
3) We're sitting here in the middle of the continent. The global average is 70 percent contributed from ocean. We expect on good scientific grounds that warming trends ought to be greater on the interior continents. That's us, folks.

Instead of talking about one degree Fahrenheit observed over the 20th century, New Mexico experienced more like two to three. Think about double the global average as being pertinent to the Southwest. That is a good rule of thumb to think about when we start thinking about the future.

If we consider the cold season (October-March, not shown here), the main ups and downs in the 20th century temperature record are the same, and the same point can be made about most of the warmest years in the recent record. The year to year variability is bigger in the cold season and the trend is a little bit smaller.

Figure 3 shows one estimate of what could happen in the 21st century. This was done for the state report on water resources that I helped write, using the current round of IPCC models in advance of the release of this year's IPCC report. These results were derived from an average of 18 global climate models, forced by a mid-range guess for what CO_2 emissions might be. As climate scientists, we do not know what the CO_2 emissions will be like, so we don't try to make a forecast. We just run the model a bunch of times with different guesses. The models simulate what might happen with this particular guess for CO_2 emissions: warming of seven or eight degrees Fahrenheit over the course of the 21st century, roughly four times what we saw in the 20th century.

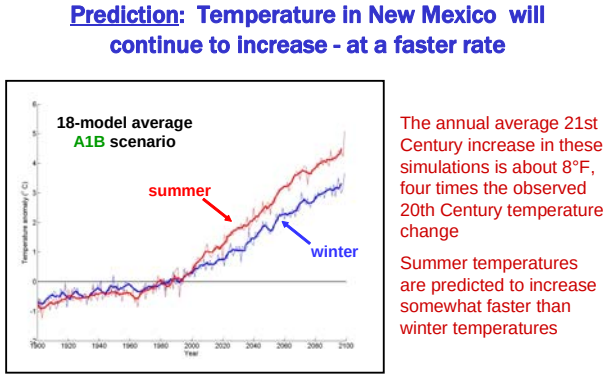

Figure 3. Simulated New Mexico seasonal temperature changes in the 21st Century, compared with model climatology (1971-2000) (Watkins/OSE 2006)

That is the major punch line when we make predictions for the 21st century: it is going to warm up. As Roger suggested before, we can choose different guesses for CO_2 emissions, but the model simulations make it very difficult to imagine a scenario in which the temperature goes down. Such a scenario would almost certainly involve other bad things that we don't want to happen, like a century's worth of intense volcanic eruptions. Our best estimate of what we ought to anticipate in the future is that it is going to warm up. The main difference between choosing one scenario over another is a matter of timing. Will temperature increase by so many degrees 50 years from now, or 150 years from now, or 200 years from now?

In terms of water resources, since this is a water meeting, there are two main points that I want to make. The first one is that, as Roger has implied, temperature is a hydrologic variable. It affects our water resources even if precipitation doesn't change. There is a large fraction of the public that doesn't understand that concept, but it is hugely important for us. For example, as temperature increases, snowpack will be reduced. The snow season will start later and end sooner. The snow line will be located higher up into the mountains. We picked a scene from southern New Mexico for the title page of the Earth Matter report because climate models suggest that all of New Mexico south of Santa Fe will no longer maintain any winter snowpack by the end of the century—well, choose your timing. That doesn't mean it will never snow there, but we should anticipate that snowpack will effectively be reduced to zero. In parts closer to the headwaters of our major rivers, we will have less snowpack that melts earlier.

Here are some scenarios from a report that was published by the US Global Research Program about a decade ago (Fig. 4). Multiple models for multiple regions across the US almost all have decreases in snow pack associated with warmer temperatures as we proceed in the 21st century. Once again, this is a temperature effect, not a precipitation effect. We are already starting to see decreases in snowpack and changes in the timing of snowmelt runoff. Figure 5 shows yet another prediction that snowmelt runoff will occur about a month earlier throughout the West by the end of the 21st century. Again we can change the timing depending on our emissions scenario.

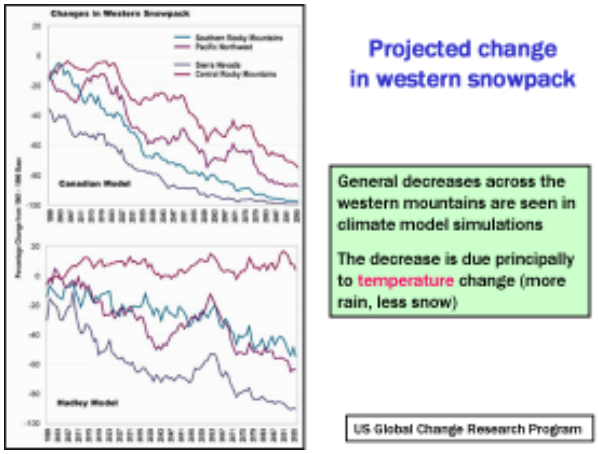

Figure 4. Projected Change in Western Snowpack

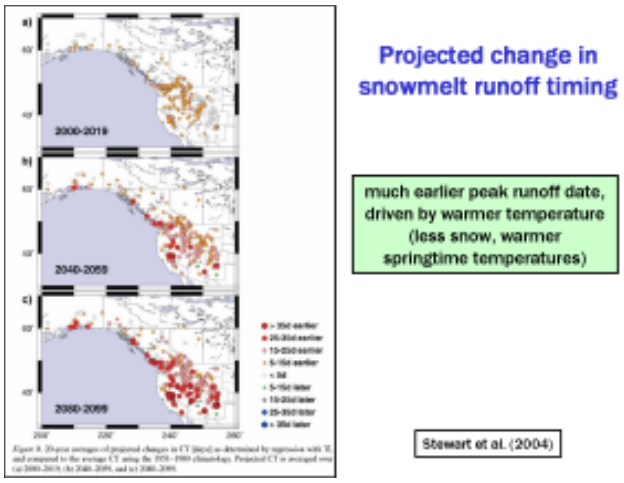

Figure 5. Projected Change in Snowmelt Runoff Timing

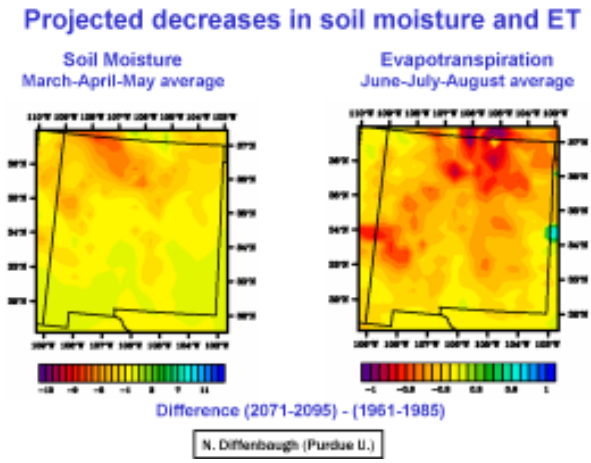

Figure 6. Snowmelt under Warmer Conditions

Perhaps we got a glimpse earlier this year into what may be climatology in the future: in Spring 2007 we had pretty close to normal snowpack through the winter that nearly disappeared during a pronounced heat wave in the month of March. So there was terrific rafting on the Rio Grande for a few weeks in March. That was good, arguably, but there are huge challenges for water management when all of that snow disappears early.

Figure 6 shows some model predictions that suggest what happens after the snow melts in a warmer climate. Soil moisture decreases, due in part to the fact that the snow that keeps the surface moist has melted earlier. Once the sun comes out and the snowpack is gone, evapotranspiration rates increase whenever there is moisture to be evaporated. We have a decrease in soil moisture in the springtime that perhaps has other effects on the monsoon circulation that I won't go into. Evapotranspiration off the surface in the summer decreases overall as the continent dries out. There is one major caveat to the projected decrease in evapotranspiration in the summer: where the surface is not water limited in a warmer climate, evapotranspiration goes way up in a warmer climate. The principal place that happens is, in our part of the world, over open water. That means that evaporative losses off reservoirs go way up in a warmer climate, posing yet another challenge for water resource management.

We'd like to quantify this projection, as was attempted a couple of years ago for the Colorado River basin. Figure 7 shows a summary diagram of a model-based projection for what happens to total storage in the Colorado River basin under one particular scenario for climate change. The basic punch line is that total storage goes down, in this case significantly (20 to 25 percent). If you plug that result into a reservoir storage management model for the Colorado River basin, the outcome is that the Colorado River Compact becomes unenforceable. There is not nearly enough water being stored to deliver a full allocation to all the people that have paper water rights to it.

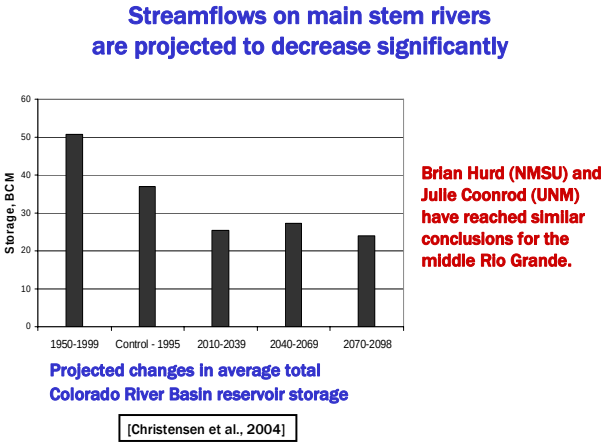

Figure 7. Model-Based Projection for Total Storage in the Colorado River Basin

Our best guess is that you could make the same statement for the major basins in this state, including the Rio Grande. Yesterday at this meeting Julie Coonrod reported on an initial attempt by Hurd and Coonrod to develop such a scenario for the Rio Grande, and later this morning Al Rango will describe an ambitious project to improve the hydrologic underpinnings of such studies for the Rio Grande. Hurd and Coonrod reach the general conclusion that we are going to have less water, and perhaps a lot less water, flowing down the Rio Grande in the 21st century as a result of climate change. We ought to anticipate that happening and start planning for it, which is an easy thing for me to say, but a very difficult challenge involving hard choices about our water consumption priorities.

Climate variability is an important part of our story, and some would argue the most important part of the story. It is easy for us to lapse into talking about average conditions when we talk about long-term climate changes, but we know that the term "average conditions" barely has any relevance to the state of New Mexico. If we know anything at all from the past climate record, average hardly ever happens. Figure 8 is an estimate of precipitation in northern New Mexico based on tree-ring data that goes back 1,000 years, taken from the Governor's Task Force report on climate change and water resources. The time series goes way down and way up and way down and way up. We know that huge droughts—severe and lengthy—are an endemic part of the climate system here. Arguably, the real 21st century doomsday story for water management, if we want to tell such a story, has nothing to do with the average trend in temperature or precipitation. Rather, it is how we get our way through these bad drought times that we would be insane not to anticipate happening again in the 21st century. I can't stand here and tell you when the current big drought across western North America might end, or when the next big one might happen later on in the century, but we would be utter fools to assume that it is not going to happen again in a warmer climate for all of the reasons I've been telling you about for the last ten minutes. With higher population, lower streamflows, and more depletions (from higher evapotranspiration), future droughts are going to be harder to get through. How are we going to manage our way through the next bad drought in a warmer climate?

More speculatively, some climatologists have suggested that the frequency and intensity of drought periods is itself correlated with average temperature. Tree ring data indicate that droughts were more frequent and more intense 1,000 years ago, when the

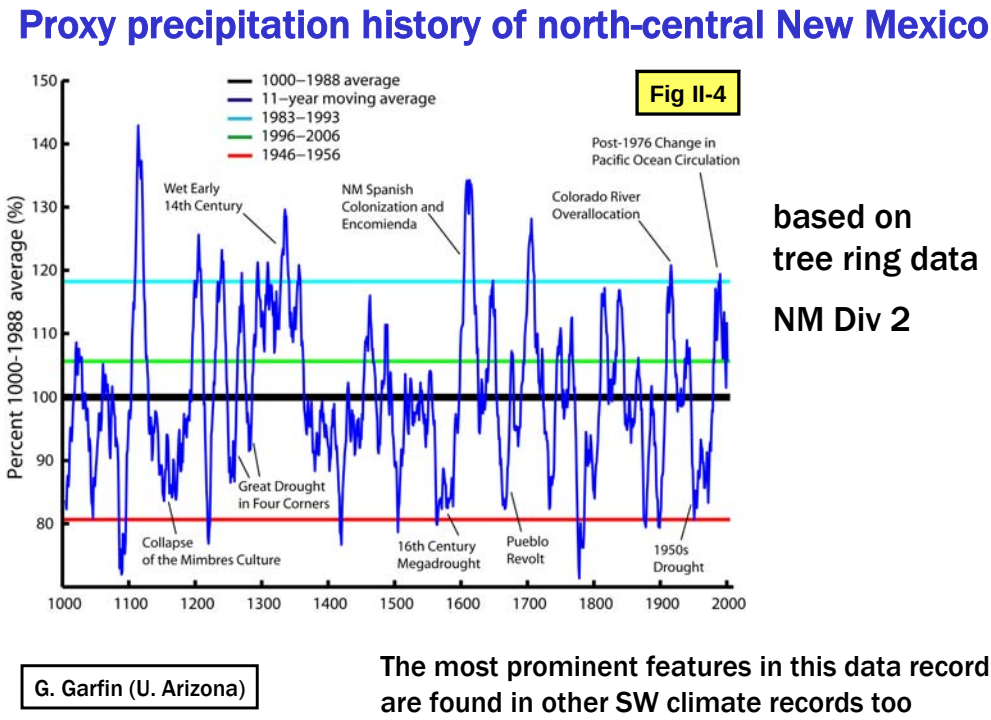

Figure 8. Precipitation Estimates for Northern New Mexico Based on Tree-Ring Data AD 1000 - 2000

temperature was closest to what it is now across the Southwest. As climate has warmed rapidly in the 20th century continuing on into the 21st century, this could mean that we are reverting from a relatively drought free millennium back to something that looks like it did 1,000 years ago. In other words, we are making our drought story even worse than simply saying more big droughts will happen in a warmer climate.

So far everything we've discussed is a temperature effect. We should anticipate significant warming to continue and perhaps accelerate, and there are hydrologic consequences to that. Just to make things worse, let's go back to the precipitation scenarios that Roger alluded to. I'll amplify those a little bit. Before I do that, I want to emphasize that the precipitation part of the climate change projection story really is significantly less certain than the temperature change. I really like to treat them separately because I think we are stupid if we don't anticipate the very large probability of warmer temperatures. The projected precipitation changes we are about to discuss are not so certain, in my opinion. I think we would be foolish to disregard them, but from the point of view of talking to the public, I think it is very important for us as scientists to make a clear distinction based on our confidence levels in our ability to predict climate systems. Nevertheless, let's talk about precipitation change.

Unlike temperature, there is no discernible trend in 20th century precipitation in New Mexico. As in the longer time series based on tree-ring data, there is pronounced variability, including the 1950s drought, and a very wet period—some would say the wettest period of the millennium—in the 70s, 80s, and early 90s, then the drought in the early 21st century, as well as a whole lot of other annual variability. Current model projections suggest that we might start seeing a precipitation trend, however. Models want to expand the Hadley circulations significantly, principally in the cold season, which would lead to significant decreases in cold season precipitatation in the global subtropics, including the American Southwest.

If we take the data points for those model runs in the state of New Mexico for one particular scenario, which is what we did for that OSE report, we get the time series shown in Figure 9. There is no clear trend in summertime monsoon precipitation (bottom curve). The top curve illustrates the "doomsday scenario"—a huge decrease in winter precipitation, whose effects would add to the impact of warmer temperatures across New Mexico and extend up into the southern Rockies. There is significantly less precipitation over the course

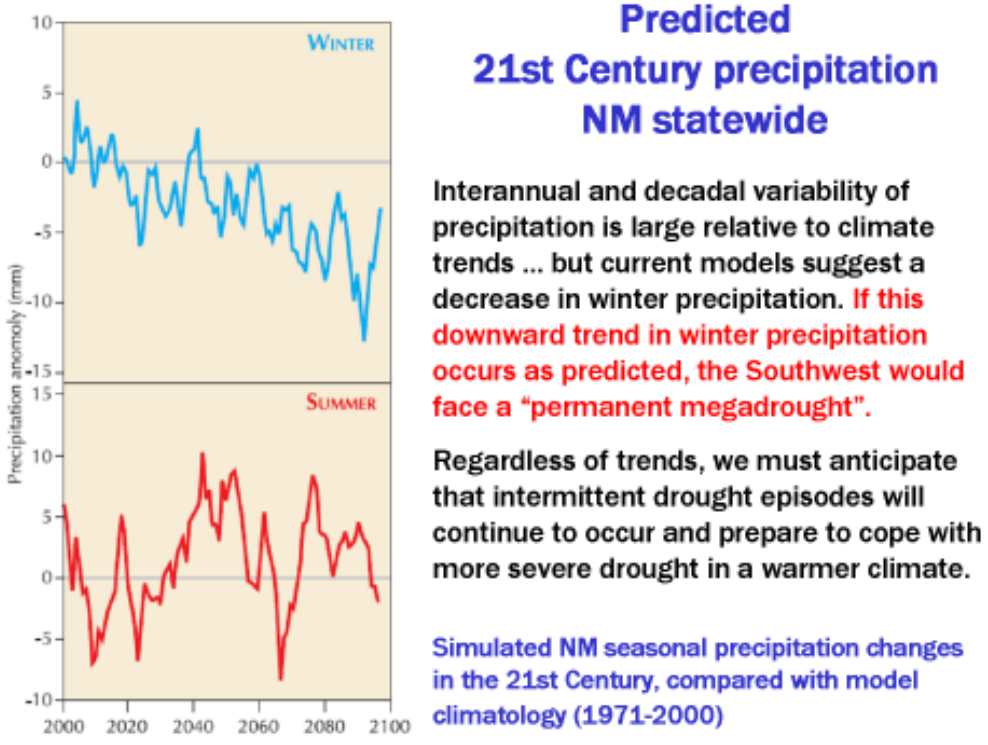

Figure 9. Projected 21st Century New Mexico Precipitation

of the 21st century so people throw around terms like permanent megadrought. Figure 10 shows another rendition of the same set of model runs, showing you there is some significant model to model variability. By the end of the 21st century, however, the IPCC models all show this sort of precipitation decrease, leading to projections of a "permanent megadrought" across the Southwest. I do not know what we would do to manage water in the face of that precipitation trend, should it occur.

Let me just make one or two more points and then stop. Obviously, it is not just supply of water that matters in a warmer climate, it is human demand for water. We can actually put some numbers to this for the city of Albuquerque, where water demand actually turned around fifteen years or so ago. That is because Albuquerque is starting to get serious about water conservation. We can model the year-to-year change associated with climate variability, especially for summer residential demand. It probably will not astonish you to learn that when we have dry or hot summers, water demand goes up. Warm and dry tend to go together, but we might continue to develop water demand models like this to start thinking about the demand side for projected climate change.

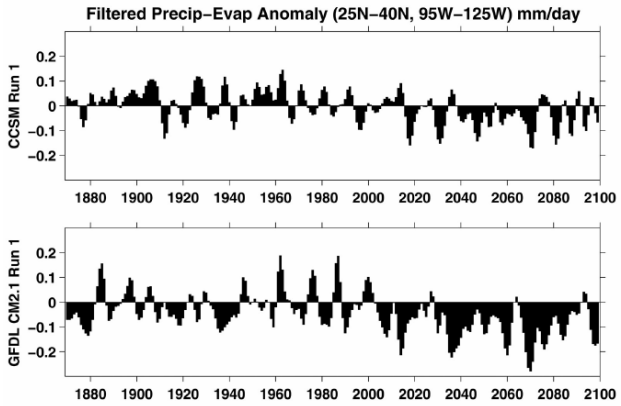

Figure 10. Projected Hydrologic Changes in the Late 21st Century American Southwest

Finally, to try to bring this all together and set the stage for other talks, Figure 11 is an estimated water budget for the Middle Rio Grande taken during the latter part of the 20th century when the climate was wet. There was a lot of precipitation falling in the mountains during the latter part of the 20th century. We have a water budget with most of the water in the Rio Grande coming in at the Otowi gauge. Inflows are shown on the left and depletions on the right. We can ask, "What are the projected changes in these inflows and depletions associated with the data for climate change?" I will illustrate those with little arrows here. Inflows decrease. Now, I can't put numbers to those yet, but that is part of what we would like to do as part of the project that Al Rango will talk about later today. As I have suggested already, we should expect less flow coming down the Colorado River and in the major tributaries of the Rio Grande. One of the largest inflows right here comes out of the Albuquerque water treatment plant, but even that will decrease as Albuquerque converts its water supply to San Juan-Chama surface water. So we expect inflows to go down as a result of climate change.

What about depletions? Open water evaporation, as I have suggested, goes up. Riparian evapotranspiration goes up. With warmer temperatures, there is a longer growing season for riverside plants that aren't limited by water as long as there is water in the river. I put depletions going up a lot off Elephant Butte Reservoir. I have not put an arrow on depletions due to agriculture, which seems to be a huge question to me. How much water will be available and will we devote to irrigation, which is pretty much the only way people will carry out significant agriculture in this part of the world, considering all of the other pressures on this water budget as a result of climate change? That involves pretty profound social questions for New Mexicans.

So we end with two main points: the climate is going to warm up, and because of that, the way our water supply works, we should expect pretty significant decreases in nature's supply of water to the state of New Mexico and concomitant increases in the natural depletions associated with evapotranspiration. Secondly, there are more speculative cautionary projections that perhaps on top of that, precipitation in the winter could actually go down over the course of

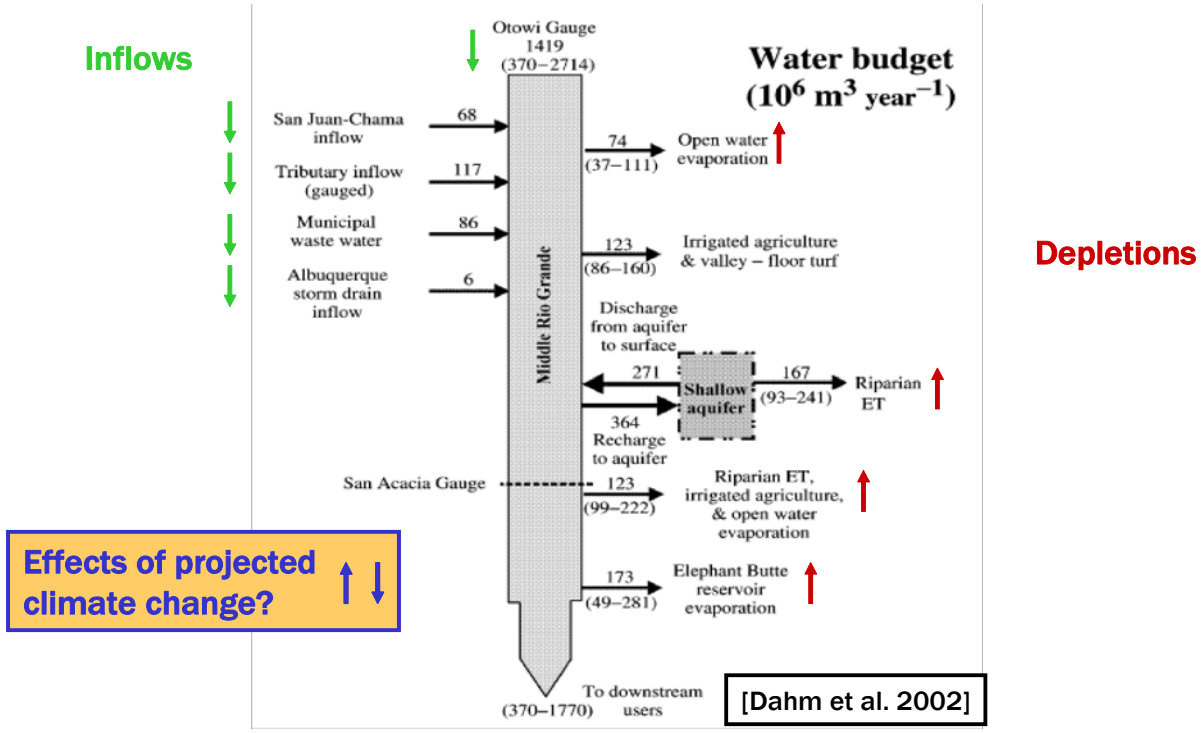

Figure 11. Estimated Water Budget for the Middle Rio Grande

the 21st century, which would make that whole situation way worse. All of this means that water resources are going to be under increasing pressure in general. Where that really hits home is when the next drought or droughts occur. It is not an average that matters; it is how we get through multi-year droughts, which we just know are going to happen sooner or later every few decades. Thank you very much.

Question: How do we make projections with regard to riparian vegetation and how they respond to climate change?

Gutzler: I am not sure that I can give you a great quick answer to that, in part because the riparian system is so actively managed right now. A lot depends on water availability. My sense, and I am not a biologist, is that an awful lot of riparian activity depends on water availability, both in terms of how much water is flowing down the river and how much we allow the river to move back and forth. So, riparian vegetation ought to thrive, unless people somehow restrict the water supply to those plants via river management. Hence the climate change arrow might go up in terms of total evapotranspiration. But obviously there are a lot of variables that go into that.

Question: We are seeing recently that there is a big social change going on because of the cost of a barrel of oil. This has also had really profound effects on agriculture and what crops farmers are choosing to grow. There is a real, real big impact on water resources, and New Mexico has a lot of energy development as a state. Are you planning on adding the impact of energy development on water resources, especially for that question mark you had there of what agriculture will do?

Gutzler: How does the price of oil factor into all of this? As a climatologist, the way it factors in is our choice of emissions scenario. That is where we bury that particular bucket of uncertainty. Different possibilities for the future price of oil and possible regulation of fossil fuel burning go into those emissions scenarios. However, you have raised sort of a different question about how the future of oil affects the state locally. A task force has been appointed by the governor to try to think about carbon emissions in general. I am not enough of an expert on New Mexico economics to be able say anything very authoritative, other than the motherhood statement that obviously oil prices will affect the state's economy in important ways. As groups of us try to think about this issue, we will need to bring people to the table that actually know about this stuff.

Question: From the global standpoint and its effects on the West, we have four time zones in America. I am wondering how much the climate models are thinking about the effect of the Eurasian continent, which is mostly permafrost, becoming a productive zone as it adapts to a warmer globe. Now there is a land mass full of photosynthetic capacities that spans 11 time zones full of plants and growth that is coming out of the Russian steppes, that in the current climate have been reduced in their production of oxygen and their absorptive capacities of greenhouse gasses. Now this new bread basket spanning across three times the land mass of America, what are the models projecting of that? Are those kind of impacts also going to swirl around the globe and have any other kind of impact? Are the models looking at that on a global and regional level in the Southwest?

Gutzler: The one-word answer is "yes." I just mentioned the first bucket of uncertainties has to do with developing emissions scenarios. The next step in making a climate change projection is to put those emissions scenarios into what we call a carbon cycle model that calculates how much of the greenhouse gasses that we emit into the atmosphere stay there. At present, on the order of a quarter of all the emissions that people emit are taken up by plants, principally in the northern hemisphere. The carbon cycle models are designed to take land surface changes as projected in the 21st century, including what will happen in Eurasia as the climate warms up, and allow the land surface to exchange CO_2 and methane with the atmosphere, so that you get an estimate of how much of the emissions actually stay in the atmosphere. So these models are designed to do exactly what you have described. How good are they? We think they are pretty good, but all of these models have uncertainties associated with them. One of the bazillion dollar questions in the climate change business is how long land plants can continue to take up about a quarter of anthropogenic emissions. Will that uptake increase as a result of land surface changes or will it decrease because we have effectively overfertilized the garden and it can't take up anymore just like you can't continue to fertilize your plants in your garden forever? Once again, there is considerable uncertainty. As you go farther north you get into permafrost and tundra with buried methane. Will these methane clathrates melt and release a whole bunch of methane? We think these models are getting better all the time. They are continually being tested against the sparse observations that we have, but we will continue to try to make that part of the projections better.

Roger Pulwarty: Just one quick backup: there are models that try to take that into account. It is a question that we have looked at. The issue has to do a lot with what David is saying. How do you know when the biosphere is "full"? There is an issue with the oceans right now and whether or not we might actually see increases. Are the oceans saturated or can they be in the future? The issue further north is a big one. I sort of question whether or not that impact will be much greater than the positive impact that you are suggesting.

There is one other question that is related to the input. Our experience has been that we hear about where the growth is and where extra water will come from on the supply side. We talked about water transfers and whether or not that is the way we want our states to go, but there is a huge other issue. All of the other recommendations we have on balancing the inputs and outputs have been sort of water banking. The water came from the environment in the successful water banks. Sure, agriculture and the environment provide a whole lot of services that are not just economic when we start to think in terms of these larger inputs and outputs. What is the input of the water balance model that comes from the environment? We are beginning to face a lot of that kind of issue.

Patrick O'Toole *is the president of the Family Farm Alliance. The Alliance is a grassroots organization of family farmers, ranchers, irrigation districts, and allied industries in 16 Western states and is focused on ensuring the availability of reliable, affordable irrigation water supplies to Western farmers and ranchers. Pat's family operates a cattle, sheep, and hay ranch in the Little Snake River Valley on the Wyoming-Colorado border. He is a former member of Wyoming's House of Representatives and served on the federal government's Western Water Policy Review Advisory Commission in the late 1990s.*

WESTERN AGRICULTURE AT RISK FROM CLIMATE CHANGE AND COMPETING WATER DEMANDS

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Thank you very much for the opportunity to be here. I don't have a PowerPoint because my talks generally ramble around. I like following Roger. I've done it one other time. His insights are helpful for me and for what I talk about later. This talk was going to be about unintended consequences, which in some ways it will be, but it will also be about, I'll use one of Roger's phrases, living in areas of risk. I think that is something we ought to talk about. This fellow down here has asked the question a couple of times, and I think it is important to talk about the reality of where we are. Farmers are the ultimate reality check as far as we're concerned. I don't have to dance around being represented by too many different groups. Really, what we represent are farmers. The Family Farm Alliance, as was said earlier, represents farmers in the western United States, from Texas, Oklahoma, the Dakotas to the West Coast. I think what we bring to the table is an ability to go to the grassroots and report back as to what is actually happening on the ground. We try to do that in a responsible way. I see Mike Connor is still here from Senator Bingaman's staff. We have tried to be a nonpartisan voice of what is happening with water in the West. I have really enjoyed the interchanges between the congressional staffs yesterday, because it really is true that New Mexico's staffs on water and on natural resources always work together, and they have been such a pleasure for us to work with.

Our group has testified before Congress and has met with people at the White House and done talks. The western governors' talk was the one Roger was at, and the western governors were looking at water issues and climate in a very in-depth way. We have been able to participate in that discussion.

Let me tell you a couple of stories. I was a legislator in Wyoming years ago. I was on a taskforce, and our current governor was on the taskforce. It was really trendy to talk about education and what we were going to do as educators and what kind of education we wanted. In Wyoming, the way that we presented this opportunity was to look at what a business wanted in an education system. Wyoming has a homogenous system. There is one university, and everything is controlled essentially through the state budget. Interestingly now, fifteen or twenty years later, there is so much money in Wyoming because of the energy plan that any kid who wants to go to the University of Wyoming gets a full scholarship so long as they maintain some median grade average. That helps a lot in terms of your education philosophy. What the taskforce did back then was to bring CEOs in from all over the country. We asked them what kind of graduate they wanted. They all said a lot of different things, and we interviewed them individually in a nice, quiet atmosphere. They all said the same thing, and I don't think they were planning to be in Wyoming. What they said was, "We will always take a kid that was raised on a farm or ranch, no matter what their degree is in. We find that they are improvisers, creative, and able to deal with stressful situations." They said a whole range of things that I find are the values that we find in kids who are raised in agricultural situations. We're very proud of that. I look back on it, and it really has helped stimulate a lot of my thinking. There is something inherently valuable about having rural people doing rural things.

Unintended consequences are part of what I want to talk about today.

We have three children. My wife, my sister, and my granddaughter are here. You might have seen the little talkative three-year-old. That is my granddaughter. My daughter, who works at the ranch now, has my other granddaughter, who is the sixth generation on our ranch. My daughter is loading sheep on trucks today, so we're able to be here. We have a son at the University of Wyoming, and he is very interested in the ranch. We have a daughter, our middle daughter, who works in Manhattan. She does PR. She, as a kid, always worked hard, but clearly did not want to be a ranch kid. She ended up in Manhattan. Just before her first day on her new job, she—this is a very confident person—called and said, "Dad, I'm a little intimidated. Everybody has ivy league degrees or some sort of resume that is really incredible." I told her, "Bridget, tomorrow you just go in there and say, 'My name is Bridget O'Toole and I can castrate with my teeth.'"

The other nonwater thing I want to talk about is bees. In that same period in the early 90s, Republicans were into budget cutting, and there was a lot of discussion in this country about who would subsidize and who wouldn't. Unfortunately for my industry—we run cattle and sheep on the Colorado/Wyoming border and irrigate—one of the political realities that came out of that was the ability to cut a couple of things. The Republicans said let's cut, so they cut a couple of things: wool and honey. Obviously, since I am in the sheep business, the wool thing was a big deal to us. Al Simpson was our senator, and we went back to him. He said, "There is nothing I can do. This thing is going to happen." It was the beginning of a long, slow decline in the sheep industry.

What I think is important to us right now is what it meant to cut the honey industry. At issue was the subsidy for honey. In fact, that market was to a great extent taken over by the Chinese, who then provided the honey. It isn't the honey that was a big deal for Americans today; it is the fact that we are now having a total beehive collapse in this country. We don't have a strong agricultural capability for those people to make enough money in the honey business to be viable and profitable. The long-term result fifteen years later is that the farmers that I represent in the central valley of California who need bees to propagate their almonds or the 60 percent of the crops in America that need bees to propagate are experiencing a beehive collapse nationwide. Unintended consequences are part of what I want to talk about today.

It really all goes back to water. As we have all heard, I have had the opportunity to hear the science about this stuff at many meetings now. Roger's presentation and Brad Udall and a whole group of people are doing the research and the science. There are many other groups that are trying to interpret the science as to what it means to them. All those people, a little fraternity or whatever, see each other at these meetings and try to interpret what it all means. The Family Farm Alliance began looking at these issues

before the drought really kicked in for other reasons. It has all kind of segued together.

We see the population issue as it relates to farming as a driver for why we should be doing certain things that we know should be happening. We are crop to crop, livestock production to livestock production. If something negative happens on a farm or ranch, what you do immediately is try to figure out how you are going to make it better quickly. The driver of the whole deal is the banker. The banker wants the thing to work, and so if it isn't working you need to do something different. Right now the banks are saying to a great extent, "Plant corn. Plant corn. Plant corn." Why? Because the country has decided in a major way, a policy sort of way, to have farmers not only producing food but producing fuel. It is going to create a tremendous dislocation in some parts of agriculture. I drove through Utah this summer, and there were sprinklers in operation. They have always had alfalfa, but they are now producing corn in Utah. The markets, in my mind, are so dislocated.

The Family Farm Alliance represents farmers. Anything that makes farmers do good, we're for. Our mission statement is very simple: Adequate supplies of affordable water. It is not much more complicated than that. In this circuit of things that are happening to us, we see that those things are changing rapidly. Our responses are in a report, and we have some copies of the report here. We've been working over the last few years on a couple of reports, one of which is on storage, which we anticipated before this became such a climate driven issue but rather because of the impact of growth. There must be more storage in the West, not for agriculture but so that agriculture is not the shock absorber for growth. That is what we are seeing. You pick a state, and I will tell you a story. We know westwide that there are things happening on such a massive level in terms of loss of irrigated acreage. We're running as fast as we can as farmers to be more competitive, more creative, and more efficient to conserve more. The reality is that it is happening faster than we can get our arms around it.

We presented a letter this summer to a commissioner of agriculture in a state I won't mention, but it was about a farmer in whose community all of the water was cut off because of the issues of groundwater that we are all so familiar with. We are familiar with the understanding of the interaction between groundwater, surface water, and drought. There are large groups of farmers, who for a lot of different reasons—political and otherwise, are losing their water. This letter talked about his two neighbors who committed suicide, one on either side of him. His new sprinkler system that he had put in now has no water. And it is the whole community that is hurting. One of the really great productive communities in this state is gone. That is going to start happening over and over again.

What we are trying to say is, as farmers, you have to do real things. You have to do things that matter. You can't do just policy interpretation. You have to be able to act today.

Right now the banks are saying to a great extent, "Plant corn. Plant corn. Plant corn." Why? Because the country has decided in a major way, a policy sort of way, to have farmers not only producing food but producing fuel. It is going to create a tremendous dislocation in some parts of agriculture.

There is a variety of things that we work on. Actually, we had a debate a couple of years ago. Gary Esslinger is on our advisory board, which is such a great group of people. Our board of directors is all farmers. Our advisory group is people from irrigation districts, attorneys, and people who work in the water world. We have a pretty good ability to see what is happening in the West and why it is happening in particular places. We talked about immigration because it was such an issue to a lot our guys. No. We'll water. That's our deal as Family Farm Alliance; we want irrigated agriculture. So we didn't do immigration.

One of the things we are working on that isn't particularly associated with irrigated agriculture is produced water. Someone asked the question about what is happening with the energy sector. I can't overstate what it means to a country that says to its farmers "Produce our fuel." It is changing the world in a very fundamental way. The unintended consequences will be generational. I guarantee that. If you try to look at it from a positive perspective, if you listen to the oil shale presentations instead of being down on the western slope of Colorado and hear about the percentages of the flow of the Colorado River that are going to be needed to boil the oil shale to make fuel, it is stunning, stunning stuff. That water has either got to come from cities or from agriculture. It is new water.

One of the things we have looked at and I have been involved in personally to some extent is what is called produced water. I know there is a lot of it in New Mexico. If you talk to the energy companies, which we have done more than maybe we want, they consider water to be a disposal issue. Can you believe that? Water is a disposal issue. We're looking at flows of tens of hundreds of thousands of acre-feet over decades of produced water that is going to come out of the western states. In some ways, I kind of think we think of ourselves as sort of being in a Forrest Gump life. All this stuff keeps happening to us.

When we talk about the implication of zoning on how we are going to plan in the West, remember that grassroots people have a very strong private property reality check that you better think about.

I listened to the Forest Guardian guy here yesterday. Forest Guardian means to people who have public land, as I do, not good things. I thought it was interesting that he did a couple of things. One was his discussion of forbearance. I thought I knew what it meant, and I kept asking, "What does he exactly mean?" Let's just say it: We don't want farmers to farm. We can't use euphemisms in this new world we're in. We have to be straight with each other. The reality of it is that farmers in every state in the West who we know about are going out of business because we have growth that is unsustainable. That is the bottom line. What are we going to do about it?

I'll go back to a cousin who is a county commissioner in Wyoming. She is a wonderful lady. She won an education award recently, which is for the best teachers in the country. She ended up being chairman of the game and fish division. She is a person with a wide range of background experience from the ranch mainly. She got behind an attempt to have a 640 acre minimum on growth and zoning. Six hundred and forty acres is unbelievable in terms of what other parts of the West are looking at in terms of zoning. In our county, which is divided by I-80, there is a guy from California, who is selling in one area called Separation Flats, which is either separated from water or separated from reality. He is selling and foreclosing over and over again on these poor son-of-a-guns who want to have some land. They foreclose, and he gets the land back and sells it again. He became engaged in a political fight, and the lady got defeated. When we talk about the implication of zoning on how we are going to plan in the West, remember that grassroots people have a very strong private property reality check that you better think about. If this lady couldn't survive a guy sending ads to the local newspaper from California, then it shows just how difficult zoning is going to be.

Several times I have been on speaking opportunities with Pat Mulroy from Las Vegas. We disagree on an awful lot of things. We do agree, and I do not know if the students are still here, that what this drought is doing and what this climate change is doing is pushing us 20 years ahead. The discussions that we were having ten or 15 years ago with a 20-year look at what might happen, those things happened just overnight.

On our farm and ranch, we have a lot of experiences that are personal. I want to just mention a few of them, because to us it is the tangible things that we see on a daily or monthly basis that make us realize that something really is happening here. That is what made the Family Farm Alliance try to anticipate what we can do as solutions. People are calling and asking: What is happening on your farm? What is happening on your ranch? We live at 7,000 feet and graze livestock at 10,000 feet in the summertime, very traditional. We are right at the base of the Continental Divide. My old legislative district was the headwaters above the Platte in Colorado. That is sort of how I got into the water business. You used to be able to know in the springtime that there were places where you didn't ride your horse. It was just marshy and springy. You just didn't go in there. You can ride right over it now. That is the accumulative effect of the loss of groundwater.

Last year in April, 80 degree temperatures made the hydrographs go like this. The creek that runs through the middle of our land you wouldn't cross horseback. Now it didn't matter. There wasn't any particular high water. Those are the kinds of things that if you have storms later, you know that the whole system is changing. We take a lot of pride in some projects that we have done. We graze livestock. We are very fortunate to be able to have almost an entire drainage of about 25 miles with either grazing permits or irrigated agriculture. We graze everything, and we also have the highest water quality in the entire system. We are working on a project with the Fish and Wildlife Service

to put structures in to integrate our fishery with our irrigation withdrawals. That's about the most fun I have. That is one of the things Family Farm Alliance, I think, is trying to do. There are a lot of different ways to describe it but one of them is called the radical center. These are people in the West that have common interests who have maybe previously been considered to be antagonistic who are now working together. We worked this year and are continuing to work on the farm bill with the Nature Conservancy. We are trying to look at it, so the Equip Program, which I am sure many of you are familiar with, can be used on a watershed basis. That is how we think that things should be approached—on a watershed basis, so that all the different players can work together to look at what obviously is a change in climate.

I think in our situation, and this is a bit selfish in a way, if warming was wet, it would be great. It means longer growing seasons and more water, but we do not know that. If it is dry and it continues to have the dry parts to it, it is not good for us. Right now we have our sheep operation, which is utterly dependent on snowfall from this time of the year forward—before Thanksgiving until March and April. Our guys are now out chopping frozen reservoirs. It gets down to zero degrees or below every night. They are chopping frozen reservoirs to get water, and that is the last of that. In another ten days to two weeks, you start hauling water, which, if you know anything about the sheep business, is the last thing you want to be doing in the wintertime. We are seeing those kinds of effects on a cumulative basis that tell us that things are happening, and we have to respond to those things.

From the Family Farm Alliance's perspective, we put out a report a couple of years ago on storage. What it said was that we are not advocating any particular storage, but we are advocating that we look at the issue. We do not want to be the shock absorber, which is what is happening today. Agriculture is the shock absorber for growth. Farms and ranches are going out of business all over the West to a great extent because of water issues. There is a whole accumulation of issues, but it will become more and more related to water issues, whether it is shutdowns from states or just the reality of less water.

On the last energy bill, with the help of Mike Connor and others, the Bureau of Reclamation put together their entire list of projects that have not been completed with an existent hydro-component. Family Farm Alliance thinks it is important for that to be out in the world so that everybody can look at it. There are a lot of potential projects. We hear from some that the big dam era is over. We know that. I drove some cattle in western Colorado and Utah. Rifle, Colorado, has a 14,000 acre-feet project, and above Rifle Ridgeway, there is a 30,000 acre-feet project. I talked to Gary Esslinger about the flood control capabilities in southern New Mexico and taking the monsoons and storing that water. That is what we are talking about, people coming together on a watershed basis with a wide variety of experiences to look at what you do with drought. We cannot all just walk away. We are going to have to make a lot of hard decisions. There will be winners and losers in every decision. Believe me when I tell you that it is farmers that are taking it right now. It is farmers that we're losing.

Agriculture is the shock absorber for growth. Farms and ranches are going out of business all over the West to a great extent because of water issues.

It is open spaces that we're losing. It is fisheries that we're losing. It is wildlife that we're losing in today's world, because we don't have the ability to synthesize this incredible pressure that is coming from, say, Pat Mulroy, who is from Las Vegas. Her current solution is to go to some of our members' places in southern Utah and go to rural areas in Nevada and take their water in pipelines to Las Vegas. I talked about the horses walking over the marshy places. I guarantee that if you take all of the underground water, there will not be any marshy places, any birds, any farmers, or anything else.

As we make these decisions, I think we are going to have to do it in a very thoughtful way. We need to be looking for partners rather than for confrontation. There is an awful lot of opportunity that this climate issue is fraught with including the ability of people to take political stances. It can't be that. I think you use the New Mexico model where people do not fight over water, they work together. I think that is really important.

As I said, our recommendations are to prioritize research needs and quantify projected water needs and hydrologic impacts. I think that is in the Bingaman and Domenici bill. We are going to testify why we think information is a good thing. Another recommendation is to implement a balanced suite of conservation and supply enhancement. That means let's look at storage and conservation. I can tell you

from experiences as an upper basin irrigator, it is that water that flood irrigation puts into the system early that creates the fishery down below and the water for irrigation later. We must be careful when we look at conservation as being just the only answer. I have some sprinklers, and I love them, but I guarantee there is no flow back into the river. Our flood irrigation is what puts water back into the river for the long-term.

Another recommendation is to streamline the regulatory process to facilitate developing new infrastructure. This is a real important one. We have met with virtually everyone—Corps of Engineers, Fish and Wildlife Service, this president's committee on water and environment—because the permitting process for anything you do in the West now is so complicated. I look at Roger's figures with all of the diagrams and numbers, and I immediately thought of the Gregorian knot and what Alexander the Great did. He took this big, complex thing and cut it with his sword. That is what we have to do with water. We have to be able to act when a state or region decides this is the right thing to do. We cannot take 20 years to permit. We just can't do it. We can't afford it. Regulatory streamlining is part of our perspective.

Another recommendation is to make sales efficiency and improved production a national priority. We are going the other way, folks. I think there is an Argentine guy that we heard about who plowed all day in the pampas in one direction, stayed to the right, and then plowed all the way back. That is the kind of food production that is being encouraged worldwide at the expense of, to a great extent, our food production. No regulatory oversight, and interestingly, he was plowing over the irrigation ditches. The irrigation ditches were made by the Incas. If you go up to Machu Picchu, there is not only incredible architecture, but the ancient irrigation system remains in place. As drought pushed natives further and further up into the mountains, they created irrigation systems up there for food and self-sufficiency. That is an important lesson for America.

The last recommendation is to find ways to protect farmland. It is pretty self-evident. I really appreciate the opportunity for the Family Farm Alliance to participate in this meeting. You have great representatives from New Mexico, and the Family Farm Alliance is out there to protect the environment.

Question: Standard economic models that I have seen—I'm not an economist—but they all seem to show that as the value of water goes up, the highest economic value of water is to invest it in cities, not farmland. Therefore, from society's perspective and approach, we come to the logical conclusion that what we ought to do in times of scarcity to maximize total economic output is to convert water in agriculture to water for the cities. I am curious how you would respond to that sort of conclusion.

O'Toole: The last fair-sized project built in the West is in our valley. It was a project I was involved in. It was a multigenerational project. We are selling that water to farmers in our valley to save our lower valley. I think it is $8 an acre-foot. You saw all of the models yesterday including the Big Thompson. What's funny about the Big Thompson is that it isn't just $20,000 an acre-foot—that is for nine-tenths or eight-tenths of an acre-foot. Obviously, the economics are divorced from the reality of producing food. We are going to have to make some social decisions. Those social decisions are: Do we want to have farmers? Do we want to have open spaces? The reason I think that some of the conservation groups and we are working so hard together is that we realize the interchange of having those social values. They are all our values. That is a decision our society has to make. Pat Mulroy tells me that in 2014, if we can't keep Las Vegas growing, the construction business is going to collapse.

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WHAT TO DO WITH WATER LEFT OVER AFTER NEEDS ARE MET?

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This morning we're going to have a little conversation about New Mexico's water inventory and some of the issues associated with them. The theme, "What to Do with Water Left Over after Needs are Met," probably astonishes some and may perplex others who would argue that our state has no "left over" water. I'll try to lead you through several attributes of this critical resource that are or may become excess to imperative needs and what we can or should do with it.

A recent article in the Deming Headlight captures the essence of how modern irrigation practices can secure and save enormous volumes of water that are left over after needs are met. The headline reads, "Farming Community Leans Heavily on Drip Irrigation." It describes how virtually all of Luna County's farms have, in the past ten years, transitioned from flood irrigation to drip irrigation, resulting in saving 35 to 50 percent of the water formerly used. The system relies on thin-walled, precisely perforated, and connected drip tapes placed in the ground in a very straight line within a quarter inch variance that waters the crop directly at its root. Water flow is computer controlled and much of the crop tending is managed by computers and GPS controlled tractors. The process relies on clean, filtered water derived from the Mimbres underground aquifer. The conversion is expensive, costing, with computers and global positioning system,

about $360,000 to install on an irrigated 160 acre Luna County farm. But savings in management, labor, crop augmentation, and water have made the changes profitable. Is this or something like it a wave of the future for New Mexico crops and a model for creating water left over after needs are met?

Let me paraphrase what's currently on the minds of many New Mexicans when thinking of water. It's basically that: Maintaining contemporary patterns of water use in New Mexico has all the attributes of an inevitable train wreck. Escalating demands on limited supplies assure us that dramatic collisions with severe consequences are unavoidable sooner or later without changes. To illustrate, we need to look no further than recent events on the Pecos that came close to destroying the economy of some communities and almost decimated several irrigation projects. It was a genuine crisis that, without timely intervention and expenditures of tens of millions of taxpayer dollars, almost became a catastrophe.

Maintaining contemporary patterns of water use in New Mexico has all the attributes of an inevitable train wreck.

The difference between a crisis and a catastrophe is that if you're fortunate enough to perceive an approaching crisis, you have time to think and act your way out of it. A catastrophe is too late and is the certain result of an unattended crisis.

Are we approaching or in a water-related crisis? And, if so, are there ways to avoid catastrophe while preserving the integrity of our water supply?

To answer, we'll discuss components of our water systems that range from large volumes that are unaccounted for; through overused, underused, and unused water; address the subject of conserved water; and look at new sources of water that may be difficult to find or develop. By necessity, there will be some focus on irrigation water. Now, don't start heating the tar bucket, plucking the chicken, splitting the rail, and heading for the city limits with me yet. There's nothing in this talk that implies a threat to anyone's valid water right – if we successfully avoid catastrophe. And, no matter how intractable and alarming our water problems appear, I'd like to leave you with a sense that, with some solutions involving excess water, appropriate direction, and adequate funding, they are manageable.

That great philosopher, Yogi Berra, observed that, "The future ain't what it used to be." Certainly, the water future of relative abundance we contemplated several years ago is radically different from the predicted insufficiencies we encounter today. Also, since part of this discussion does have to do with water rights – any consideration of which is an anathema to some with older claims – I again turn to a foremost authority on addressing sensitive subjects. It's Will Rogers who profoundly stated that, "Sacred cows make the best hamburger meat."

After more than thirty years of examining and assessing New Mexico's water as a professional geologist, former legislator, past interstate stream commissioner, and involved citizen, I've concluded that with regard to our water issues we've been imprisoned for more than 100 years in a confining box where little or nothing changes. It's like trying to get out of a bucket you're standing in by pulling its handle. To achieve a sustainable water supply and continuing economic prosperity, we must do some creative thinking out of that bucket or box.

The timing couldn't be better. Several years of drought and shortages have prompted significant public awareness of deficiencies in the state's water supplies and some doubt of our ability to cope with them. The public is ready to move. Solutions, however, demand more innovative and original thinking, some legislation, and better application of available resources than those in Santa Fe have, so far, appeared willing to apply. Currently dealing with enormous financial windfalls, they have the means today to initiate and fund measures that can go a long way toward achieving water self-sufficiency.

They can start by adjudicating or otherwise validating our water rights. Once we know with certainty who owns the right to use what water and where their right appears in the pecking order of priority use, procedures to lease water from them to those wishing to use it will follow. Especially in the Middle Rio Grande valley, where almost half the state's population resides and its economic fulcrum is located, water rights confirmation followed by transparent, sanctioned water leasing markets would provide relief from concerns about our economic future related to water availability.

At a hearing before the U.S. Senate Committee on Energy and Natural Resources on New Mexico Water Supply in Las Cruces in 2001, then State Engineer Tom Turney stated, "Adjudications are key

to providing a viable water market... As challenges to New Mexico's water supply increase and more and more demand for new water sources arise from entities such as municipalities and commercial interests, only those rights that have been adjudicated will be marketable at low risk to the purchaser." In response to Senator Bingaman's question about the status of adjudications, Turney said, "In the past 100 years, the State of New Mexico has completed about 15 percent of its adjudications. At the rate we're going right now, that is about 600 years to complete the entire state. Clearly, that is not acceptable... And the cost is going to be very expensive. I think about $170 million..."

Earlier this week State Engineer John D'Antonio, in response to a legislator's question, said that less than a quarter of the state's water rights have been adjudicated and that it would take about $300 million and 55 years to settle the rest.

Last year, State Engineer D'Antonio suggested that a method to license water rights might be a viable alternative to the lengthy and very expensive adjudication process. In order to be a satisfactory and acceptable substitute in our water world, a number of critical conditions must be met. Paper trails with certainty as to priority dates and consumptive use are imperatives if effective and relatively inexpensive water markets are to be built. Current practices of extensive and expensive document research, preparation and examination, usually followed by lengthy and costly litigation in order to transfer a water right should no longer be acceptable. "Paper water rights" must be identified and removed. Lessors and lessees, buyers and sellers, must have the confidence in their transactions and the expedited closing time that those dealing in real property attain with title insurance in lieu of expensive abstracts. It will cost money – lots of money – to secure, examine, evaluate, and provide the necessary files and records. So, with water adjudications or acceptable alternatives so crucial to the economic future of our state, I leave it to you to judge whether recent legislative priorities for expenditure of extraordinary financial windfalls have adequately incorporated impending and impelling water urgencies.

Water and the right to use it in New Mexico begins with irrigated crops managed by Native Americans at their pueblos hundreds of years ago. Spanish settlers dramatically expanded these irrigation processes with the development of acequias on the Rio Grande almost 500 years ago. New Mexico Territory's first water code was established in 1907. It "grandfathered" in pre-existing uses, virtually all of which were dedicated to irrigation, as "rights." But it didn't require registering or documenting them, so they are not adjudicated. The state's constitution, adopted in 1911, confirmed these rights.

Especially in the Middle Rio Grande valley, where almost half the state's population resides and its economic fulcrum is located, water rights confirmation followed by transparent, sanctioned water leasing markets would provide relief from concerns about our economic future related to water availability.

Where's the water for new and expanding uses going to come from? Mostly, we'll have to create it. It may surprise some – and be heretical to others – to know that the root cause of our water problems is not necessarily shortages, but distribution. Data on the State Engineer's website says that in the year 2000, New Mexicans diverted over 4.2 million acre feet of surface and groundwater for all purposes and depleted or consumed about 2.6 million acre feet of it. That's an enormous volume of water that, if otherwise managed and distributed, would meet the needs of all the state's users well into the foreseeable future.

Irrigated agriculture's share of this bounty is about 1.8 million acre feet. Reservoir evaporation accounted for another 431,000 acre feet. Since few of these reservoirs would exist except to store irrigation water, it is not unreasonable to suggest that the combined use of more than 2.2 million acre feet means that almost 85 percent of all the water we consume is used to irrigate crops. Municipal, urban, and public water supplies account for 8 percent of our water and all other uses are for the other 7 percent. Now, I'm fully aware that large volumes of the water charged to irrigation don't reach crops and are consumed elsewhere in the hydrologic cycle and that less than full reservoirs don't evaporate as much water. But, in the broader context, there's no escaping that irrigated crops are by any measure the primary beneficiaries of our water treasure.

Crop production is a fundamental cornerstone of New Mexico's culture. It was here long before any of the rest of us. Its priority status in water use is well recognized in its ownership of most of New Mexico's senior water rights. When the Territorial legislature vested them one hundred years ago, the state's economy was virtually wholly based on agriculture: cattle and crops.

Our water laws have changed little since 1907, but our society and economy are vastly different. Statistics from the New Mexico Department of Agriculture at New Mexico State University tell us that in 2005 the total cash receipts from all of New Mexico's crops was $621 million. That's certainly significant. But it's less than one percent of our state's 2005 Gross Domestic Product of $69 billion as determined by the U.S. Department of Commerce. Might we conclude, then, that the direct monetary value of crops grown with 85 percent of our water is less than one percent of our economy? Including the indirect financial benefits contributed by our farming communities tied to irrigated agriculture would change this statistic some, but not much.

[Crop production's] priority status in water use is well recognized in its ownership of most of New Mexico's senior water rights.

Like it or not, this illustrates the dramatic imbalance in the use of and benefits from New Mexico's water today. From it, might we also determine that many of our water woes are or will be as much a product of unchanged, long term, archaic, and – dare it be stated – obsolete management of available supplies as they are of shortages?

None of us here were around when the state's water laws were codified. Or when irrigation and conservancy districts were formed. Or had anything to do with enacting river compacts. So we can't take responsibility for initiating, developing, and approving them. Yet, these are the very elements that have absolute control over our lives today and, in some cases, threaten our economic future. But those leaders and decision makers in charge now and those coming along behind them are and will be responsible if they don't recognize that following many of the identical water paths of our ancestors may lead us to crisis if not catastrophe. Is it too provocative to suggest that it's time, perhaps, to question compacts or adjust ancient water laws to present and future conditions? Forty years ago New Mexico's greatest water legend, former state engineer Steve Reynolds said, "Pigs will fly before we ever change those compacts!" Perhaps somewhere in all the great technical, medical, and scientific advances that have taken place since that statement, there's now a pig with wings!

It is clear that to meet future needs of our citizens and sustaining or improving the economic vitality of our state, providing new uses from New Mexico's fully appropriated water supplies will require easy and expedited transfers of water from irrigated crop agriculture. This doesn't necessarily mean sale of water rights. And it doesn't necessarily mean a dramatic change in the way a farmer does his business or grows his crops.

Under current water law it is relatively easy to transfer water use from one irrigated tract to another within an irrigation or conservancy district and acequias, but very difficult, costly, and time consuming to convey the same water right to a different use, place of use, or new point to divert it. The latter can be done, but it usually requires a sale of the right and a concurrent permanent loss of the water to the originating location and owner. In general, farmers who could conserve irrigation water that might be shifted to other uses are constrained by "use it or lose it" provisions, time and expense, loss of the right, lack of infrastructure and storage facilities dedicated to marketed water, and – perhaps most of all – the absence of sanctioned water markets.

If laws and rules are modified slightly, water that is surplus to irrigation needs that has been authenticated but perhaps not fully and expensively adjudicated can be leased, preserving ownership in the region of origination as well as the holder of the right. If properly sanctioned and accompanied by minimally restrictive institutional administration and regulation, active and transparent water leasing markets will be established that won't destroy the utility of the farm or dependent communities. And because these markets preserve the integrity of ownership in the right holder and its region of origination and the term of use or transfer is not permanent, institutional administration and regulation should be considerably less than those required of a sale.

We've all encountered farmers, some of whom are attending this meeting, who will admit that with adequate incentives, usually money and assurances against loss of water rights, they could conserve,

salvage, or save a substantial part of their water and still grow their crop. This water will become a primary source of "water left over after needs are met" and will be of great benefit to all water users during good and bad water years, providing extra income and less work for the farmer and rapid and easier access to water by those needing it.

I promised earlier to describe some other sources of water that we can consider "left over after needs are met." Let me digress to include some of these before I conclude.

- Recent years of drought leave the impression that sources of surplus or unused water are limited or non-existent in New Mexico. One has only to review the storage history of Elephant Butte reservoir in the '80s and '90s to learn that there were several years of overcapacity that resulted in actual or calculated "spills" over the dam. During "spill" years, not only are all Rio Grande Compact credits and debits accrued by compact states eliminated, the volumes of water overflowing are "free" of any compact requirements and accounting. Spill water volumes of more than one and a half million acre feet were lost during these periods. It will happen again, and the state should initiate procedures to "shortstop" this water, clean it up and add it to storage, preferably underground.

- Provisions of the Rio Grande Compact permit participating states to accumulate debits and credits based upon over or under annual deliveries of compact water. It would be prudent for the state to begin efforts to determine the conditions, tradeoffs, and negotiations that could lead to storage of its Rio Grande Compact credit water, currently 168,000 acre feet, in the Middle Rio Grande underground aquifer.

- There are geologically and hydrologically unexplored basins in New Mexico potentially capable of containing large volumes of potable water. A recent example is the Otero Mesa Salt Basin south of Alamogordo, described by the USGS as containing 45 million acre feet of freshwater. We should be actively searching for them.

- Some of us recall a very prosperous uranium industry in the southern San Juan Basin in the late 1970s. But how many remember that almost half of the electricity PNM generated then was devoted to that industry to pump enormous volumes of water from their underground mines? That water is still there.

- Research must, of course, continue on efforts to make use of the state's immense reserves of brackish water. Currently the main barrier appears to be the expense of the large amounts of energy required. Not all ideas are new. Would it surprise you that I have in my library a copy of a 400-page study for the Federal Energy Agency completed in 1977 by Los Alamos National Laboratory that describes the feasibility of a 2,480 megawatt nuclear generating plant in the Tularosa Basin, using brackish water as a cooling medium and 340 MW of its electricity to condense this water to provide 380,000 acre feet of water containg 5 ppm of dissolved solids annually?

- And, what could be called the "Las Vegas Solution?" That Nevada city, facing eminent critical water shortages, has floated the idea of constructing large desalination plants for coastal California cities in return for a portion of their Colorado River allocation. Ridiculous? Who knows?

Finally, validated or authenticated water rights and sanctioned water markets are only one part of solving the water puzzle. To think out of that box or bucket we've been in for a hundred years, the state needs to look beyond adjudication to eventual storage of leased water and assuring that it can be held over and is not subject to meeting compact or other requirements subsequent to its acquisition. If this is done, dramatic new paradigms have appeared in recent years that can go a long way toward accompanying and accomplishing long-term water planning and availability.

The most dramatic new dynamic is the completion of the Albuquerque Bernalillo County Water Utility Authority's (ABCWUA) 400 million dollar municipal water supply system to remove water from the Rio Grande, clean it up, and distribute it to the community. Half of this cost was for the stand-alone treatment plant.

Second is the groundwater aquifer underlying the Middle Rio Grande Valley. Over the past 40 or 50 years it has been the source of water for the valley communities and during this time has been depleted of about 1,000,000 acre feet of its stored water. Much of

the space formerly occupied by aquifer water is now available for cleaned and injected river water that may be leased and left over after needs are met. Over time, with sufficient new water filling the aquifer, domestic requirements are more easily met and the Rio Grande could once again become a gaining stream that would more easily meet compact requirements.

Third might be the proposed Navajo-New Mexico settlement of San Juan River water rights. If and when accomplished, it gives the Navajos about 340,000 acre feet of the 611,000 acre feet of San Juan water allocated to New Mexico under the Colorado River Compact. They currently can't use this amount because their irrigation project is unfinished, and a large part of it still flows downstream to slake the thirst of California. Today, it's the greatest source of surplus water in the state.

Then we deal with some What Ifs that require out of box thinking and some legal maneuvering. And I acknowledge that the older I get the easier it becomes to make provocative statements and draw conclusions that in earlier years might have been considered impractical, irrational, unreasonable, or worse. Today, to me, in this context, they're bold and creative.

- If the Navajos agree and the State Engineer grants approval for Rio Grande water users to lease Navajo surplus water.

- If Congress approves transferring this water, in addition to our San Juan-Chama water, through the continental divide tunnels to the Rio Chama (The capacity is there. It is restricted to 110,000 acre feet by federal law).

- If the Corps of Engineers (CE) and Rio Grande Compact participants approve increasing Abiquiu reservoir's storage capacity to temporarily accommodate this water (it's currently restricted by CE and Compact to 183,000 acre feet). There would be tradeoffs for gaining approval (like sharing a portion of this leased water to southern New Mexico, Texas, and Colorado). But we'll never know if we don't indicate a willingness to negotiate.

- Then, the lessees of the stored leased Navajo water negotiate with ABCWUA for use of its treatment plant to clean and inject it into the underground aquifer where, under certain conditions it is "on call" for drought or other contingencies.

- I mentioned earlier the very impressive water savings Luna County's farmers derived by their switch to drip irrigation. That isn't a directly feasible option for irrigators on the Rio Grande. Not only because of cost, but because this drip system relies on clean water obtained from the underground Mimbres basin aquifer. But, what if water users in the Middle Rio Grande valley cut a deal with irrigators to provide them with clean irrigation water and the infrastructure to distribute it in return for the water the process saves? It might be considerably less than constructing a water treatment plant or purchasing water rights at current prices in excess of $12,000 an acre foot, assuming they're available.

Thanks for indulging me in defining water that is or could be "left over after needs are met" and what could be done with it. These are choices, some more viable than others, that in lieu of the return of a permanent El Niño might avoid an inevitable crisis. Doing nothing is not an option and in the midst of a crisis might invite the wrath of an outraged public that would demand and compel remedies much more dramatic than these. If you agree, I encourage you to express your thoughts to our decision makers. Thank you.

Albert Rango *is a research hydrologist with the USDA-ARS Jornada Experimental Range in Las Cruces, NM. He has B.S. and M.S. degrees from Penn State University and a Ph.D. from Colorado State University. Al has over 350 publications in the fields of remote sensing, rangeland applications, watershed management, and snow hydrology. He is a past president of the IAHS International Commission on Remote Sensing, the American Water Resources Association, and the Western Snow Conference.*

FUTURE CLIMATE CHANGE IMPACTS ON NEW MEXICO'S MOUNTAIN SOURCES OF WATER

Albert Rango
USDA-ARS-Jornada Experimental Range, Las Cruces, NM
Enrique Vivoni, New Mexico Tech, Socorro, NM
David Gutzler, University of New Mexico, Albuquerque, NM
Brian Hurd, New Mexico State University, Las Cruces, NM
Stephanie Bestelmeyer, Chihuahuan Desert Nature Park, Las Cruces, NM

I am going to talk to you about a project Dave Gutzler mentioned earlier whose goal is to study the possibilities of what is going to happen as a result of future climate change and how that is going to impact New Mexico's mountain sources of water. I hope to tell you why that is important. I do want to point out, based on earlier discussions at this conference, that the three major research universities in New Mexico are just working together happily—Aggies, Lobos, and for want of a better word, the Techsters. The reason I don't know their nickname is because they, surprisingly, have no NCAA varsity sports at that school. I've also discovered when going to meetings there that they have no requirement for parking permits on campus. I don't know what this world is coming to with no nickname and no parking permits. In any event, we are working well together and hoping that this project goes forward. It is an EPSCoR project, which is being submitted to the National Science Foundation, so it is not yet finalized. If successful, it will be funded for a five-year period. I am going to outline to you what that involves and show you some early results because we have been working on this research topic.

You saw this slide already from Dave Gutzler. I don't have to go over it. I will just confirm what others have said: it is going to get warmer here in New Mexico. Dave has explained this quite nicely. He has also shown you this slide (see Figure 1). I just want to indicate that this is the Del Norte basin in Colorado on the Rio Grande and the most highly productive tributary in the Rio Grande basin. As a result of this increase in warmth, the snowline is going to retreat to higher elevations. As Dave Gutzler mentioned, the depletion curve of snow covered area in the lowest elevation zone in the Del Norte basin—will go from what it is today in this particular year to virtually zero snow cover in future years. All these other elevation zones higher up will experience decreasing snow cover. This was generated from a test, with a model that I will talk about later, using a two and a half degrees Celsius warming. It is going to become very important, and as we have seen earlier, this warming has already begun and will continue.

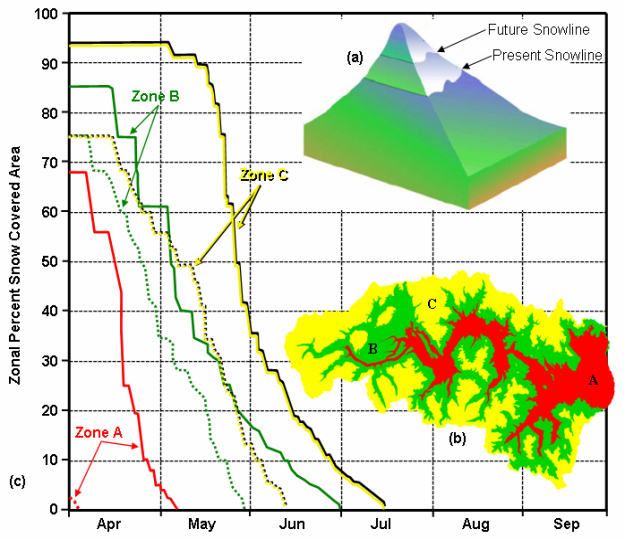


Figure 1. Remote sensing and the Snowmelt Runoff Model have been used to analyze climate change impacts on snow covered area and the resultant effects on water supply derived from the snowmelt.

There are a number of important aspects of this problem of water supply forecasting as shown in Figure 2 (courtesy of R. Abramovich, NRCS, Boise, ID). Water forecasters have a problem early on in any particular year coming up with volume forecasts. Following the volume forecasts, they are then asked to do peak-flow forecasts and then eventually low flow forecasts. The users are very dependent on these forecasts. When they reach the time of low-flow forecasts, people are starting to ask what will happen next year. Water users and managers have a real problem in knowing what the water supply will be in the future, and we would hope to help in this area as well. One of the things that forecasters do is look at the El Niño/La Niña phenomena. In Figure 3 (Courtesy of D. Gutzler, UNM), you can see that it means different things in different parts of the west. In the Idaho area and in other parts of the northwest, El Niño means a very dry year for them, whereas, in New Mexico and parts of Arizona and Utah, an El Niño year is a nice thing if you like above normal runoff. The forecasters have told me that they do not want to put all of their eggs in one El Niño basket when forecasting, so they need additional techniques. I'll show you a little bit of what happens here.

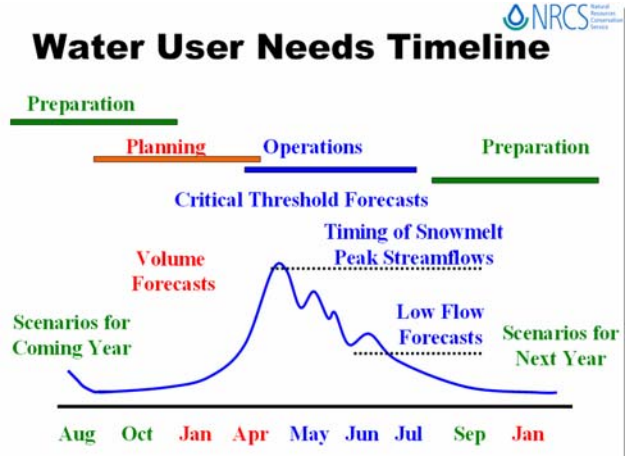


Figure 2. Water user needs timeline that results in different types of forecasts.

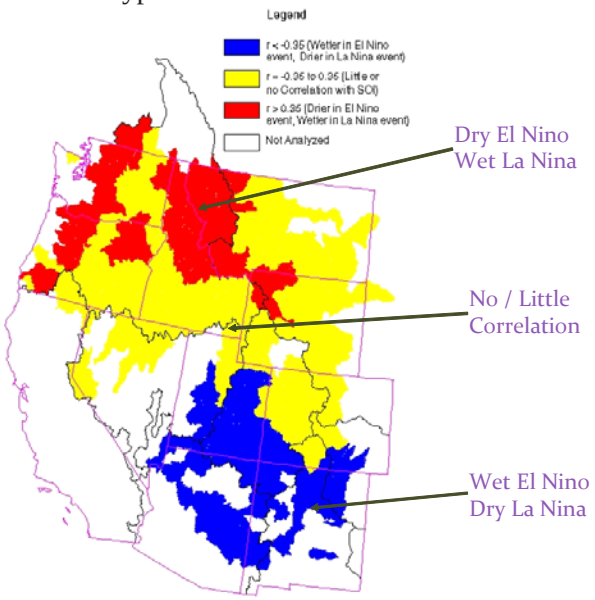


Figure 3. El Niño phenomena in the West as it impacts water availability.

We've mentioned throughout this conference that the snow cover is going to decrease, and we might be more reliant on the monsoon season in the summer for some of our water supply. If we look at this particular map, also from Dave Gutzler, it shows that we are very reliant on the snowpack accumulation, but we have learned to be flexible in the summer as well. This slide (Figure 4) shows the percent of annual average precipitation that occurs in July through August. You see that less than ten percent occurs in the upper northwest and Idaho, whereas parts of Colorado and Arizona and most of New Mexico can experience up to 40, maybe even 50, percent of their total annual precipitation during this time of year. As an example, back in 2006, it was an extremely good monsoon year in New Mexico. You can see that New Mexico in the monsoon season was 150 to 200 percent of normal. What resulted from the high monsoon precipitation was a lot of runoff. It blew out arroyos in Hatch and caused a lot of turmoil in the form of flood damage. During that period, Elephant Butte Reservoir, which is usually releasing water then so that the water level is going down, actually stabilized and experienced a slight increase in the water volumes stored there. We need to take a look at this for a lot of the streams in the southern part of the state to see if we can be ready to catch this flow. It was mentioned in a couple of the talks earlier.

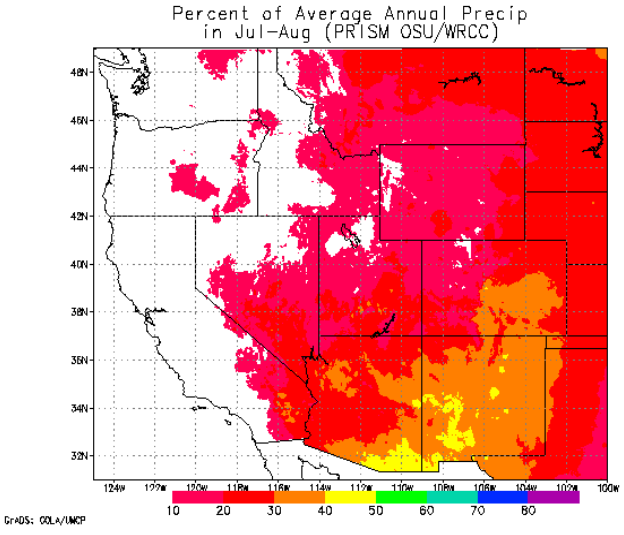


Figure 4. Percent of average annual precipitation occurring in July - Aug (PRISM OSU WRCC) for different western states.

Let's look at the Rio Grande in Figure 5. This is the area that we are focused on. It covers two countries and eight different states, including the Mexican states. The river length is about 1,900 miles, the third longest in the U.S. The drainage area is about 336,000 square miles. It includes the Pecos and a major tributary in Mexico, the Rio Conchos. The lower two-thirds or three-quarters of the basin receives only seven to fifteen inches of precipitation a year. Another look at this in Figure 6 shows that the major population areas are somewhere near or along the Rio Grande. If we overlay the Chihuahuan Desert, which is North America's largest desert, we see that the Rio Grande actually flows through a lot of the Chihuahuan Desert and past these high population areas. If we look further, we see that along the northern perimeter of the basin, the red area, is where a large portion of our runoff comes from that makes its way down the Rio Grande. It does dry out below El Paso, but because of the tributaries coming in southeast of El Paso, the flow of the river resumes. There is a public misconception of the importance of snow to the water flow because few people live in the snowmelt areas, whereas a preponderance of people lives in the desert portion of the Rio Grande.

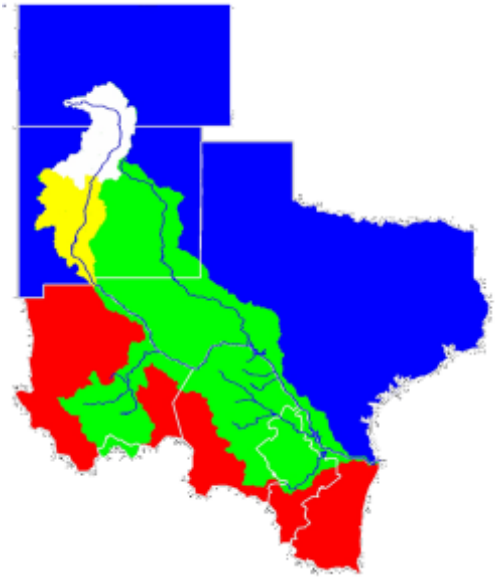


Figure 5. Characteristics of the Rio Grande: 2 countries, 8 states; river length 1,900 miles; 3rd longest in the U.S., 21st longest worldwide; drainage area: 336,000 mi^2; which includes Pecos River and Rio Conchos; lower 2/3 of the basin receives only 7-15 inches of annual precipitation

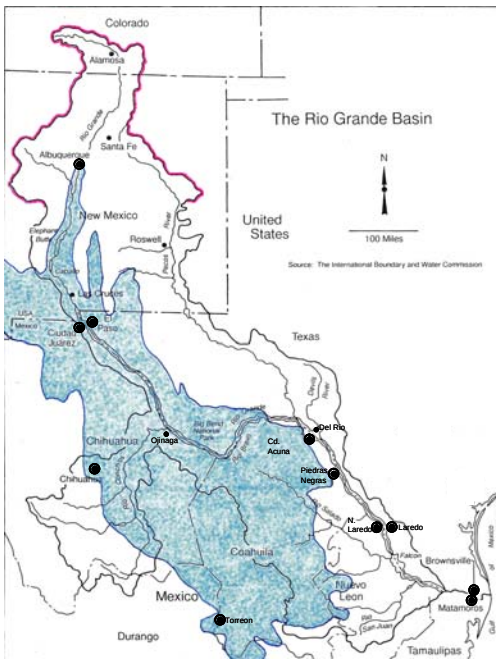


Figure 6. The relative locations of population centers (20,000-100,000 and over 100,000) and water supply source areas (in red) in relation to the Rio Grande main channel and the Chihuahuan Desert (in blue) results in a public misconception of the importance of snow.

The reason that snow is so important is that it accumulates for the entire winter and then it melts off in a very short period of time, from several weeks to a month or month and a half. The snowmelt runoff, because of this, is a very efficient runoff process, more efficient than rainfall runoff. In the mountainous areas, the soils are relatively thin, and as a result, not much of the water percolates to the groundwater reservoir at the higher elevations. Most of the high mountain snowmelt makes its way to surface runoff. In the Rocky Mountains, about 90 percent of the total runoff results from snowmelt. In the upper Rio Grande, it is down to about 75 percent because we are further south. Around the world, some of the mountain basins have 99 percent of their runoff coming from snowmelt. The contribution of snowmelt is going to change here in New Mexico first, actually. If we examine different parts of the basin, in the Colorado portion, the snowmelt contribution averages about 51 percent and can exceed 75 percent in specific tributaries. If you go further south into the northern New Mexico tributaries of the Rio Grande, about 35 percent of the runoff comes from snowmelt, which could vary between 16 and 60 percent. There is even a small snowmelt component down around Elephant Butte.

Figure 7 shows the basins we are going to study. You'll see that the Colorado-New Mexico boundary is here. These are the basins, the Rio Chama and the Rio Hondo, that we are going to look at in great detail with additional instrumentation and field studies. We will investigate all the shaded basins because they have a significant snowmelt component at present. Using remote sensing data, we will be looking at the tributaries in Colorado as well. The most productive tributary is the Rio Grande near Del Norte, Colorado. The Conejos River basin is another very important snowmelt runoff basin, and then all these other basins that I identified in Figure 7. The study basins where we will be doing extensive instrumentation will be the Rio Chama, the Rio Hondo, and, because of prior studies there, the Jemez River basin. You will see that different watershed models will be running in these different areas.

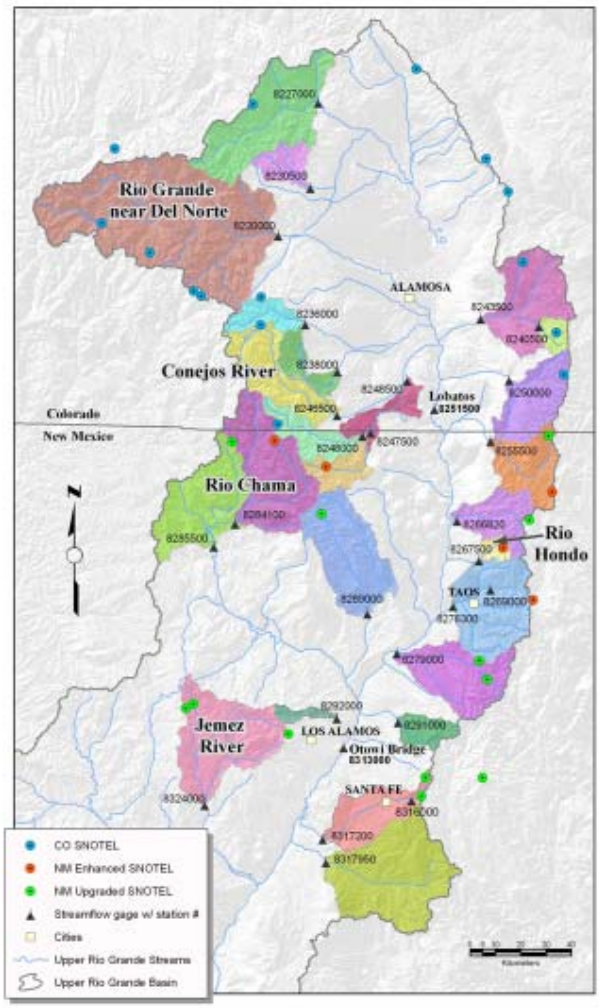


Figure 7. Significant snowmelt runoff basins in the upper Rio Grande used to evaluate the potential effects of climate change

We are going to be using remote sensing data as input to several of the different models. The first model (shown in Figure 8, courtesy of Enrique Vivoni, NMT) is one that is being developed at New Mexico Tech, tRIBS, which is a distributed hydrologic model that is very detailed and works on a very small grid size and requires a lot of data on soil moisture, infiltration, heat fluxes, radiation and energy balances, interception, and evaporation. Because of that, it is a very data-intensive model, and it can only run currently on relatively small tributaries. In addition to streamflow generation, we learn a lot from this model about the different processes that are important in a particular basin and what is happening to them as the environment changes. Enrique Vivoni has recently also modeled the winter part of the hydrologic cycle with tRIBS. This particular portion of the model is what we will be testing in these snowmelt basins.

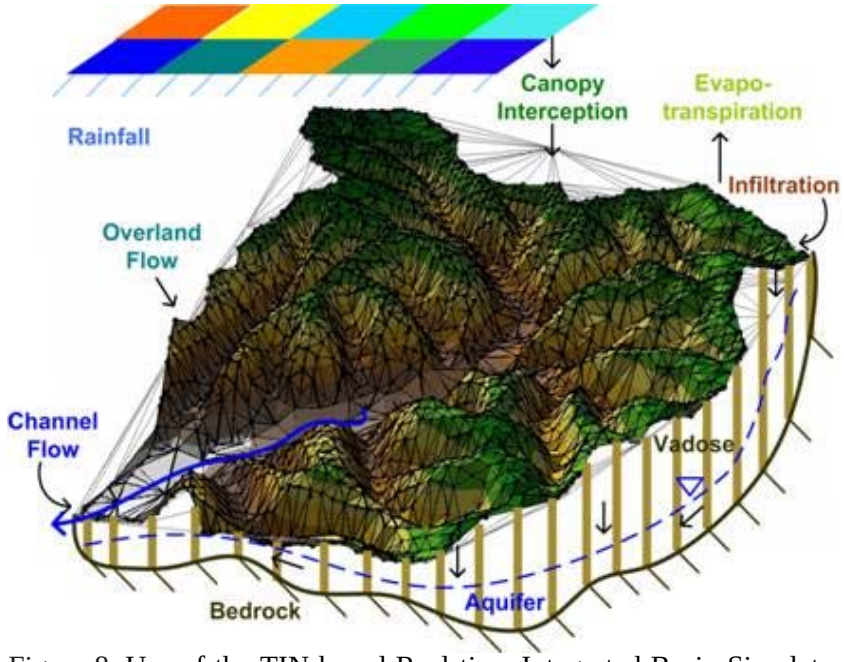


Figure 8. Use of the TIN-based Real-time Integrated Basin Simulator (tRIBS) for distributed modeling of coupled hydrologic processes in complex basins.

Another one that I know more details about is this snowmelt runoff model (SRM) shown in Figure 9. It is a model that requires three major inputs: temperature, precipitation, and remotely sensed snow covered area. In addition, it was one of the few models that was designed with remote sensing in mind. In recent years, it has added a formalized climate change algorithm. If you give me a scenario of how the precipitation and temperature would change in a new climate regime, the model can then run a climate change scenario for you and give you a change in basin runoff as a result of climate change. We have done this on a number of basins. First of all, SRM has been tested mostly on basins, like the basins chosen for this study that I showed you in Figure 7 that range from 100 square kilometers to about 10,000 square kilometers in area. It has been tested around the world on about 120 basins. It is capable of producing for the user the percent of runoff coming from seasonal snowmelt, from new snow melting, from rain, and from ice melt as shown in Figure 10. This particular model in Switzerland has a glacial component that we do not need here. When working with SRM, we are using the MODIS satellite sensor data. It is input for deriving the snow cover depletion curves that we talked about earlier that will change with warmer conditions. The snow cover is directly input into the SRM model along with the temperature and precipitation.

Figure 11 shows a comparison of the MODIS snow mapping for the Rio Grande near Del Norte. It shows you that in the middle of March in 2003, there was relatively little snow cover in the upper elevations, more snow in 2004, and 2005 in this particular basin was a relatively good runoff year. It shows about 59 percent snow covered area. It shows you that snow cover can vary from year to year. It can be very important generating runoff.

Not going into all of the details here, it is sometimes asked why we use snow cover and not snow water equivalent. We use snow cover from existing satellites on a very repetitive basis, so we chose to go that route because we can keep track of the snow with time in the basins and you can only melt so much snow on a given day. If the satellite passes are relatively frequent, we keep up with the changes in the snow covered area. The problem with trying to do it for snow water equivalent is that it is very difficult to get areal coverage of snow water equivalent. Secondly, models that calculate snow water equivalent do it in a flawed way

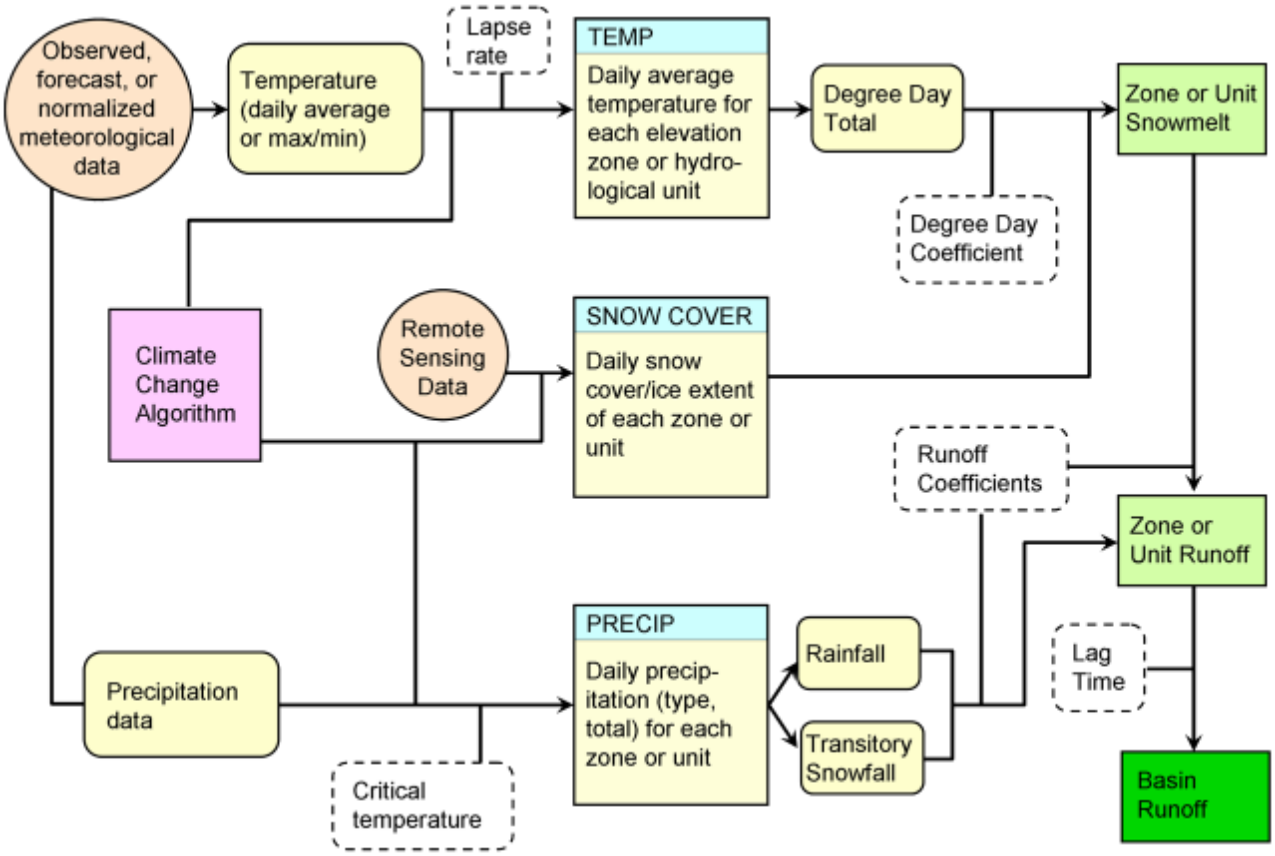


Figure 9. Schematic diagram of the organization of the Snowmelt Runoff Model (SRM)

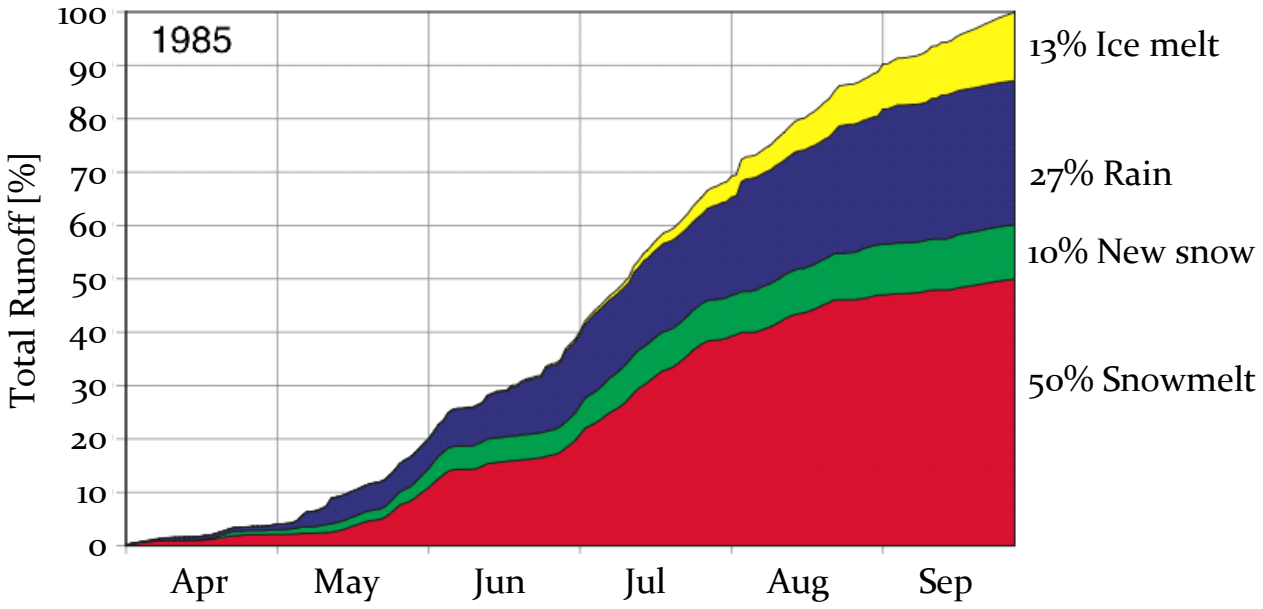


Figure 10. Contributions of runoff components in the basin Rhone-Sion (3371 km^2, 491-4634 m a.s.l.) as determined by SRM

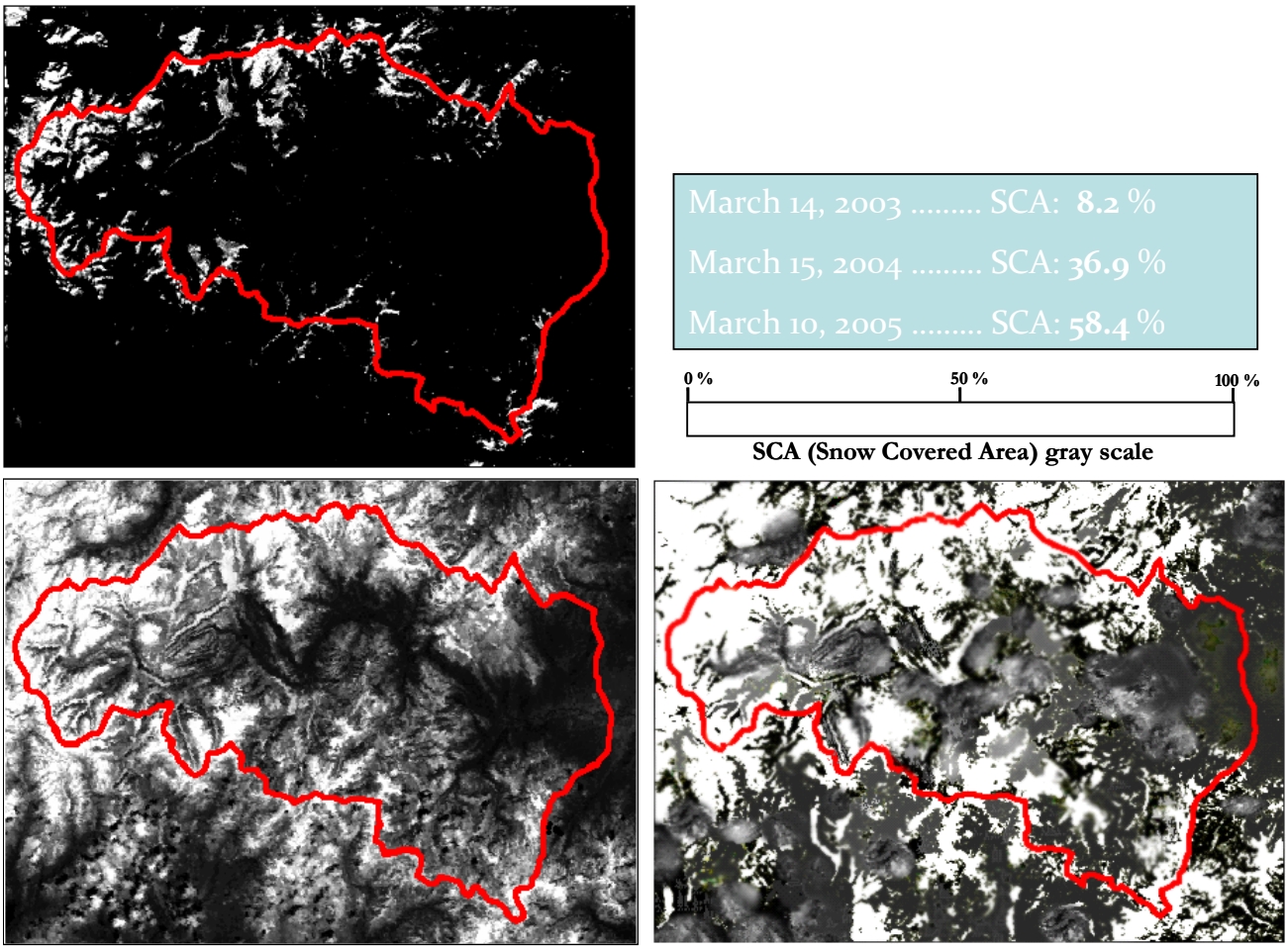
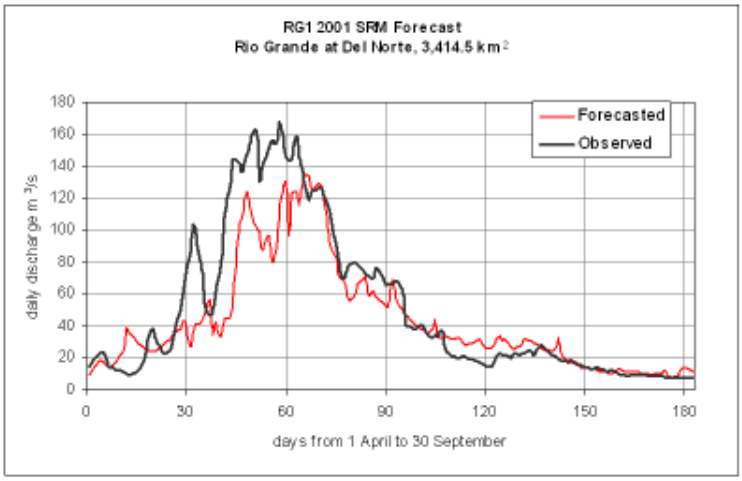


Figure 11. MODIS snow mapping for the Rio Grande at Del Norte Basin (3,415 km^2) near March 15

because they use precipitation data they have at gauging stations and do not correct for the wind-caused undercatch that these gauges experience up in the higher elevations. Without the catch-deficit correction, the model parameters then have to be tweaked later to account for that. We prefer to use the real data from snow cover rather than generate snow water equivalent and have to correct the model later.

In any event, we used the model for forecasting in 2001 on the Del Norte basin as shown in Figure 12. The dark line in this slide is the actual flow, and the red line is the forecasted flow starting on April 1 and never updated after that date. We were able to explain about 77 percent of the variation in the daily runoff through this six-month period with SRM. If we updated it with the actual flow from the day before, we, of course, get a much better fit at about 97 percent of the variation explained. We think that we can do this on nearly all of the snowmelt basins here in Colorado and New Mexico because SRM has been tested in this manner around the world in basins just like this. It has worked in every case. We are hoping to expand this to the other basins when the ESPCoR project starts.

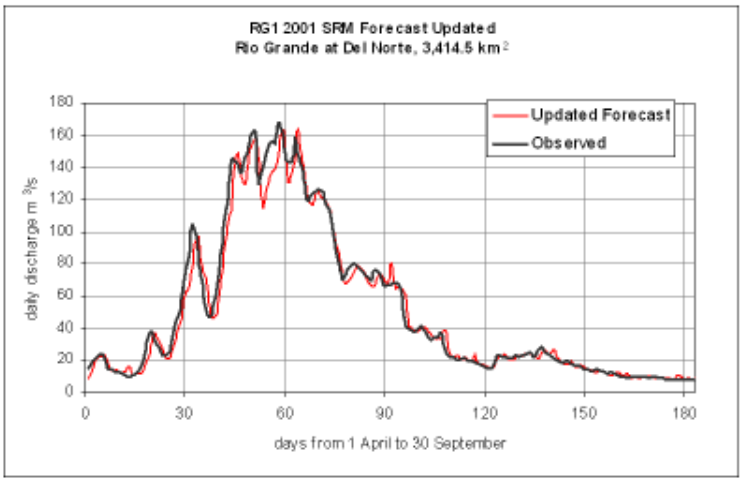
Climate change can be evaluated using the model, and if we put in various climate scenarios, in this case an increase in temperature of 4 degrees Celsius and a decrease in the diurnal range in temperature, the model parameters need to be shifted because spring snowmelt will occur earlier and earlier. It is this shift to earlier snowmelt (see Figure 13) that is going to cause problems. We have also input a ten percent increase in precipitation to SRM for this scenario which is sort of an optimistic future scenario. We are thinking, as Dave Gutzler pointed out, that the precipitation is going to go down considerably while warming occurs. By 2050 from the year 2000, this is what the hydrograph will look like. You'll see more runoff in April and May and a lot less runoff in June and July when we need the water the most. By year 2100, there is going to be a major change. You will see twice as much runoff in



1 April to 30 September:

Forecasted vol. = 692.1 Hm³
Observed vol. = 808.2 Hm³

R^2 = 0.773
Dv = 16.78 %



1 April to 30 September:

Updated forecast vol. = 786.9 Hm³
Observed vol. = 808.2 Hm³

R^2 = 0.971
Dv = 2.70 %

Figure 12. 2001 SRM Forecasting: Rio Grande at Del Norte

April and May as we got before. This reduction in flow in June-August is pretty significant. We're going to have to figure out how the reservoir storage capabilities, releases, and operating rules are going to cope with this kind of new scenario.

This is something we see in almost all of the studies that have been done on future warming effects on snowmelt runoff. There is a shift towards earlier runoff. And for some reason that we haven't quite been able to figure out yet, when this total of four degrees kicks in as opposed to two degrees, we also had this peak that exceeded the existing peak in 2000. A threshold could have been exceeded here. This is the kind of situation that scientists are saying could lead to an increase in significant events like flooding and drought.

The final model that we will use is the SLURP model, which is the total river basin model that accounts for irrigation diversions, endangered species requirements, urban diversions, and industrial water supplies. Any changes that we put into this basin can be accounted for. In addition, SLURP, which covers the entire Rio Grande, has been modified to take outputs directly from SRM as an input at the various gauging locations. They are working in tandem. As I mentioned, it is a total basin model. It is good for "what-if" management scenarios. It has been applied to many basins throughout the world as well. It actually was developed outside the United States. It can model linkages between farm and irrigation schemes at relatively small scales as well as very large basin scales, diversions into the basin, and so on. It also uses remote sensing data and is another of the few models that were designed to work with remote sensing data. We will probably run it for future scenarios either using the climate stations on a grid like this or perhaps with input from general circulation models running into the future that would provide the temperature and precipitation that we need at these grid points across the basin.

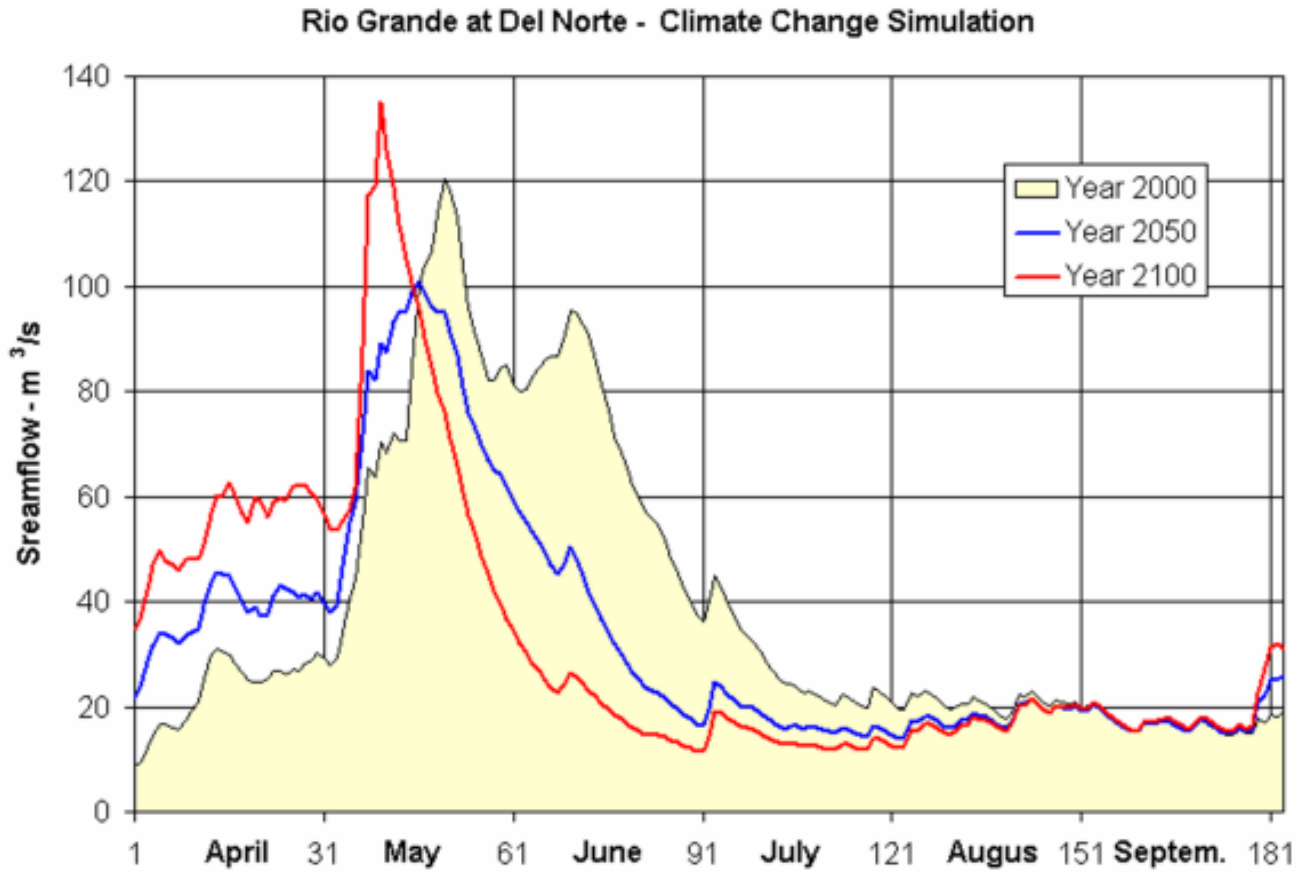


Figure 13. Climate change simulation Rio Grande at Del Norte with periodic changes throughout the 21st century. By 2100, temperature has increased by 4 degrees C, the diurnal temperature range has decreased by 1.4 degrees C, model parameters are shifted, and a 10% increase in precipitation is expected.

I will not talk about this because we saw it yesterday, but all of these models will be linked to the RioGEM model, which is the hydroeconomic model for the Rio Grande that Brian Hurd has developed and Julie Coonrod reported on yesterday. We will be looking at the economic side. We are also linking the model results to education and outreach in the project. We have a method for taking the results from the science and climate change impacts on mountain sources of water and getting the information to various state and tribal entities, science educators, who of course then will address the K-12 community, undergraduates, and graduates. We hope to be working very closely with the educators to get this out.

The major objective here is to continuously measure the spatial distribution of key variables that affect the water quantity in New Mexico's mountains: snowfall, snowmelt, rainfall, evapotranspiration, soil moisture, and runoff. To do the snowmelt portion, we will be increasing the number of SNOTEL sites in the mountains by five. We will also be upgrading 12 of the SNOTEL sites that exist to provide more relevant data from these particular locations. The climate networks will be upgraded, at least in the northern part of the state. SCAN stations from the NRCS will be installed to measure soil moisture at four new locations in the north. We are hoping to install a few more runoff stations where the tRIBS model will be tested. We have these three models that I mentioned in addition to the economics model and the climate models that feed these models. These will be semi-operational basin models from fine resolution all the way up to the river basin scale. They will allow the climate change impacts to be assessed. We hope that the research will provide a better understanding of how the hydrologic processes will be susceptible to climate change. We will also have cyberinfrastructure money in this project, along with high performance computing in order to be able to run the models very efficiently.

We have three hydrologic models that are already operating in some way in New Mexico. They can be used to improve the forecasting of flow over employing just the current methods. That is a start. Improving forecasting is important. We have the methodology being developed that will allow projections into the future that will allow assessment of the effects of climate change on our water supply. We need, from what we have seen in prior model runs, to start adapting now to new climate and a changing water supply. We have the chance with this NSF-EPSCoR project to upgrade our instrumentation networks, improve our computational power, storage capabilities, and develop our remote sensing capabilities to understand better what is going to happen with this new climate. Based on that—and these objectives get progressively more optimistic or tough to achieve—we will have new forecasting approaches. We need to, based on that and the climate scenarios, adapt our water use. That will be difficult. What will be more difficult is modifying reservoir operating rules and the Rio Grande Compact. In a new climate, one would hope that these would change to be able to cope with the hydrologic effects of new climate. One goal that will probably be very difficult to do is to establish moratoriums on unrestricted development based, now and in the future, on water availability. I think that we have a chance to do all these, but if we can accomplish some of them, I think we will be pretty happy.

From the early runs that we have done in a couple of basins, this is what we have learned. In extreme years, droughts are very likely going to be intensified, especially if precipitation decreases. Floods will become more common because of the dramatic nature of the monsoon events. We will probably have more problems like we had recently in the southern part of the state in future years. The gap between water supply and water demand will grow even faster than it is now because of development and population coming into the state. Even without a volume reduction, the temporal redistribution of runoff shows runoff moving from June and July into April and May. It is going to cause a major problem for the various reservoirs to cope with. Although we don't have glaciers in this basin, there will be effects on them as well in other parts of the western U.S. Reservoir operating rules will have to change. Particularly, old and weakened water systems will fail if we have more of these flashy kinds of events. We have to think about new or reinforced reservoirs and distribution systems that will be needed. We might need to put some small reservoirs on some of the tributary streams. The general circulation model generates climate change as inputs to the hydrologic models. We need to come to a consensus on these climate changes so that we can impact a particular basin with the best available information. We think hydrologic models are the only way to forecast hydrologic responses to climate change, but a consistent method of application is needed between the models.

Question: My question has to do with the upper Rio Grande and some of those areas and water management. We work pretty closely particularly with Colorado and NRCS on their similar runoff forecasts for that basin of March and April. Have you linked into that? I would just suggest that you do. Have you talked with Tom Pagono about the work that he is doing?

Rango: I visited with Tom last week as a matter of fact. We will work closely with them. NRCS is a very important cooperator in this project because not only do they have experience forecasting in those basins you referred to, they also are quite agreeable to our upgrading their SNOTEL sites and putting in additional SNOTEL sites. Once we have done that with this project, NRCS will continue to maintain those sites and run them for however long they are viable. We feel that is very important. The SCAN sites, which are in the lower elevations for soil moisture, will also be maintained by NRCS. They will do the same things for those sites. We will work with them in the forecasting mode, but particularly with the data instruments that go in to provide better infrastructure in both northern New Mexico and the southern Colorado portions of the basin, where we will be restricted to remote sensing data. Of course, we will be using remote sensing on all of the basins that I showed you today.

Question: Is there inadequate coverage of the NRCS and the weather bureau water equivalent sites right now?

Rango: There are a lot of gaps in the network. We hope to fill those gaps. In addition, I don't know if you are familiar with the fact that there is a basic SNOTEL site, which has snow depth, water equivalent, temperature, and precipitation; the enhanced sites add radiation budget instrumentation and soil moisture and so on, which turn out to be extremely good if you are using a very high powered model. They are also

important for forest fire susceptibility forecasts. Those are the kind of instruments that will be added. NRCS also hopes to answer those questions.

Question: What has the weather bureau used for decades to predict water elevation in the floods?
Rango: For decades they were using, when they used NRCS data, manual snow surveys once a month. The SNOTEL sites that were starting to be installed about 25 years ago make those measurements every day on an automated basis; those data as well as data on precipitation, snow depth, and temperature are bounced off of meteor trails in the ionosphere and reflected down to three central receiving stations in the United States. Those data are available online to everybody within a day. That is why they are very important. The National Weather Service uses that data as well in their forecasts.

Question: The picture you had of the runoff against the models showed that the end of the runoff shifted earlier, but the start of the runoff didn't seem to shift at all.
Rango: I showed you the six-month snowmelt season from April through September. We run it year round as well, and if I had shown you that, you would have seen the snowmelt starting in March, even in February in the southern part of the basin. We have the twelve month hydrograph capability as well, and you could see that.

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WATER PRODUCTIVITY AND WATER CAPITAL – ADDRESSING FRESH WATER AVAILABILITY CHALLENGES

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BACKGROUND

Access to fresh water is an increasingly critical national and international issue, especially since demand for fresh water in many regions of the world has already outstripped fresh water supplies. Based on data from the United Nation's "World Water Development Report," more than 50 percent of the nations in the world will face water stress or water shortages by 2025, and by 2050, as much as 75 percent of the world's population could face water scarcity (United Nations, 2003). Recently, the United Nations Secretary General Ban Ki-moon urged business and political leaders at the World Economic Forum in Switzerland that the looming crisis over water shortages should be at the top of the global agenda in an effort to prevent conflicts over the growing scarcity of fresh water supplies.

Like so much of the world, access to fresh water is an increasingly critical issue in the United States. This was highlighted in a recent Government Accountability Office (GAO) report in 2003 on fresh water supply availability (GAO, 2003). In that report, the GAO presented results of a national survey of state water managers on expected water shortages. As presented in Figure 1, the responses show most regions

of the country expect local to regional water shortages over the next decade under average climate conditions. Water shortages are not just a Southwestern or Western U.S. issue anymore! The reason for these concerns is a combination of high population growth in the Southeast and the West, and the continuing limitation on fresh surface water supplies and continued unsustainable use of fresh groundwater in many of the major aquifer systems across the U.S.

WATER PRODUCTIVITY AND WATER CAPITAL

The growing limitation of fresh water resources is forcing a rethinking about how water is valued, used, and managed. Water is a natural resource heavily used by all sectors including agriculture, energy production and electric power generation, industrial processing and cooling, and for domestic supplies. This makes water availability and water use a significant driver for future economic output and growth. This is highlighted in Figure 2, where growth in the U.S. Gross Domestic Product (GDP) since 1940 is compared to two economic growth indicators, water and energy supply availability. As shown, our GDP tracks more closely with the growth in water resource development over the past 60 years than with energy development and production.

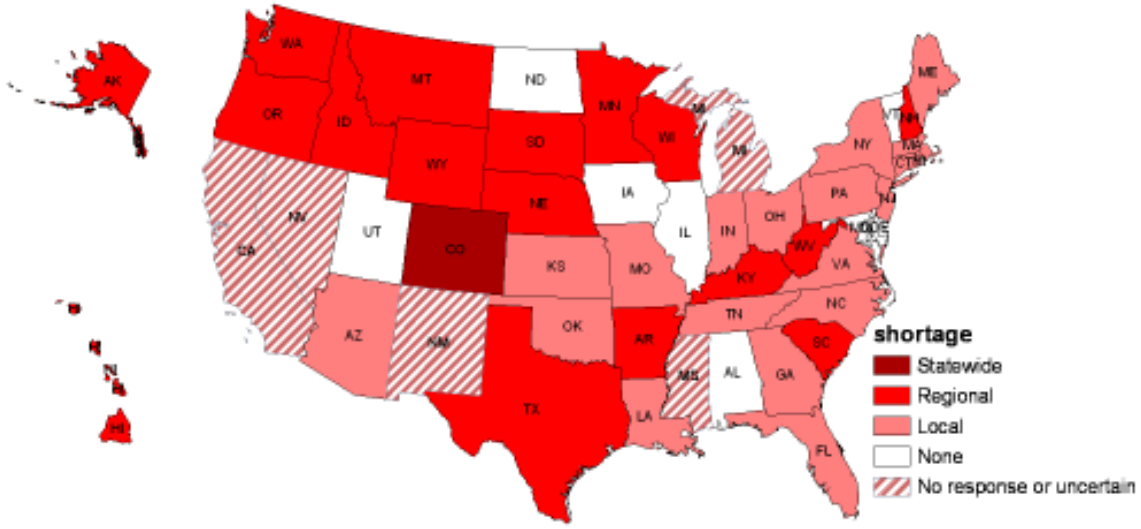
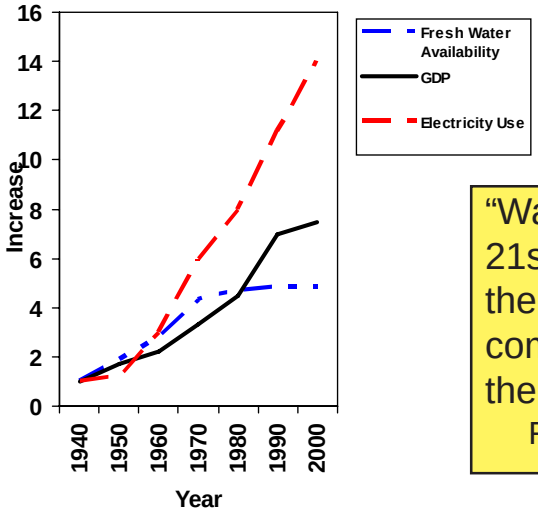


Figure 1. State Water Managers Expecting Water Shortages over the Next Decade



"Water promises to be to the 21st century what oil was to the 20th century: the precious commodity that determines the wealth of nations."
Fortune Magazine, May 15, 2000

Figure 2. Growth in U.S. GDP Relative to Energy and Water Resource Growth

Water is increasingly seen as the major critical resource driving future economic growth, and as noted in the quote above from Fortune magazine, water could become one of the most precious commodities of the 21st century. No wonder there is growing international concern over potential national or regional conflicts over water. It is also no wonder that water is now being discussed in economic terms such as "water capital" and "water productivity."

The term "water capital" is used loosely and is not well defined. In the context of economic considerations, "water capital" defines the intrinsic value of a water resource or water supply. Fresh water often has the highest economic capital in that it has the highest value, able to be used directly for almost any use at minimal treatment or cost. Therefore, using fresh water resources for applications where lower quality water could be used is not valuing the intrinsic value of fresh water, and thus wasting "water capital." In the economic analogy, the misuse of fresh water for other than high value needs is wasting capital and makes poor economic sense.

On the other hand, "water productivity" is more commonly used and denotes increasing the efficiency of use of water resources. In terms of water use, it would include efficiency concepts such as "more crop per drop" in agriculture and "more watt per drop" for electric power generation. While increasing efficiency or productivity is applicable to all water resources, when applied to fresh water, "water productivity" includes using nontraditional waters where they can be cost-effectively substituted for fresh water. This increases nontraditional water use, increases fresh water productivity, and at the same time preserves fresh water capital.

Traditionally, water management in the U.S. has relied on water allocation approaches primarily based on water quantity use or delivery metrics. Therefore, water management approaches often do not value water quality or the intrinsic value of fresh water in water allocations of water utilization. As concerns over water become more heated and fresh water supplies become increasingly strained, water management approaches that incorporate both "water capital" and "water productivity" considerations and optimization will become common.

BACK TO THE FUTURE

While this may appear to be a major shift in water management, the concepts have actually been used for millennia. For example, the Romans saw the importance of water to public health and economic development, and during the Second Samnite War in 310 B.C., chose to begin to address their inadequate and unreliable water supplies. The Roman Senate developed a water infrastructure and water management program to procure water rights from surrounding areas and develop a system of reservoirs, aqueducts, cisterns, springs, and community distribution systems to maintain a steady and reliable supply of fresh water. Many of the water systems they built are still operating as originally designed throughout Italy today, as illustrated in Figures 3 and 4.

Figure 3. Roman structure protecting a fresh water spring in Sienna, Italy

The concepts used included water infrastructure security and watershed management principles as well as approaches to optimize water capital to improve public health and to optimize water productivity. A few examples of these Roman water management principles highlighted in a Sandia National Laboratories paper (Ekman, 2001) on water security include references to Roman water management approaches from 40 BC to 95 AD. Examples include:

> "...purposely sunk their aqueducts in the ground and did not show them on their plans, so that they were not easily cut by the enemy..."
>
> "...The basins...have for the most part been connected with the different aqueducts by two pipes each, so that if an accident should put either of the two out of commission...the service may not be interrupted..."
>
> "…managed watersheds and provided treatment to insure water quality for each use..."

Figure 4. Roman fountain providing different waters for drinking and washing

> Reserved aqueducts for separate purposes
> "...separate them all and then allot their separate functions…according to their special qualities..."
> "...distributed water of three qualities, for drinking, for public baths and fountains, and for use in residences…"

The Romans understood the social and economic aspects of providing adequate water supplies to support a growing nation. As can be seen from the excerpts above, they focused on using water wisely, which drove both their water infrastructure development and water planning, which is still serving them well 2000 years later.

WATER MANAGEMENT USING WATER CAPITAL AND WATER PRODUCTIVITY CONCEPTS

To finish this discussion I would like to provide a couple of current examples of how "water capital" and "water productivity" concepts could be easily incorporated into water management strategies today. For example, Figure 5 shows the average daily direct and indirect water use per person per day. While direct domestic water use, such as showers, baths, flushing toilets, and watering lawns, is often used by planners to identify future water needs, each person uses daily a significant amount of water indirectly for irrigating the food they eat and to cool the power plants that provide the energy they need for lights, electric appliances, and air conditioning. Interestingly, the water used indirectly significantly exceeds the water needed for direct personal uses and improvements in agricultural water use efficiency and electric power water use efficiency could significantly increase overall "water productivity." Therefore, for growth planning, "water capital" and "water productivity" must be considered within a total water system needs context, which will require broader water planning involvement in sectors other than just domestic water use.

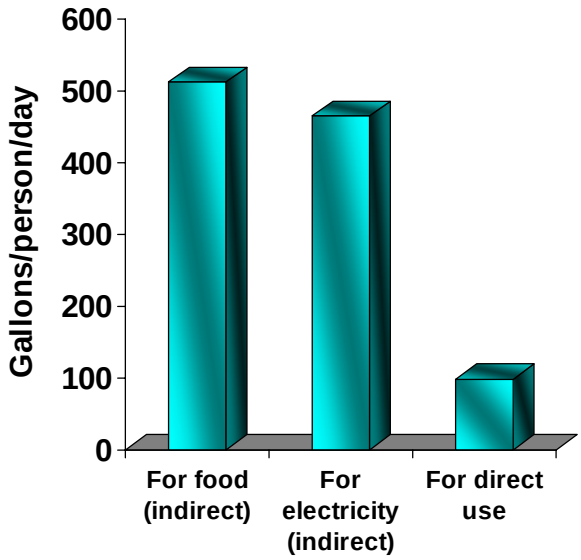


Figure 5. Average Direct and Indirect Water Use per Person per Day (Gleick, 2003)

As an example, Figure 6 below shows the water balance for a typical 500 MW, evaporative-cooled coal power plant, the bulk of the electric power plants projected to be constructed through 2030 (EIA, 2006). As shown in Figure 6, the plant uses over 5,000 gallons of water a minute. Of that amount, about 80 percent is

lost to evaporation from the cooling towers, and 20 percent is discharged to on-site evaporation ponds as high salinity blowdown or wastewater. Several options exist to increase fresh "water capital" and "water productivity" by decreasing fresh water use and increasing water use efficiency in electric power generation. Examples include:

INCREASE FRESH WATER CAPITAL

This would include approaches that eliminate the use of fresh water in electric power generation, leaving as much fresh water as possible for higher uses and saving fresh "water capital." Options include:

- Use of non-fresh water, such as produced water, wastewater, seawater, or brackish groundwater, etc. for cooling and process water
- Use of cooling technologies that do not require water, such as dry cooling
- Substituting part of the plant output with renewable energy technologies that do not use fresh water, such as wind, solar, or geothermal energy

INCREASE FRESH WATER PRODUCTIVITY

In cases where fresh water resources need to be used because of energy cost and reliability issues, options are available to increase fresh "water productivity." Examples include:

- All of the previous examples that use non-fresh water or little fresh water all increase fresh water productivity
- Utilizing hybrid cooling designs that combine evaporative and dry cooling to reduce the fresh water needed
- Using technologies to condense evaporation from cooling towers and reuse the water
- Using the blowdown pond water to grow algae for use as biofuels or animal feed, minimizing fresh water needed to grow crops or produce biofuels

These examples are not applicable to all sites and can have cost and energy performance penalties. Using brackish or seawater for cooling can require the use of special materials, water treatment, or special withdrawal approaches to protect ecosystems, all of which can increase costs. Use of renewable energy systems, because they are often intermittent, can negatively impact energy reliability. The benefits of saving water compared to increased energy costs or reduced energy reliability must be evaluated within a system-level context to balance energy reliability and costs with sustainable water use economic growth.

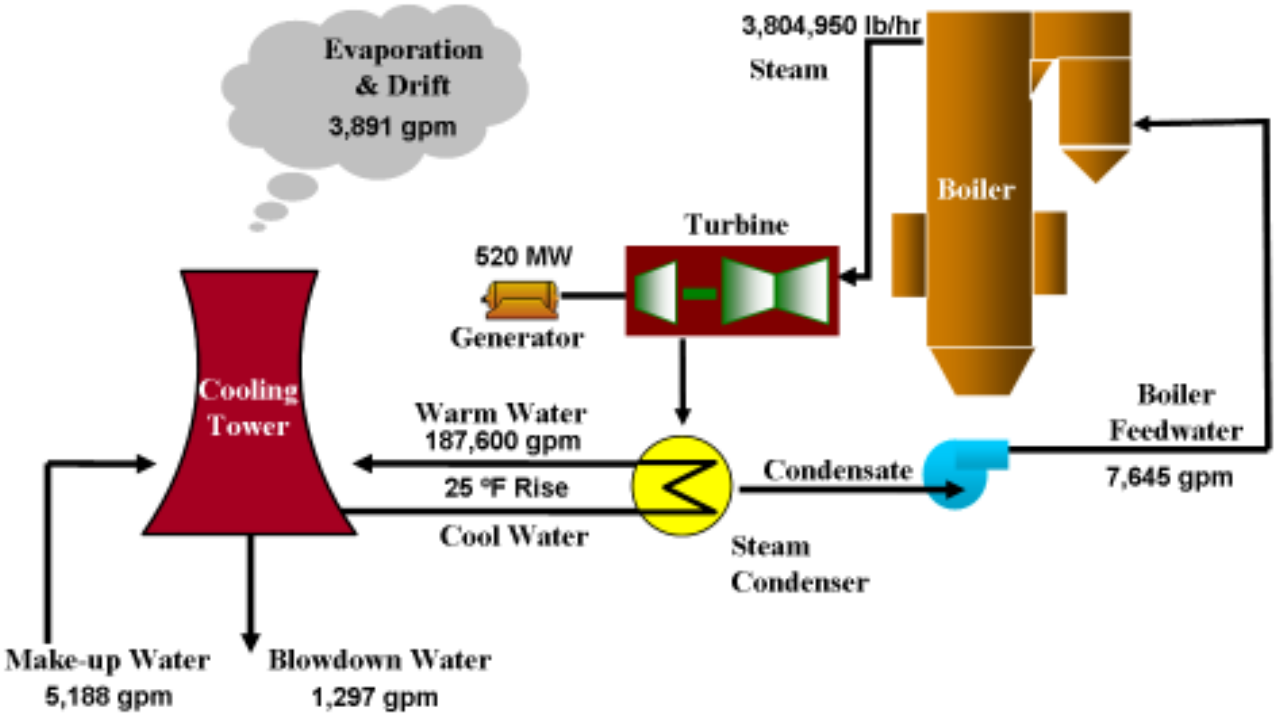


Figure 6. Water Balance for a 500 MW Coal Power Plant

The examples do highlight that terms such as water "capital" and "productivity" can provide a metric for integrating sustainable water and natural resource management within a system context.

A similar set of considerations and water use improvements can be presented for the agricultural, industrial, and domestic water use sectors. Improvements in irrigation practices and return flow reuse, domestic and industrial wastewater reuse, and improvements in water use efficiency in each sector have increased "water productivity" and preserved fresh "water capital" for future uses.

CHALLENGES AND EMERGING OPPORTUNITIES

Integrating water and natural resource policies and management approaches is unfortunately easier said than done. This is especially true in any state with different agencies managing energy resources and development, water resources and development and water rights, environmental and ecological oversight, coastal development, and economic development. In general, this is most states! In many cases state agencies have policies that discourage preserving fresh "water capital" or increasing fresh "water productivity." For example, while Texas encourages the use of coastal waters and seawater for desalination and power plant cooling, which preserve fresh water and reduce fresh water use, California's Coastal Commission has severely curtailed opportunities for siting coastal power or desalination plants, unwittingly exacerbating California's endemic and worsening fresh water demand and supply problems.

On the other hand, innovative water treatment technologies have significantly increased the ability to use non-traditional water resources such as brackish water and wastewater more cost-effectively and for a larger number of purposes, encouraging their use. Technologies like GPS have accelerated the use of drip irrigation and improved water use efficiency in agriculture as well as improved computing, and communication and control technologies have significantly improved water control, management, and use in all sectors. Innovative technology development and implementation will enhance opportunities to further improve fresh water use and conservation.

As noted above, water management concepts using metrics such as "water capital" and "water productivity," though used extensively in the past, are not current water management drivers. To meet future water demands sustainably, water supply and use associated policies such as agricultural, energy, industrial, domestic, and environmental will need to be considered within a system-level water management context. By incorporating emerging technology improvements and utilizing concepts and metrics such as preserving "fresh water capital" and encouraging "fresh water productivity," we can effectively manage our water and natural resources in a way that preserves our fresh water resources while meeting future economic development water demands.

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