WRITTEN TESTIMONY OF
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HEARING ON CURRENT DROUGHT CONDITIONS AFFECTING NEW MEXICO AND THE STATUS OF REPORTS TO BE ISSUED PURSUANT TO SECTIONS 9503 AND 9506 OF THE SECURE WATER ACT REGARDING A REVIEW OF THE CURRENT SCIENTIFIC UNDERSTANDING OF THE IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES AND AN ASSESSMENT OF THE RISKS ASSOCIATED WITH CLIMATE CHANGE ON WATER RESOURCES IN CERTAIN RIVER BASINS.

BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
U.S. SENATE

APRIL 27, 2011

Chairman Bingaman and other members of the committee, thank you for the opportunity to speak with you today on climate variability and climate change as they relate to water supply in New Mexico and the broader Southwest United States.

My name is Jonathan Overpeck. I am the founding co-director of the Institute of the Environment at The University of Arizona, where I am also a professor of geosciences and a professor of atmospheric sciences. I have published more than 140 papers on climate and the environmental sciences, and recently served as a coordinating lead author for the U.N. Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (2007). I have been awarded the US Department of Commerce Bronze and Gold medals, the Walter Orr Roberts award of the American Meteorological Society and a Guggenheim Fellowship for my interdisciplinary research. I also serve as principal investigator of the Climate Assessment for the Southwest (CLIMAS), an interdisciplinary Regional Integrated Science and Assessment (RISA) project funded by NOAA. In this capacity, and others, I work not only on generating climate system knowledge, but also on supporting use of this knowledge by decision-makers in society. I am a well-known expert on climate variability and change, as well as drought.

Overview of testimony

In this testimony I first discuss the current severe drought that is affecting New Mexico, Arizona, Texas, Oklahoma and adjoining regions. I then put this current drought in a 2000-year perspective that makes it clear that the current drought, although serious, is modest compared to the magnitude of drought that could happen in the future even in the absence of climate change. I

then focus on the dominantly human-caused climate change that has already started in the Southwest, and how continued climate change could make the risk and impacts of drought and decades-long megadrought much greater for the region that includes New Mexico. In my discussions of past natural drought and likely future human-caused climate change, I cover the well-established science, as well as provide updates on important new science that is just emerging. *The bottom-line is that New Mexico and the rest of the broad Southwest – extending from California through east Texas and Oklahoma – are at an increasing risk of unprecedented warming, drying and drought, and should prepare accordingly to ensure secure water supplies through this century.*

The current drought

The current drought is part of a broader western – and southwestern – drought that has persisted on and off across the region since the late 1990's. As such, the current drought is an extension of the worst drought the region has seen in the 100+ years of rain gauge record. At the present time, the drought is most severe eastward from southern Arizona, across New Mexico, Texas, Oklahoma, and into Arkansas and Louisiana (**Figure 1**). All of New Mexico is in drought. For New Mexico as a whole, the October to March period has been the 6th driest on record (116 years; according to PRISM data) and two climate divisions in southern New Mexico have endured their 2nd and 3rd driest winters on record (Z. Guido, CLIMAS, pers. comm.). Since the start of the "water year" (October 1, 2010) all climate divisions in New Mexico measured precipitation less than 68% of the 1971-2000 average, and drought has worsened to the present (**Figure 2**). Headwater regions for New Mexico's large rivers are also experiencing drought, a fact that has led to spring-summer streamflow forecasts across the state being well below normal as of April 1, 2011 (**Figure 3**).

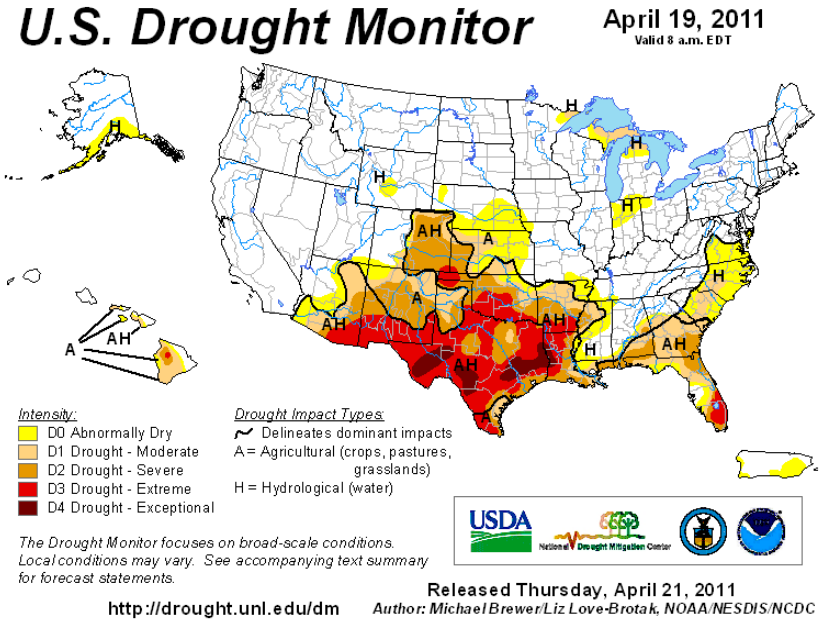

Figure 1. Federal Interagency U.S. Drought Monitor showing current drought conditions. Drought in New Mexico ranges from "Extreme" to "Abnormally Dry," with regions of Texas experiencing even drier "Exceptional" drought. (Source: http://www.drought.unl.edu/dm/monitor.html)

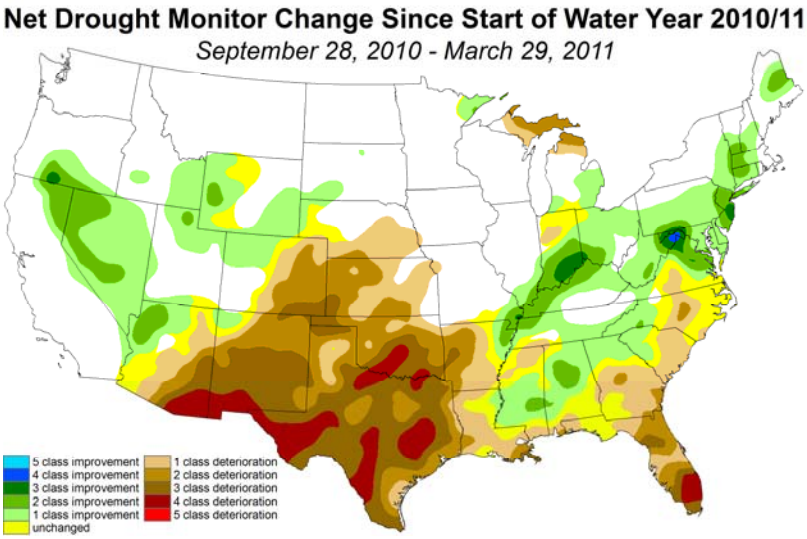

Figure 2. Map showing the change in Drought Monitor designations since the start of the current water year. Poor winter precipitation, mostly likely connected to the La Niña state of the tropical Pacific, is the primary cause of the current drought (Source: NOAA Climate Prediction Center)

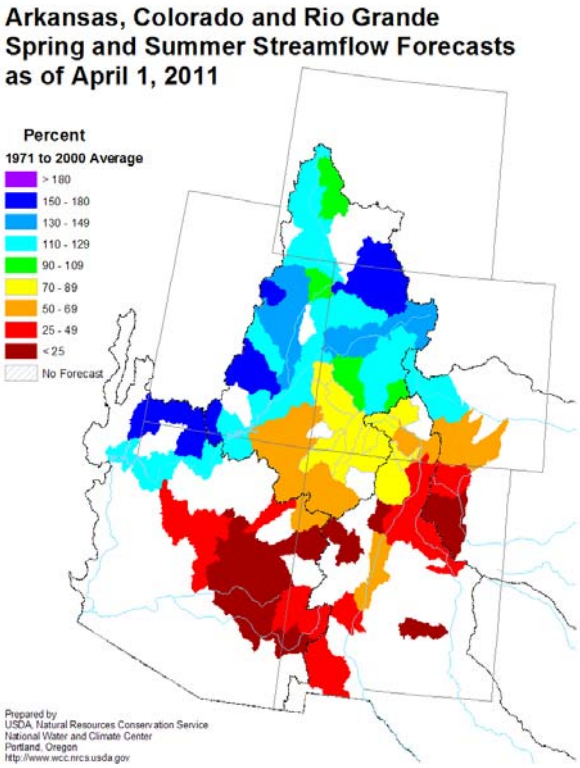

Figure 3. Map showing spring-summer streamflow forecasts for major Southwestern rivers as of April 1, 2011. All mapped river basins in New Mexico are forecast to flow at levels below normal in coming months (Source: USDA National Resources Conservation Services)

The natural range of drought variability in the Southwest

Although the current drought is quite notable, particularly as part of a drought that has plagued the Southwest off and on over the last decade, it is modest compared to some of the longer and more severe droughts of the last 1200 years (Woodhouse et al., 2010). For example, the state-the-art published tree-ring based streamflow reconstruction for the Colorado River at Lees Ferry (Meko et al., 2007) indicates that multiple "megadroughts" (droughts lasting multiple decades)

have occurred in the Southwest, with the worst – in the 12th century – lasting over 30 years. Most of these natural droughts were apparently driven by low precipitation during the winter and spring (Woodhouse et al., 2010), much like the drought currently affecting New Mexico (**Figure 2**). Most were also apparently associated, at least in part, with cool La Niña-like conditions in the equatorial Pacific – again, quite similar to the current drought in New Mexico (Conroy et al., 2009; Seager and Vecchi, 2010). The difference between the current drought and the much longer and more severe droughts of the last 1200 years is that the latter droughts were likely associated with monger longer periods of below average sea surface temperatures in the equatorial Pacific.

New scientific research, not yet published, provides evidence that the megadroughts currently believed by scientists and water managers alike to be the worst-case possible may not be as bad as it could get. Longer and more severe megadroughts occurred in both the Upper Colorado River Basin and the headwaters of the Rio Grande:

- New paleoclimatic work at the University of Arizona indicates that even the worst southwestern droughts of the last 1200 years (i.e., the 12th century megadrought) was eclipsed by a drought in the 2nd century A.D. that lasted 49 years in the headwaters of the Rio Grande, and was interrupted by only one year with above normal precipitation (C. Routson, Woodhouse and Overpeck, in preparation)

- Other new work at the University of Arizona also indicates that the severity of "worst-case" medieval period megadroughts of the last 1200 years (Meko et al., 2007) may have been underestimated by 20% or more. (Ault, Pederson, Cole, Overpeck, and Meko, in prep.; also G. Pederson et al. in prep.)

Widely recognized likely climate change impacts on the Southwest

Climate change is already clearly affecting the Southwest, particularly in terms of increasing temperature (**Figure 4**), decreasing precipitation falling as snow (**Figure 5**), decreasing spring snowpack, and decreasing Colorado River flow (Karl et al., 2009; Overpeck and Udall, 2010). These changes were anticipated by climate scientists, and simulated by many climate models (e.g., note current temperature and precipitation projections, **Figures 6 and 7**). The mechanisms of change observed in nature are similar to those driving the change in the climate model simulations. All of these factors give the climate science community greater confidence in asserting that the current warming and drying trends will continue into the future, and this spells trouble for water supplies throughout the Southwest, particularly where the supplies are currently snow-fed (e.g., the Colorado and Rio Grande Rivers).

Indeed, all of the published streamflow projections for the Colorado (the river that has received the most scientific attention) indicate future streamflow will be on average less in volume, with the chief uncertainty being how fast. Most recent work suggest a 10 to 20% decline by mid-century, with a finite chance that all reservoir storage on the Colorado could go dry absent effective shortage management (Rajagopalan et al., 2009; Overpeck and Udall, 2010).

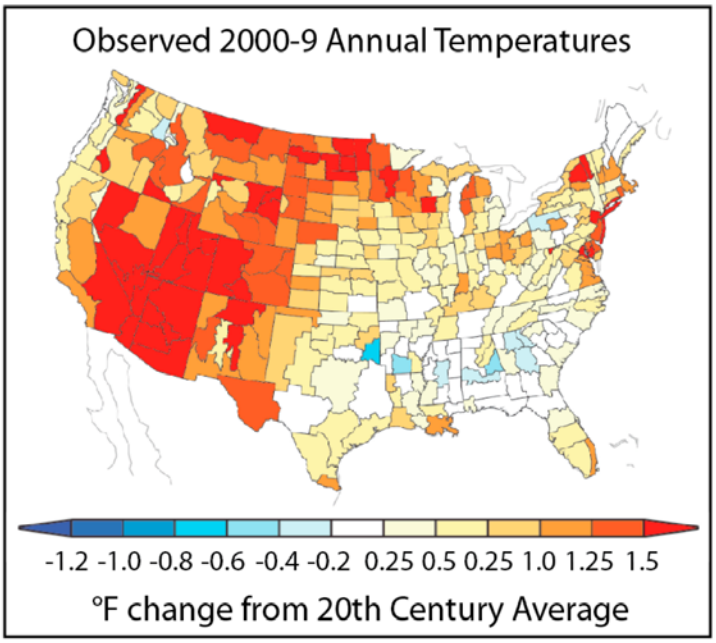

Figure 4. Map showing the observed average annual temperature of the 21st century (10 years) minus the average for the 20th century (100 years). (Source: NOAA Earth System Research Laboratory).

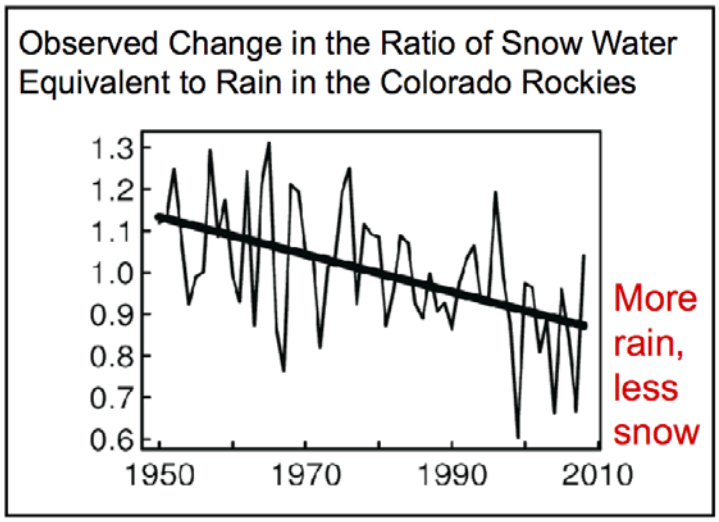

Figure 5. Change in the observed ratio of snow (snow water equivalent) to precipitation for snow courses in the Colorado Rockies headwaters of the Colorado and Rio Grande Rivers (updated from Pierce et al., 2008).

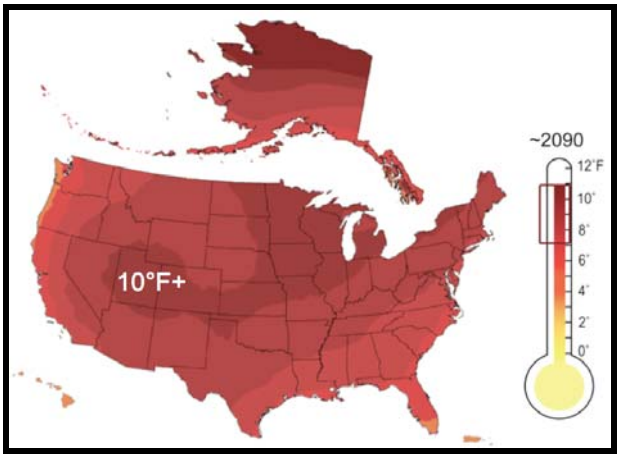

Figure 6. Projected annual average warming at the end of the 21st century based on three climate models driven by business-as-usual (IPCC SRES A1FI) greenhouse gas emissions. Future warming could be concentrated in the headwaters of the Colorado and Rio Grande rivers, and this could lead to lower streamflow and much hotter drought. (Source: Karl et

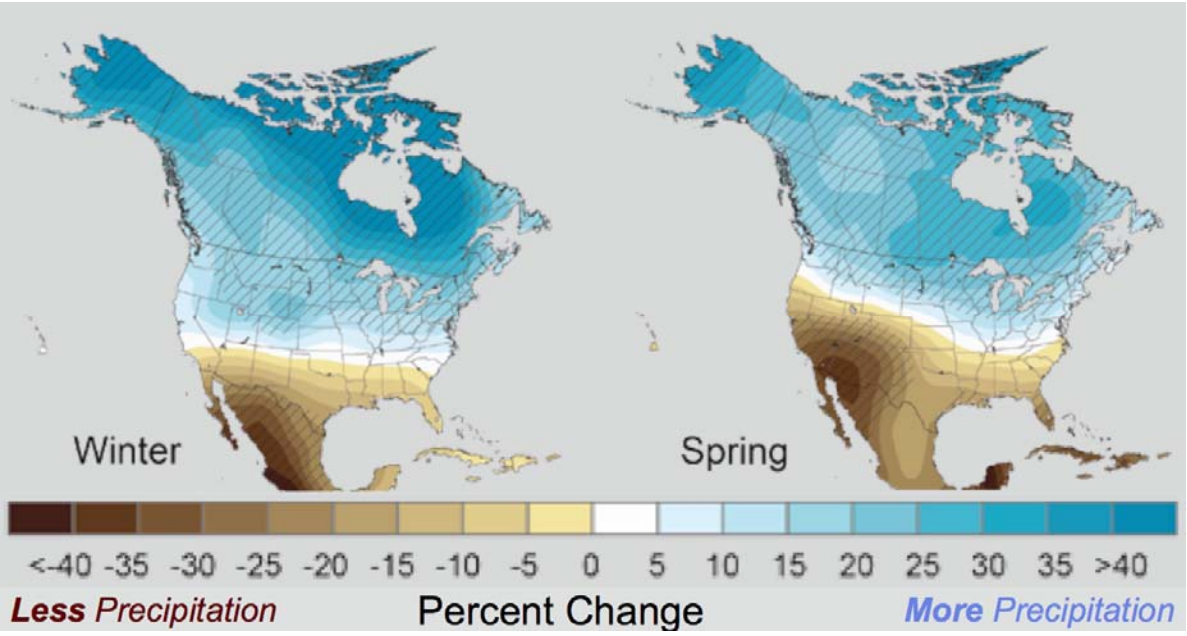

Figure 7. Projected changes in North American precipitation by the end of the 21st century in winter and spring. Cross-hatching represents regions with greatest model agreement, which includes portions of the Southwest that are projected to dry significantly. (Source: Karl et al., 2009).

Additional issues that could place Southwest surface water supply more at risk:

1) Future behavior of the El Niño-Southern Oscillation (ENSO) system could increase future drought risk substantially.

- The current drought, as well as the worst megadroughts of the last 1200 years, were all apparently associated with cool "La Niña like" conditions in the equatorial Pacific, and this will likely be the case in the future. However, state-of-the-art climate modeling is still not able to determine if there will be more or less La Niña-like conditions in the future. If there are, then the worst-case droughts of the future might be substantially worse than currently simulated (Seager and Vecchi, 2009).

2) More generally, current state-of-the-art climate models appear to be underestimating the true risk of future megadrought.

- New research results at the University of Arizona indicate that state-of-the-art climate models underestimate the full range of drought variability exhibited in a variety of paleoclimatic records. Correcting for this bias suggests that the odds that a megadrought like that of the 12th-century could occur in the next 90 years is as high as one in two for a Southwestern region that includes New Mexico (Ault, Pederson, Cole, Overpeck, and Meko, in prep.).

3) It is unclear whether future changes in the summer monsoon will help offset water losses in the winter and spring, or whether summer drought could make the future situation more challenging.

- Projections of future monsoon rainfall are still highly uncertain because global models lack the realistic regional or "mesoscale" processes needed to simulate the monsoon correctly. However, work at the University of Arizona and elsewhere is employing both global and regional climate models to solve this problem. It also remains uncertain if the large-scale influences on summer precipitation in the Southwest are captured realistically enough in global models for regional modeling results to be robust.

- As with cool-season precipitation (snow and rain), the 20th century record of summer monsoon rainfall variability underestimates the full range of variability that can occur naturally. For example, a new tree-ring reconstruction of monsoon variability over the last 350 years indicates that the 20th century lacked monsoon droughts of the type that occurred in the 19th century. Moreover, comparisons of the new monsoon reconstruction with cool-season drought reconstructions indicate that winter-spring droughts are never compensated fully by wet monsoons, and that cool-season droughts are frequently accompanied by summer drought (work by University of Arizona climate scientists D. Griffin, C. Woodhouse and colleagues).

4) Growing incidence of climate-related tree die-off could further limit future water supply

- Forests and woodlands in the Southwest appear highly sensitive to drought and warmth, with over 7% of southwestern forest and woodland area in the region recently (since 1997) impacted by die-off of trees due to drought and insects since 1997, and an additional nearly 3% of forest and woodland area also affected by wildfires (Williams et al., 2010).

- Growing drought and infestation-triggered tree die-off in the Southwest will likely affect water supply in different ways, and the latest research (Adams et al., 2011) suggests it would be prudent for water managers to assume the widespread (and growing) tree die-off in the Southwest could act to further limit available water in the future.

5) Growing land-use and desertification in the Southwest could further reduce streamflow in snow-dominated river systems (e.g., the Colorado and Rio Grande rivers).

- Recently published research (Painter et al., 2010) indicates that human land-use and desertification in the Southwest (and particularly in the Four Corners region) is already decreasing the duration of snow cover in the Colorado headwaters by several weeks, and that this in turn is likely contributing to reduced flows in at least the Colorado River. Better land-management could therefore yield greater water supply.

Bottom-line advice to water managers in New Mexico and the Southwest:

1) There is broad agreement in the climate science research community that the Southwest, including New Mexico, will very likely continue to warm. There is also a strong

consensus that the same region will become drier and increasingly snow-free with time, particularly in the winter and spring. Climate science also suggests that the warmer atmosphere will lead to more frequent and more severe (drier) droughts in the future. All of the above changes have already started, in large part driven by human-caused climate change.

2) However, even in the absence of significant human-caused climate change, the Southwest is prone to drought and megadrought much more severe than droughts witnessed in the last 100 years. The 2000-year record of drought in the region makes it clear that droughts lasting decades are likely independent of human-caused climate change. For this reason, the "no-regrets" strategy is to plan and prepare for droughts no matter the cause – human or natural – and to do so under the assumption that droughts will very likely be hotter and thus more severe in the future than in the past 2000 years.

3) Scientists and water managers alike, however, should be careful not to assume the currently estimated "worst case" drought scenario will remain so for long. As climate science has advanced in the Southwest, there have been a steady progression of new results that imply that today's "worst-case" drought scenario is tomorrow's second-worst case scenario. Water managers should pay particular attention to the emerging science that has been highlighted in the testimony above.

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