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CLIMATE CHANGE AND WATER SUPPLY

HEARING

BEFORE THE

SUBCOMMITTEE ON WATER AND POWER

OF THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

TO

RECEIVE TESTIMONY ON THE IMPACTS OF CLIMATE CHANGE ON WATER SUPPLY AND AVAILABILITY IN THE UNITED STATES, AND RELATED ISSUES FROM A WATER USE PERSPECTIVE

JUNE 6, 2007

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*Senator Thomas passed away on June 4, 2007.

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CLIMATE CHANGE AND WATER SUPPLY

WEDNESDAY, JUNE 6, 2007

U.S. SENATE,
SUBCOMMITTEE ON WATER AND POWER,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:48 p.m. in room SD–366, Dirksen Senate Office Building, Hon. Maria Cantwell presiding.

OPENING STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. The Committee on Energy and Natural Resources Subcommittee on Water and Power will come to order. We are glad to have a hearing today to talk about the impacts of climate change on water supply and availability in the United States and related issues to water, water use, and various perspectives.

I would like to thank the two panels here and we apologize for the vote interrupting our start time. I am, in the interest of that, going to put my opening statement into the record so that we can go with the panels. But I'll ask either of my colleagues if they would like to make an opening statement.

[The prepared statements of Senators Cantwell and Salazar follow:]

PREPARED STATEMENT OF HON. MARIA CANTWELL,
U.S. SENATOR FROM WASHINGTON

I call to order this hearing before the Water and Power Subcommittee. It's my pleasure to welcome everyone to this afternoon's hearing. We have a distinguished set of witnesses today, most of whom have traveled across the country to be with us today. To each of them, we appreciate your willingness to be here today, and share your views with the Subcommittee.

I'd like to specifically thank Dr. Phillip Mote and Tim Culbertson who have both traveled from Washington state to be with us today. Dr. Mote's work at the Climate Impacts Group at the University of Washington and as the Washington state Climatologist in documenting an asserted decline in Cascade Mountain glaciers has become well-known and respected within the scientific community.

Tim Culbertson, General Manager of the Grant County Public Utility District in Eastern Washington. Grant County PUD is demonstrating leadership in optimizing the management of water on the Columbia River for hydropower generation, irrigation in the agricultural rich Columbia River Basin, and for fish management.

The purpose of the hearing is to receive testimony on the impacts of climate change on water supply and availability in the United States, and related issues from a water use perspective. These issues are garnering more attention these days as the debate about whether climate change is occurring, and its root cause, recedes to the background.

We know that temperatures are rising and we know that human activities account for most of the cause. We now need to fully understand the implications. In

the arid West, the impact of climate change on water resources is an issue that deserves in-depth and ongoing scrutiny.

As recently documented by the Intergovernmental Panel on Climate Change, we know that increasing temperatures are resulting in increased and earlier run-off from glacier-and snow-fed rivers; changes in precipitation to less snowpack and more rainfall; and significant warming in lakes and rivers, affecting habitat and water quality. These changes, and a host of others that are being studied, add to the significant challenges already facing water managers across the United States.

Drought, population increases, environmental demands, and overuse of limited water supplies, have already created numerous situations in which federal, state, and local water managers have had to react quickly to address potential water shortages and conflicts.

With emerging information on the impacts of climate change on water, planning will now likely expand to address this new area of concern. I am particularly interested in this aspect of global warming since the Pacific Northwest faces unique challenges in trying to deal with impacts on water supply.

Snowpack is the largest component of the water storage system in our region—much more than man-made reservoirs. As snowpack decreases, and runoff occurs earlier in the season, less water will be available during the dry summer months for hydropower generation, irrigation, and recreational purposes.

Salmon fisheries, a symbol of the Pacific Northwest, are already being stressed beyond sustainable limits, and now face reduced flows of higher temperatures at certain times of the year. Exacerbating the problem, is the fact that most of the 950 glaciers in Washington state are receding rapidly, compounding complications from reduced flows of higher temperature.

In short, the impact of climate change on water supplies poses a major threat to the economic vitality of the Pacific Northwest, as well as other regions of the country. The issue therefore deserves the attention of Congress.

We need to fully evaluate the problem and the adaptation strategies needing implementation. This will help determine the extent to which the Federal government needs to mobilize its resources to help states and local communities address the challenges ahead. Today's hearing is a good start in that process, and I look forward to gaining additional insight from the witnesses.

PREPARED STATEMENT OF HON. KEN SALAZAR, U.S. SENATOR FROM COLORADO

Thank you Chairman Cantwell and Ranking Member Corker. I want to thank you for holding today's hearing on the impacts of climate change on water supplies and availability, particularly in the Western United States. I also want to thank the witnesses who have traveled to be with us today.

Climate change is a very real and very present problem. Human activities have changed the climate of the Earth. This Congress is working hard to promote clean energy technologies that significantly reduce the amount of greenhouse gas emissions released to the atmosphere. We anticipate next week the Senate will be begin debate on an energy bill that will ramp up domestic renewable energy production, promote efficiency throughout the U.S. economy and invest in groundbreaking research designed to reduce carbon emissions.

However, we are learning that some adaptation measures are inevitable to reduce the harm from climate change that proves to be unavoidable. In February 2007, the United Nations Foundation/Sigma XI released a scientific expert group report titled "Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable." That report gave significant attention to adaptation measures that will likely have to be implemented to reduce the harm from climate change that proves to be unavoidable.

Today's hearing is particularly important for the Western states of the U.S. because many scientists are now saying the American West will experience the effects of climate change sooner and more intensely than most other regions. Our scarce snow and water of the West is already being impacted, much of it in ways that we do not clearly understand.

Colorado, my State, has a lot at stake when it comes to global warming. We have a world-class tourist industry that has flourished because of our State's natural beauty. Colorado has some of the best ski areas in the world, and some of the best big game fishing anywhere in the continental U.S. But, these tourist industries depend on sufficient winter snowfalls, slow spring melts, and river and lake temperatures capable of supporting native fish species.

This hearing today is exceedingly important to help us learn what is known and not known about the impacts global warming will bring to the Western U.S., and especially the impacts being mitigated through water. It is also important to help us understand what adaptation measures must be planned for to ensure adequate water supplies for agricultural, industrial, business and residential uses.

Madam Chairman, I thank you again for holding this important hearing so that we can learn from the experts testifying today.

STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE

Senator CORKER. Madam Chair, I think because of the time factor I'll let mine be entered, though I think it might be appropriate for Senator Craig to make some comments about our deceased colleague.

[The prepared statement of Senator Corker follows:]

PREPARED STATEMENT OF HON. BOB CORKER, U.S. SENATOR FROM TENNESSEE

Chairwoman Cantwell, it's a pleasure to be here today to discuss the impacts of climate change and variability on water supply.

I am pleased with the work the United States Geological Survey and its partners are doing to better understand how climate variability is impacting our water management decisions. The more we understand about climate variability and climate change in regards to our water resources, the better we can cope with both near and long-term water resource challenges. I applaud the work Reclamation is undertaking to improve their knowledge of general circulation climate models at the level of individual Reclamation drainage basins, and how to incorporate the data into their water management decisions within these basins.

We have come a long way in our understanding of how the weather impacts our water management decisions. In the Western United States, water managers have taken steps to improve their project operations and efficiencies, which have led to water savings. In addition, technologies have been developed to reuse and reclaim water that was once thought of as only a waste product. These actions are important because regardless of how climate change impacts water supply and availability, significant challenges such as population growth already exist that require attention and adaptation. I am a firm believer that the more we can do with less water, the better off we will be in times of need. I would urge each witness today to continue to utilize the best available data and incorporate the data into how they manage our water resources, while acknowledging that we still have a lot to learn about the future of climate change and its potential impacts.

Again, I thank the witnesses for your presence, and thank you, Chairwoman Cantwell, for conducting this hearing. I look forward to hearing the testimony today.

Senator CANTWELL. That would be very appropriate. Senator Craig.

STATEMENT OF HON. LARRY E. CRAIG, U.S. SENATOR FROM IDAHO

Senator CRAIG. Well, Madam Chairman, thank you very much. Senator Corker, thank you.

We have all lost a very real friend in our colleague Senator Craig Thomas. I had the privilege of not only being his neighbor out West with a bordering State, but I also served with the Senator in both the House and the U.S. Senate, and as a result of that we grew very close in not only friendship, but of course the commonality of issues.

Today we are talking about water and its importance, and out in the arid West Craig Thomas understood that better than anyone else. As a westerner, I think Craig would have said very early on "Whiskey's for drinking and water's for fighting." That was kind of the rule of thumb from the day his parents got to Wyoming and my grandparents got to Idaho, and I suspect under climate change

or any other scenario, Madam Chairman, it would still be the fact. That would have been the character and the belief of our deceased colleague Craig Thomas.

So certainly our best thoughts to his wife Susan and their family. Wyoming lost a great champion, as did the United States, and we will miss him in very real ways.

Thank you.

Senator CANTWELL. Thank you, Senator Craig, for those comments. I, too, will miss Senator Thomas and his gentle style which he seemed to bring everywhere with him, to committee hearings, to the floor of the Senate, to the halls of these buildings, and having a ready smile for individuals.

But when he showed up at these committees he had a certain fierceness in advocating for his position and I won't forget that fierceness. I also had the pleasure 1 day of following him down to the White House as he was driving his favorite automobile, his prize possession, only to see the system at the White House rip his bumper off. I assumed that would be a pretty frustrating experience, but he took it all in great stride, as he did so many things, and continued to have humor about it.

We will miss him in the U.S. Senate and his advocacy. He stood up for the people of Wyoming on a constant basis. Oftentimes I feel like the Energy committee is the western committee, no offense to my colleague here. But I feel oftentimes that the Energy Committee has a lot of westerners on it and a western perspective. But his perspective will be sorely missed.

So thank you for reminding all of us about his presence on this subcommittee and his contribution, and our thoughts and prayers are with his family.

Senator Bingaman, did you wish to make any opening comments?

STATEMENT OF HON. JEFF BINGAMAN, U.S. SENATOR FROM NEW MEXICO

The CHAIRMAN. I'll forego opening comments. Thank you very much for having the hearing and I appreciate your very good comments about Senator Thomas.

Senator CANTWELL. Thank you.

Let's start then with the first panel. Dr. Philip Mote, who is joining us from Climate Impacts Group from Seattle; Christopher Milly, Dr. Milly, who is a research hydrologist from the USGS; and Bradley Udall, Cooperative Institute for Research in Environmental Sciences at Boulder, Colorado. We welcome all of you. Thank you for being here. We have plenty of room for full written testimony, as long as you want, but we ask if your opening statements could be limited to 5 minutes. We'll start with you, Dr. Mote.

STATEMENT OF PHILIP W. MOTE, PH.D., RESEARCH SCIENTIST, JISAO-CSES CLIMATE IMPACTS GROUP, UNIVERSITY OF WASHINGTON, SEATTLE, WA

Mr. MOTE. Thank you, Madam Chair and members of the Committee, for holding this hearing. I'm Philip Mote and I'm a research scientist at the University of Washington with the Climate Impacts

Group, which is one of eight regionally focused teams sponsored by NOAA's Climate Program Office.

In a warming world, a reduction in ice and snow is a general consequence as warmer air provides energy to melt government in its solid form in preference for the liquid form. Indeed, melting ice contributes roughly half of the observed 3 millimeters per year of sea level rise, and also provides visual indicators of climate change.

This general fact that there's less snow and ice in a warming world has special consequence for those of us out in the western third of the country, where about 70 percent of annual stream flow is snow melt. Snow stores far more water than all the manmade reservoirs and this is important because out West most precipitation falls in the winter and the peak stream flow is in spring or early summer. Snow delays runoff by several months. Human enterprises, including agriculture, municipal water supply, hydropower, flood control, recreation, and several others, which are the subject of the second panel, are all built around the assumption that the future stream flow will have the same annual shape as past stream flow. But that assumption is breaking down.

You should have a two-sided, one-page handout with color figures on each side and a bit of a journal article by Ira Stewart and colleagues, that illustrates some of what is happening. They looked at about 300 stream gauge records in the western United States on snow melt-dominated rivers and showed that spring snow melt has shifted earlier by roughly 2 weeks during the past half century. The pink and red dots in the single figure at the bottom of the first page show where those changes were largest, roughly 1 to 4 weeks. These include changes in Washington, Oregon, Idaho, and California, where the changes were largest.

On the reverse side you find two panels showing that runoff has shifted from June to March. The summer peak flow is decreasing and the late winter flow is increasing.

These observations are consistent with other observations that during the past half century winter and spring temperatures have warmed substantially, plants are blooming earlier, winter snow fall has diminished at most weather stations in the West. Especially relevant to water supply, spring snow pack has declined at about 73 percent of monitoring sites, with largest declines near the snow line.

Many of these changes are largest, again, in Washington, Oregon, Idaho, and California, where much of the winter precipitation falls at temperatures close to freezing.

The warming in the West can now be attributed to rising greenhouse gases and is not explained by any combination of natural factors.

Computer models of global climate, of regional climate, and of hydrology can be used to estimate a range of possible future changes. Global model simulations performed by 21 modeling centers around the world were summarized in the 2007 report of the Intergovernmental Panel on Climate Change, which I was privileged to serve with.

For most of the continental United States, warming is projected to be roughly 6 degrees Fahrenheit during the 21st century for a high CO_2 scenario. That will significantly erode the West's main

water storage reservoir, its snow pack. Models are divided over whether precipitation will increase or decrease for the middle swath of the country, but they agree on increases in the northern tier of States, which our calculations estimate will not be enough to overcome the warming as far as snow pack is concerned; and they also agree on a decrease in precipitation in the Southwest.

Physically based models of hydrology can be used to translate these climate model scenarios into changes in snow pack, stream flow, soil moisture, and so on, and such studies suggest that future changes are very much in line with what we've seen in the past, reductions in summer flow and a shift toward earlier spring snow melt.

To begin to manage this huge risk posed to the West's main water storage reservoir, the Federal Government could do these three things: First, Federal agencies involved in water management could use existing academic tools to estimate ranges of future stream flow and consider management options. Second, the Government should ensure that existing observation networks do not suffer further neglect and decline, but instead are upgraded to effectively monitor changes. These networks include the USGS stream gauge network and the National Weather Service Cooperative Network. Third, the Government could catalyze river basin-scale policy planning using reservoir optimization models that optimally balance management objectives.

Thank you for turning your attention to this important subject.

[The prepared statement of Mr. Mote follows:]

PREPARED STATEMENT OF PHILIP W. MOTE, PH.D., CLIMATE IMPACTS GROUP, UNIVERSITY OF WASHINGTON, SEATTLE, WA

INTRODUCTION

In most river basins of the West, especially in California, Oregon, and western Washington, snow (rather than man-made reservoirs) is the largest component of water storage. Most precipitation falls in the winter but about 70% of annual flow is snowmelt; snow provides a roughly half-year delay in runoff. Furthermore, a significant portion of the mountainous West receives much of its annual precipitation as warm snow, with temperatures above -3°C (Bales et al. 2006). Hence, the West is (to varying degrees) vulnerable to climatic variations and changes that influence snowpack. This document updates the testimony I gave to the U.S. Senate Committee on Commerce, Science, and Transportation (Mote 2004).

OBSERVED CHANGES

What changes have been observed in the West since the mid-20th century?

1) The West has warmed by roughly 0.8°C in the November-March season (Mote et al. 2005).

2) Snowfall has diminished at most weather stations; these changes are large and statistically significant in California, Oregon, and Washington (Knowles et al. 2005).

3) Spring snowpack has declined at roughly 75% of sites and the magnitude of declines is largest at low elevations (Mote et al. 2005).

4) Spring snowmelt is generally occurring earlier, roughly 2 weeks (Stewart et al. 2005) and these shifts are larger at lower elevations than at higher elevations (Regonda et al. 2005).

5) In most snowmelt-dominated basins, winter flows have increased and late spring-early summer flows have decreased as flows shift (Stewart et al. 2005).

6) The timing of biological events like flowering of lilacs have also shifted in response to springtime warming (Cayan et al. 2001).

7) Flood risk appears to have changed in many river basins, decreasing in snow-dominant basins and increasing in those with some snow storage.

In several of these studies, a clear quantitative link was established between the observed change and temperature in winter or spring. The warming in the West can now confidently be attributed to rising greenhouse gases and are not explained by any combination of natural factors (Stott 2003).

These hydrologic shifts in response to warming—elevation-dependent losses in snow storage, with concomitant increases in winter flow and decreases in summer flow—are a harbinger of changes to come.

PREDICTED FUTURE CHANGES

The starting point for future changes are the physically consistent global simulations of climate from climate models (e.g., IPCC 2007 Chapters 8, io, and ii). Such projections typically are reported as seasonally averaged changes in temperature and precipitation (see Figure below*, for the A1B socioeconomic scenario). Modeling centers around the world have contributed hundreds of climate simulations to a database maintained by the Program for Climate Model Diagnostics and Intercomparison at the Lawrence Livermore National Laboratory. From such simulations one can construct average changes or produce also a range of changes. The projected warming in North America is greatest in high latitudes in winter, but is greatest in midlatitudes in summer owing partly to a soil moisture feedback. For much of the Lower 48 states, warming is projected to be roughly 0.3°C/decade for winter and 0.4°C/decade in summer for the A1B scenario. Precipitation changes globally tend to be positive in the tropical rainy belt and also in high latitudes, and negative in low latitudes. For North America, models are divided over whether precipitation will increase or decrease for a swath (white area in the bottom row of the Figure) of the Lower 48, but tend to agree on increases in the northern tier of states and tend to agree also that precipitation in the Southwest will decrease.

Physically-based models of hydrology can be used to translate such changes in climate into future changes in snowpack, soil moisture, streamflow, and so forth. Studies with such models are still relatively new, but it is clear that projected future hydrologic changes (e.g., Payne et al. 2004 for the Columbia River Basin, Christensen et al. 2004 for the Colorado, Maurer and Duffy for California) produce the same types of changes in snowmelt-driven basins as have been observed. For low-end scenarios of future temperature change, the reductions in summer flow, shifts in timing of spring snowmelt, and increases in winter flow over coming decades would be as large as those observed in recent decades, whereas for high-end scenarios of future temperature change the projected hydrologic changes are extremely large.

MANAGEMENT AND POLICY IMPLICATIONS

Few water management agencies have begun to explore what these changes would mean for their ability to meet management objectives, let alone proactively address the changes. Some academic studies (e.g., Payne et al. 2004) have attempted to estimate changes in reliability of various water supply systems, and to explore adaptation options.

Federal policy responses could include:

a) directing federal agencies involved in water management to study future streamflow.

b) ensuring that existing observation networks (e.g., the USGS stream gauge network and the National Weather Service cooperative network) do not suffer further neglect and decline but instead are upgraded to effectively monitor changes.

c) catalyze river basin-scale policy planning, using reservoir optimization models that optimally balance management objectives.

References

Bales, R. C., N. P. Molotch, T. H. Painter, M. D. Dettinger, R. Rice, and J. Dozier, 2006: Mountain hydrology of the western United States, Water Resour. Res., 42, doi:10.1029/2005WR004387.

Cayan, D.R., S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson, 2001: Changes in the onset of spring in the western United States. Bull. Amer. Meteor. Soc., 82, 399-415.

Christensen, N.S., Wood, A.W., Voisin, N., Lettenmaier, D.P. and R.N. Palmer, 2004: Effects of climate change on the hydrology and water resources of the Colorado River Basin, Climatic Change 62, 337-363.

*Graphics in this document have been retained in subcommittee files.

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [S. Solomon et al., eds.]. Cambridge University Press, Cambridge, UK.

Maurer, E.P. and P.B. Duffy, 2005, Uncertainty in projections of streamflow changes due to climate change in California, Geophys. Res. Letts. 32, doi:10.1029/2004GL021462.

Mote, 2004: U.S. Senate testimony, http://commerce.senate.gov/pdf/mote050604.pdf.

Mote, P.W., A.F. Hamlet, M.P. Clark, and D.R Lettenmaier, 2005: Declining mountain snowpack in western North America, Bull. of the Amer. Meteorol. Soc., 86, 39-49.

Payne, J.T., A.W. Wood, A.F. Hamlet, R.N. Palmer and D.P. Lettenmaier, 2004, Mitigating the effects of climate change on the water resources of the Columbia River basin, Climatic Change 62, 233-256.

Regonda S., Rajagopalan B., Clark M., and Pitlick J., 2005: Seasonal cycle shifts in hydroclimatology over the Western US, Climate, 18, 372-384.

Stewart, I.T., D.R. Cayan, and M.D. Dettinger, 2005: Changes towards earlier streamflow timing across western North America. J. Climate, 18, 1136-1155.

Stott, RA., Attribution of regional-scale temperature changes to anthropogenic and natural causes. Geophys. Res. Letts., 30, doi:10.1029/2003GL017324, 2003.

Senator CANTWELL. Thank you.

Mr. Udall, thank you for being here.

STATEMENT OF BRADLEY H. UDALL, DIRECTOR, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION-UNIVERSITY OF COLORADO WESTERN WATER ASSESSMENT, BOULDER, CO

Mr. UDALL. Thank you, Chairman Cantwell. It's my pleasure to be here. My name is Brad Udall. I'm the Director of the Western Water Assessment at the University of Colorado. The Western Water Assessment is the sister program to Dr. Mote's program at the University of Washington. There are eight of these regionally based programs around the country and we are on the front lines of providing decisionmakers with climate information.

I am not a scientist. I have spent the last 4 years of my life embedded with scientists at the single largest laboratory that NOAA operates in Boulder, Colorado. During these 4 years I've learned a tremendous amount about climate and also managed to impart some knowledge to those scientists about how water management works, because my background is in engineering. This has been a fabulous and life-changing experience for me.

As Phil said, all water planning is based on the idea of a static climate. We now know this is no longer true. My favorite quote is from the novelist T. Morris Longstreth, who wrote: "Of course we weren't lost; we were merely where we shouldn't have been without knowing where that was." That's the perfect analog for water management these days.

I want to talk about three issues: The Colorado River, Federal management of climate change science, and regional decision support efforts. Even without climate change, the Colorado River has a serious problem. We've had 8 years of drought. We've lost half, half, of the storage on that river. This is the fastest growing area in the Nation. At the current rate of use, Lake Mead has 10 years of water left in it. Reclamation modeling under average hydrology shows that Lake Mead never refills at its current rate of use.

If you add climate change on top of this, you then potentially have a very serious problem. Every model, every study that I've

ever looked at, shows that if precipitation stays the same or declines you end up with less water in the Colorado River. Dr. Milly I think will address that.

Let me switch now to Federal climate change science management. I truly believe this is not effective. The CCSP, the Climate Change Science Program, is a small office. It's directed by a committee from 13 different Federal agencies. It's underfunded and I truly believe it's not effective. For one, it has no decisionmakers on its management staff. You know, water managers in the West, they're not aware of this program and it's truly a shame. We can do better about this.

There's also a lack of resources inside the Federal Climate Change Science Program being spent on decision support.

One idea potentially—and Congress actually has passed this—is for a national climate service. In 1978 Congress passed an act. It's a great act. It has languished for lack of funding, and I would urge you all to look at funding it adequately.

We need a coherent data policy. No data, simply put, means no science. Bad data gives us bad science. Management, of course, requires good data.

We need to devote more resources to regional climate science. The Intergovernmental Panel on Climate Change studies are great, but they're not directed at regional decisionmakers. Decisionmakers are now very eager for information at a regional level.

The first way to do this is to get regional climate modeling up to speed. It's not perfect, but it's the only tool we have. Water resource managers, like Metropolitan, San Francisco, everyone wants this. We also need additional computing power. The RISAAs, the programs, these Regional Integrated Sciences and Assessments, provide one model for allowing this Nation to adapt to climate change. We could scale up the eight programs that exist in the Nation to a national effort. This will take time. It can't be done overnight.

But in my experience, when you combine academics, the Federal Government and its power, and decisionmakers, you generate quite wonderful products that are of real use to regional decisionmakers.

One of my favorite quotes is that "The proper response to uncertainty is insurance, not denial." Many forms of insurance. One is knowledge and we need to do a much better job of getting the knowledge of climate change out there to the decisionmakers that matter.

Thank you for this opportunity.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF BRADLEY H. UDALL, DIRECTOR, NOAA-UNIVERSITY OF COLORADO WESTERN WATER ASSESSMENT, BOULDER, CO

Chairwoman Cantwell, Ranking Member Corker, my cousin Senator Smith, and other Members of the Committee, thank you for the opportunity to speak with you today on the impacts of climate change on water supply and availability in the United States.

My name is Brad Udall. I am the Director of the Western Water Assessment, an interdisciplinary Regional Integrated Science and Assessment (RISA) project funded by the NOAA Climate Program Office and a joint effort of the NOAA Earth System Research Laboratory and the University of Colorado. The eight RISAs around the country are innovative programs designed to connect climate science with decision makers. There are no other programs anywhere like these, and we are on the front

line of dealing with requests for regional information on all aspects of climate variability and change.

Although I was invited to sit on a panel with scientists, I am not a scientist. I am an engineer by training and I have an MBA. During the last four years of my life I have been embedded with scientists at the largest NOAA laboratory in the country where I have had the opportunity to learn about climate from scientists while providing them with a real world view of water management. It has been a fabulous and life changing experience. Formerly, I was a principal at a consulting engineer firm. In preparing this testimony I talked to scientists, water managers, and consulting engineers. Many were eager to share their thoughts on this important topic.

All water planning is based on the idea of a static climate. Normal engineering practice for designing water supply and flood control projects is to plan as if the future will look like the past. However, we now know that our future climate will not look like the past, and that in addition to warmer temperatures the normal patterns of water movement around the globe will change. This is because the water cycle redistributes heat from the equator to the poles—and it is this movement of heat and water that determines our weather and climate. As the planet warms, these relationships will change, and the water cycle will adjust with potentially large impacts on humans.

This fundamental fact has profound implications for water management. The novelist T. Morris Longstreth once wrote, "Of course we weren't lost. We were merely where we shouldn't have been without knowing where that was." This is the position water managers find themselves in today. As we move forward, all water management actions based on "normal" as defined by the twentieth century will increasingly turn out to be bad bets.

I would like to discuss three issues concerning adaptation to climate variability and change today. The first is the serious situation due to drought and increasing demands that has developed on the Colorado River which climate change threatens to make far worse. The second is my concern about how our national climate change scientific enterprise is being managed, and the third is the need to devote more scientific resources to meeting the needs of decision makers, almost all of whom have a regional or local focus.

THE SITUATION ON THE COLORADO RIVER

Please indulge me in a small bit of family history. My great-great grandfather John D. Lee was asked by Brigham Young to found what is now called Lee's Ferry, the all-important dividing line on the Colorado River between the Upper Basin and the Lower Basin in the 1922 Colorado River Compact. My great-grandfather and my grandfather farmed on the banks of the Little Colorado River in northeastern Arizona. My father, Morris Udall, was part of the Arizona delegation that passed the Central Arizona Project Act in 1968 which now moves large quantities of Colorado River water over 300 miles and 3000 vertical feet to Phoenix and Tucson. And during the course of my life I have been both a Grand Canyon River Guide and a water engineer.

I care deeply about this river which affects 30 million people in seven states and faces an uncertain future even without climate change. The population of the American Southwest is the fastest growing of anywhere in the nation. The recent drought, which has featured extended low flows not seen in the 100-year gauged record, has resulted in the loss 30 million acre-feet of water, the equivalent of two years of annual flow and half of the maximum total storage. The two largest reservoirs, Lakes Mead and Powell, are now approximately half full. Lake Mead is currently losing 1.4 million acre-feet per year, and contains only 10 years of water at this rate of loss[1] because the Lower Basin states have grown accustomed to using excess water from the Upper Basin, water that may not be there in the future under either climate variability or under climate change. According to Reclamation modeling, even under average historical hydrology Lake Mead never refills and Lake Powell takes decades to refill.

With climate change the picture is even more troubling. The West in general is experiencing warmer springs, reduced snowpack, and earlier runoff[2]. The Colorado

[1] With Lake Powell at about 50% of capacity, current operating practice is to release 8.23 million acre-feet (mat) to Lake Mead which combines with approximately 750,000 acre-feet of tributary inflow to make total annual inflow to Mead of 9.0 maf. Annual releases from Lake Mead total 10.4 maf: 7.5 maf total to Arizona, California and Nevada, 1.5 maf to Mexico to meet our treaty requirements and an additional 1.4 maf in evaporation and other losses.

[2] For an overview of climate related impacts see: "Climatic and Hydrologic Trends in the Western U.S.: A Review of Recent Peer-Reviewed Research" available at: http://

River basin has warmed approximately 2°F since 1976[3]. Recent studies on the Colorado River indicate that the basin is likely to have less streamflow in the future[4]. In fact, all climate change studies on the river, some dating back to 1979, have found that less runoff will occur in the future under warmer conditions with either the same or less precipitation, the most likely future according to climate models. A variety of new studies[5] based on the most recent Intergovernmental Panel of Climate Change (IPCC) modeling also paint a future with less water in the. basin. Two other second order effects of rising temperatures associated with climate change potentially influence water supply. Insect pests such as the pine beetle are projected to increase, which will affect forest health and the potential for fire[6]. Large forest fires have increased in recent years[7] which may lead to increased reservoir sedimentation and water quality degradation. While these studies and projections may be wrong, the collective picture is troubling and it would be foolish to ignore them.

While the Lower Basin states of California, Arizona, and Nevada have over-consumption and growth problems, the Upper Basin states have another set of problems relating to the uncertainty of their compact entitlements. In the state of Colorado, for example, there is no unappropriated water in any basin other than the Colorado River, but use of Colorado River water is constrained by a 1922 Colorado River Compact downstream delivery requirement at Lee's Ferry. Developing additional water to meet Colorado's needs is now highly uncertain—there could be anywhere from 0 to 800,000 acre-feet, enough to supply anticipated new growth for the next twenty years. Ever more problematic is the concern that climate change induced drought might lead to drastic curtailment of all 'Post-Compact' water rights. Such curtailment could include shutting off half of the water which is now used by the major municipalities of the Front Range of Colorado where 75% of the state lives.

There is at least one bright spot on the river. For the last two years Reclamation has been working on an Environmental Impact Statement on how to share shortages and operate Powell and Mead during drought. This effort has lead to a noteworthy and imaginative agreement among the seven Colorado River states and Reclamation should issue a Record of Decision later this year. However, given climate change projections, I fear that this agreement will not be enough and the states will soon have to deal again with the delicate issue of not enough water for too many people.

BETTER FEDERAL MANAGEMENT OF CLIMATE CHANGE SCIENCE

We need a better way to manage the nation's overall climate change science enterprise. This is a critically important national problem yet the existing management structure seems ill-suited to the task. Does anyone really think an effective way to manage $2b of climate change science occurring in thirteen different federal agencies is by a small office overseen by a national interagency committee without budgetary authority? Despite good intentions, the Climate Change Science Program (CCSP) is a feel-good veneer on a problem that requires a far bigger response with an effective management structure. In addition, it is now time to include resource managers and decision makers along with scientists in the management of this very important program.

One sign of the current management problems is that despite being eager for climate change information, almost no water manager in the country is aware of the Climate Change Science Program. And they are certainly not aware of the twenty one Synthesis and Assessment Products being rolled out over the next two years,

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wwa.colorado.edulproducts/forecasts and outlooks/intermountain west climate summary/articles/ww a jan—2007feature.pdf

[3] National Research Council (NRC) 2007. Colorado River basin Water Management—Evaluating and Adjusting to Hydroclimatic Variability. The National Academies Press, Page 61.

[4] For an overview, see http://wwa.colorado.edu/products/forecasts and outlooks/intermountain west climate summary/wwa may 2007.pdf

[5] See for example: N. Christensen, D. P. Lettenmaier. 2006. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrology and Earth System Sciences Discussions, 3, 3727-3770. Hoerling, M. and J. Eischeid. 2006. Past Peak Water in the Southwest. Southwest Hydrology, 6(1). Milly, P. C. D., K. A. Dunne, et al. (2005). "Global pattern of trends in streamflow and water availability in a changing climate." Nature 438(7066): 347-350. Seager, R., M. Ting, et al. (2007). "Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America." Science: 1139601.

[6] Colorado's Grand and Summit counties now have over 1000 square miles of diseased and dying trees.

[7] Westerling, A. L., H. G. Hidalgo, et al. (2006). "Warming and earlier spring increase western US forest wildfire activity." Science 313(5789): 940-943.

several designed specifically for decision makers[8]. Another example is the lack of resources for "decision support", the term used to describe information readily usable by policymakers. This is clear from both the small budget devoted to these activities and from actions of the program. I attended a CCSP workshop in 2005 on Decision Support attended by several hundred scientists yet there were just a handful of resource managers and decision makers in the audience. Please note that none of my comments are meant to malign the hardworking staff or management of the CCSP; they simply do not have the resources to pursue their mission effectively.

A National Climate Service, an idea under discussion by some in NOAA and in the academic community, might provide an umbrella to solve some of the climate variability and change needs of decision makers if it were crafted with care. This enterprise would "connect climate science to decision-relevant questions and support building capacity to anticipate, plan for, and adapt to climate fluctuations." [9] NOAA's new National Integrated Drought Information System (NIDIS) is one contribution to climate services. A national service would need to work closely with the many federal agencies that already deal in climate. Done effectively, this service would allow research scientists and resource managers to overcome the differences between the academic and management worlds. This concept already passed Congress in 1978 as Public Law 95-367 but has languished for lack of funding.

National scientific leadership should also entail a coherent policy for dealing with data. Simply put, no data means no science, and bad data leads to bad science. Good management also requires good data. In my experience with scientists, the first thing they love to argue about is data, the best example being the current dispute over hurricane trends. We will never end these arguments, but we should do our best to minimize these problems when possible. All data—National Weather Service data, USGS streamflow data, and National Resource Conservation Service snow and soil moisture data among many others—should be covered by a consistent national plan and be provided adequate funding. Data collection is unfortunately the first thing that gets cut in time of shortfall. Meta-data, that is data about data, is especially critical ancillary data because it lets scientists cull bad data from good.

DEVOTE MORE SCIENTIFIC RESOURCES TO REGIONAL PROBLEMS

In the last two years, the confluence of the severe on-going drought, eye-opening information on far more serious droughts in past centuries supplied by tree-rings, and the growing scientific certainty over the causes of climate change, have provided a focus such that water utilities and managers are now ready to be full participants in the scientific enterprise on climate. This means, however, that we need to be able to provide regionally specific information on risks, such as changes in snowpack, timing of spring runoff, increases in water demand from temperature increases, amount of sea level rise, and changes in the length of the growing season. Unfortunately, to date, scientific assessments like the IPCC have focused on the global and continental scale effects of climate change and hence are of limited use to regionally focused decision-making.

One example of the burgeoning demand for climate change information came out of a water utility climate change summit early this year hosted by the San Francisco Public Utilities Commission (SFPUC) which I attended. This watershed event brought together some 250 water and wastewater utility leaders from around the nation, agency officials, top climate researchers, representatives from NGO's and the business community. Organized by and for water utility leaders, the Summit focused primarily on adaptation responses utilities are—and should be—thinking about in light of climate change. As a result of that Summit, a steering committee chaired by SFPUC General Manager Susan Leal and made up of managers of some of the largest utilities in the nation—Metropolitan in Southern California, New York, Seattle, Las Vegas, Denver, Portland and San Diego—has begun meeting to learn from one another and speak with a collective voice about what they need from federal, state, and regional agencies.

Much of the regional response needs to revolve around regionally specific climate modeling; this is an explicit concern of the utility group. Regional modeling is urgently needed to inform water supply and capital improvement planning in the water and wastewater utility community. We know the climate models have problems dealing with precipitation in mountains, and they do not represent important

[8] Namely 3.1: Climate Models: An Assessment of Strengths and Limitations for User Applications; 4.3: The effects of climate change on agriculture, land resources, water resources, and biodiversity; and 5.1: Uses and limitations of observations, data, forecasts, and other projections in decision support for selected sectors and regions.

[9] Miles, E. L., A. K. Snover, et al. (2006). "An approach to designing a national climate service." PNAS 103(52): 19616-19623.

aspects of climate variability like decadal fluctuations. They most certainly are not a substitute for judgment. But they are the only tool we have for investigating likely future conditions and as such are critical. Used with care these models can provide an estimate of the range of possible future conditions. Despite their limitations, we must move forward with all forms of regional modeling as quickly as possible and this includes educating decision makers on their strengths and limitations.

Regional water management organizations need to work with regionally-based entities to solve their climate needs. During their 10-year existence, the existing RISA programs have provided valuable climate-related services and information for portions of the country. Seattle Mayor Nickels' leadership on climate change with the US Conference of Mayors is in part due to his connection to the Climate Impacts Group at the University of Washington. The California Applications Project at the Scripps Institution of Oceanography has been heavily involved with Governor Schwarzenegger's climate change initiative. My program has recently convened a panel of experts to draft a road map to help the Lower Colorado office of Reclamation prepare for climate change. Time over and again, RISAs have shown the capability of providing regionally relevant information on a whole host of issues ranging from information about past climates, to seasonal forecasts, and recently to climate change.

The RISAs provide one model of meeting regional climate needs that with additional resources could be scaled up to cover the nation. But this can not be done overnight. The effort takes time, dedication and commitment; overcoming the differences between the academic and professional management world can be challenging but innovative solutions come when academics, federal employees, and professionals share and combine their knowledge.

CONCLUSION

Drought and increased demand have combined to create a serious water supply problem on the Colorado River which climate change threatens to make far worse. To help the nation adapt to water supply problems caused by climate variability and change, we need more effective federal climate change science management and much more regionally-directed science. Both of these will require the involvement of resource managers and stakeholders in addition to scientists. Solutions will involve challenges to everyone. Scientists will need to understand needs and constraints of decision makers and adjust research to fit. Water Managers will need to understand the science better, and learn how to fit the uncertainty of climate change into their already significant capability to deal with variability. And even Congress will need to provide the necessary structure and oversight to allow the best climate change adaptation response possible.

Someone once said that the "proper response to uncertainty is insurance, not denial." It is time that we start acquiring 'insurance' against the effects of climate change by making sure that we have the necessary management, resources, tools and people to pursue critically needed water sector climate change adaptation measures. Thank you for the opportunity to address you today.

Senator CANTWELL. Thank you, Mr. Udall.

Dr. Milly.

STATEMENT OF CHRISTOPHER MILLY, PH.D., RESEARCH HYDROLOGIST, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

Mr. MILLY. Senator Cantwell and members of the subcommittee. Thank you for this opportunity to present testimony on the impacts of climate change on water supply and water availability in the United States. Water is the lifeblood of the Nation. Water keeps our bodies hydrated and clean and sanitizes our living spaces. Water in the soil grows the food we eat. We use water in the processing of food and fuel and the manufacture of products. Water flowing through our rivers generates electricity and transports cargo. Water is habitat and highway for fish and fowl. Water, liquid or frozen, is the Nation's playground in summer and winter.

The distribution of water across the Nation depends largely on climate. Changing climate is now affecting the availability of water

in the United States. Water availability can be measured in many ways. Precipitation is the gross income of our Nation's water budget. Stream flow is the net income. It's what remains after the evapotranspiration tax has been extracted.

Snow pack, reservoir levels, soil moisture, and water tables represent the contents of our water bank accounts. The bank accounts are important for getting us through hot, dry summers or the inevitable years of drought. But ultimately stream flow is the single best measure of disposable income in our national water budget.

So what stream flow changes have been observed? The very normal ups and downs of annual stream flow are superimposed upon subtle longer-term changes. For example, during the last 30 years the U.S. Midwest and Alaska received more water income than during earlier years of record and the U.S. Southwest received less.

Long-term changes in seasonal timing of stream flow, as you've already heard, have also been observed. In the western United States and the northern tier of the eastern United States, seasonal stream flows typically rose and fell about a week earlier on average during recent decades than during the prior period of record.

Are all these changes just normal variations or do they reflect climate change? The observed pattern of stream flow trends roughly matches the pattern that emerges from climate models when they try to simulate national stream flow during the 20th century. When we look at a global comparison of observed and climate model changes, this rough agreement for the United States is repeated over and over on the other continents. Such a level of agreement across the globe would be very unlikely to arise from natural variability alone.

We conclude that the same factors causing global warming have been changing the global water cycle. The change in the global water cycle in turn has contributed to the observed changes in stream flow and water availability in the United States. Additionally, the earlier stream flow timing observed in western and northeastern United States has been correlated with rising temperatures and a declining snow pack and is consistent with expectations from models of forced climate change.

So what about the future? The demonstrated skill of climate models when looking back at the past means that they are credible, though admittedly far from perfect, tools for looking forward into the future. These models project sustained drying of the Southwest and moistening of the Midwest and Alaska. These projections are only caricatures of the real future and they leave a lot of room for improvement. Climate models represent areas larger than the State of Maryland all the way from the Eastern Shore to the Allegheny Plateau by a single point. Much higher resolution climate models are needed in order to support optimal water management.

The Nation has no comprehensive network of stream flow measurement stations dedicated to monitoring long-term changes across the landscape. However, keeping higher resolution models honest and tracking ongoing changes in water availability will require higher resolution measurements.

Climate information needs to be delivered in a form that is more relevant to its consumers, water management. Water management needs flexible design and planning tools, recognizing that climate

will change during the lifetime of a project and that those changes are uncertain.

Thank you for this opportunity to present testimony and I'll do my best to answer any questions that you or the subcommittee may have. Thank you.

[The prepared statement of Mr. Milly follows:]

PREPARED STATEMENT OF CHRISTOPHER MILLY, PH.D., RESEARCH HYDROLOGIST, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

INTRODUCTION

Mr. Chairman and members of the subcommittee, thank you for this opportunity to present testimony on the impacts of climate change on water supply and water availability in the United States.

Water is the life-blood of the Nation. Water keeps our bodies hydrated and clean and sanitizes our living spaces. Water in the soil grows the food we eat. We use water in the processing of food and fuel and the manufacture of products. Water flowing through our rivers produces electricity and transports cargo. Water is habitat and highway for fish and fowl. Water, liquid or frozen, is the Nation's playground in summer and winter.

The distribution of water across the Nation depends largely on climate. As discussed below, we believe the same factors causing global warming are changing the global water cycle.

Water availability can be measured in many ways: precipitation, streamflow, reservoir levels, snow pack, soil moisture, glaciers, and water tables. Precipitation is the gross income of our Nation's water budget; streamflow is the net income—what remains after the evapotranspiration tax has been extracted. Snow pack, reservoir levels, soil moisture and water tables represent the contents of our water bank accounts. The bank accounts are important for getting us through hot dry summers or the inevitable years of drought, but ultimately streamflow is the single best measure of disposable income in our national water budget.

How might water availability be expected to respond to a general climatic warming? The behavior of the water substance is very sensitive to temperature variations. Warm ice melts. Warm water expands. Warm air can hold more water vapor. Together with some more advanced atmospheric physics, which predicts subtle shifts in atmospheric circulation, these facts suggest the changes in water availability that can result from warming:

- Systematic regional increases and decreases of total annual streamflow.
- Rising sea level, resulting in increased risk of saltwater contamination of coastal freshwater supplies.
- Loss of snow pack, resulting in increased winter streamflow and winter flood risk and decreased summer streamflow.

OBSERVED STREAMFLOW CHANGES

During the last several decades, annual streamflow in the United States fluctuated widely over time. In 1988, the Ohio River gave 115 million acre feet of water to the Mississippi; the next year it gave 270 million acre feet. Such wide variation is a normal state of affairs.

The normal ups and downs of annual streamflow are superimposed upon more subtle, longer-term changes. In recent decades, the U.S. Midwest and Alaska became wetter, while the U.S. Southwest became drier. For example, the flow of the Ohio River at Metropolis, Ohio, during the last 30 years was 12 percent higher than during the preceding 48 years of observations. The flow of the Colorado River at Lees Ferry, Arizona, was 3 percent lower than during the preceding 71 years (after making adjustments for flow decreases associated with water withdrawals). The flow of the Yukon River at Eagle, Alaska, was 3 percent higher than during the preceding 26 years.

Long-term changes in seasonal timing of streamflow, possibly related to warming-induced changes in snowfall and snowmelt, have also been observed. As the western United States has warmed during recent decades, a tendency toward earlier timing of streamflow has been noted. Similar trends toward earlier streamflow have been seen in the northern tier of the eastern United States. In both regions, seasonal streamflows are typically rising and falling about a week earlier in the year during recent decades than in the prior period of record.

CAUSES OF OBSERVED STREAMFLOW CHANGES: NORMAL VARIABILITY VS. FORCED CLIMATE CHANGE

On the basis of statistical analyses of streamflow measurements, tree-ring records, and models, it appears that the recent long-term changes in annual streamflow observed over large areas of the United States were not unprecedented. Consequently, taken alone, these streamflow changes are not unequivocal evidence of forced climate change, but might be explained as mere manifestations of natural, internal variability in the climate system.

However, these data need not be taken alone. We have other sources of information, including streamflow measurements from around the world and computer simulations of changing climate in the United States and the rest of the world. The observed pattern of a wetter Midwest, a drier Southwest, and a wetter Alaska is also the pattern that emerges from climate models when they try to simulate streamflow during the 20th century. And, when we look at a global comparison of observed and climate-modeled changes in annual streamflow during the 20th century, this rough agreement for the United States is repeated over and over on the other continents. Analysis suggests that such a level of agreement across the globe would be very unlikely to arise simply by chance. On the basis of this global perspective, we conclude that the same factors causing global warming are changing the global water cycle. The change in the global water cycle, in turn, contributes to the observed changes in streamflow and water availability in the United States.

The earlier streamflow timing observed in the western and northeastern United States has been correlated with rising temperatures, but changes in precipitation amounts and timing have also played a role. Changes in streamflow timing have not been clearly attributed to forced climate change. However, we can say that the observed changes in streamflow timing are qualitatively consistent with expected impacts of forced climate change.

PREDICTING FUTURE WATER AVAILABILITY

It is not valid simply to extrapolate the observed past changes in water availability forward into the future. However, the demonstrated skill of climate models in simulating the global pattern of 20th-century change in annual streamflow means that those models are credible, though far from perfect, tools for looking into the future. Given best assumptions about future atmospheric carbon dioxide concentrations and other drivers of climate change, these models project a long-term drying trend in the Southwest and moistening trends in the Midwest and Alaska. The drying trend in the Southwest can be expected to imply also an increasing probability of occurrence of Southwestern drought.

These projections, at best, are only crude caricatures of the real future. Are they the best that we can realistically hope for? Not at all. There is much room for improvement:

- Climate models typically represent conditions over areas larger than the State of Maryland by a single point. Such an approach has been adequate to assess global warming. However, climate varies geographically on a much finer scale, especially in mountainous regions. Therefore, to assess practical impacts on water and to design, plan, and implement needed adaptations, water managers need information on a much finer spatial scale, more like that of a county. To deliver this, much-higher-resolution climate models are needed.
- The Nation has no comprehensive network of streamflow measurement stations dedicated to monitoring long-term changes in streamflow in natural, developed, and developing environments across the national landscape. The available measurements, assembled from stations established for other purposes, have proven critical for the progress that has been made in detecting global changes in water availability. However, keeping higher-resolution models honest and tracking ongoing changes in water availability will require higher-resolution measurements.
- Climate models have only begun to include the effects of water-resource development, land use, and land-cover change on climate. This has not been identified as a crucial impediment for global analyses, but it probably matters at the finer spatial scale of water management.
- Water shortages come about when supply falls short of demand. Increased demand can create shortage, even when supply is stable. A change in climate causes a change in water demand, e.g., for irrigation and for natural ecosystems. Our understanding of this relation between climate and water demand needs improvement.

- Production of better climate information is necessary but not sufficient to assess future impacts. Climate information needs to come in a form that is relevant to water management. In order to ensure the relevance of climate-model information to water managers, accelerated and continuing dialogue will be needed between climate science and water managers.
- To make best use of available information in a changing climate, water management will need to adopt more flexible tools than those that have sufficed in the past. These new tools, unlike those that currently do the lion's share of water-system planning and design, must recognize that climate will change during the lifetime of a project and that estimates of the changing climate are uncertain. This will require a sea change in the field of water management. Such a change will not be accomplished without a concerted effort by government, academia, and professional societies.

Mr. Chairman, thank you for this opportunity to present testimony. I will do my best to answer any questions that you or other members of the subcommittee may have on this topic.

Senator CANTWELL. Thank you, gentlemen. Thank you for your testimony.

I guess I'll go ahead and start. I was going to defer to Senator Bingaman, but I'm happy to start.

You talked particularly, Dr. Milly, about water management and all of you talked about the need for more information. Are there some things that are known now that we should be doing? I'm going to pose a question, too, whether storage capacity is something that we should be looking at. Obviously, our views on storage capacity have changed over the last several decades. Do we need to rethink that and what else do we need to do in this area of water management?

Mr. MILLY. I could only say generally that storage capacity is one of the tools that I understand water managers use to help us match supplies and demands. I'm more at the end of being able to report to you on the changes in the supply and I'd prefer to defer to my colleagues here on the management questions.

Senator CANTWELL. Dr. Mote or Mr. Udall, for us in the Northwest, as I'm sure you understand, Dr. Mote, the change in climate even at 1 percent for an economy that is built on cheap hydropower is quite a significant impact. So what should we be doing?

Mr. MOTE. First of all, climate change should clearly be factored into any long-range plan involving water, whether it be evaluation of new storage supplies—

Senator CANTWELL. Do you have your microphone on?

Mr. MOTE. I'm sorry.

Senator CANTWELL. Thank you.

Mr. MOTE. It's one of those things we forget if we don't do this every day.

The relicensing of dams under FERC, for example, involves calculations of flows and reliability of different objectives. Clearly, climate change should be factored into things like that. But in addition, just with today's reservoir management approaches, one thing that could be done is to design reservoir optimization models. This is a sort of a 21st century technological approach replacing the sort of pen and paper version of earlier decades, where you construct a cost function or a benefit function for each use of water and then you let the model decide, is it best to hold this water in May or release it, because you're balancing hydropower with the needs for fish and agriculture and so on.

This is an approach that has been tried in an academic setting. It could be done on a wider scale and involve stakeholders in designing the cost functions.

Senator CANTWELL. Mr. Udall.

Mr. UDALL. Senator, there are 8,000 reservoirs in the United States over 6 feet tall according to the USGS. Eight thousand of those are considered large, 4,000 in the West, 4,000 in the East. Certainly reservoirs play a role here. But should anyone think that this is going to solve all of our problems, I think they're going to be quite saddened that it will not.

Groundwater storage may be a potential opportunity here, that the State of Arizona is doing and others are doing. But any reservoir—the good reservoir sites are gone now for the most part.

Senator CANTWELL. So that's a no on any new reservoirs. I think—

Mr. UDALL. It's not a no, but it's a very considered, there may be some reservoirs that help us, but it will not be the universal solution.

Senator CANTWELL. Yes, I'm more getting at that I think that the Bureau of Reclamation and our policies here have basically turned in a different direction, away from reservoirs, and maybe rightly so. But the question is what should we be considering.

So you're not objecting to it being a tool, as Dr. Milly mentioned, as far as management, but you're just saying just don't overfocus on that that's a great solution?

Mr. UDALL. Any reservoir that needs to be built nowadays has to be off-channel for the most part because of the environmental consequences, I think.

Senator CANTWELL. Dr. Milly, did you want to add something?

Mr. MILLY. Yes. I should comment that there are regions in which, as I said, the net income basically of water is declining, that no amount of storage capacity can create that water, of course.

Senator CANTWELL. Thank you.

Senator Corker.

Senator CORKER. Thank you, Chairwoman, and thank you for your testimony. Dr. Milly, I've seen some of the modeling and I couldn't agree more that we need higher resolution and need to be able to look at this data in much closer detail. I appreciate your comments in that regard.

I was listening to Mr. Udall's comments about Lake Mead and the need for climate modeling, but based on the scenario you were describing it seems to me that far more urgent activity needs to occur. By the time you've developed climate modeling, based on what you said, Lake Mead would have no water. I'm wondering if there's other efforts under way while modeling is being proposed?

Mr. MILLY. Absolutely, and I think Dr. Fulp here will address this on the second panel. Reclamation now has an EIS under way that's going to solve, at least for the short term, the water management problems on the Colorado River. The larger question is is this enough. Basically, this environmental impact statement allows shortages to Arizona of 600,000 acre-feet a year, and yet we're digging a 1.4 million acre-foot hole in the reservoir every year. Those numbers still diverge in a way that's scary, and if some of the scenarios that play out here with climate change and reduction

of water in the Southwest come about we're going to be talking about this again in the not too distant future.

Senator CORKER. Dr. Mote, as far as the 0.8 Centigrade change that's taken place in warming recently, if you look back through historical times, how does that relate?

Mr. MOTE. For the globe as a whole, a 0.8 degrees—we experienced 0.7 degrees in the last 100 years, according to the IPCC, and it was very likely that that rate of change over any 50–year period had not been experienced in at least the last 1300 years.

For the West as a whole, I'm not sure whether such a rate of change has been experienced within the last thousand years. But it is faster than the warming that occurred in the early part of the instrumental record by quite a lot.

Senator CORKER. Thank you, Chairwoman.

Senator CANTWELL. Senator Craig, do you have any questions for our panelists?

Senator CRAIG. Thank you, Madam Chairman. Thank you.

I guess one question, Dr. Milly. You've described a number of studies that are under way by the administration to study the effect of climate change in relation to water supply. Can you give us any idea of what those studies will bear, meaning what anticipated information will change the way we operate our current water systems? What are you anticipating?

Mr. MILLY. The question of how one operates water supply infrastructure is not one that I claim to have expertise in.

Senator CRAIG. So what are we looking for, baselines from which to make decisions?

Mr. MILLY. We believe that's true, yes. So the one who has to manage that supply, if we can tell him, for example, on average over the next 30 years you're going to see 20 percent less water coming down the Colorado, although it'll be fluctuating up and down, of course, as it always has in the past, then we understand that that's useful information to them, and that's the sort of information that we try to provide.

Also, the information on the fact that with the loss of snow pack you may expect to see stream flow declining earlier in the year, so that as late summer draws on there's just not nearly as much water coming down the river as you've been accustomed to in the past, that kind of information. Then it's up to the water manager to decide how to meet the demands, given that information.

Senator CRAIG. Mr. Udall and the chairman just got involved in a discussion about potential additional storage. I don't disagree that if it comes it's probably off main stem. Would your information attempt to help us understand as those flow patterns change times when there may be a greater opportunity to store than was historically the case? Is that the intent?

Mr. UDALL. The intent of regional climate modeling is to provide hydrology, future hydrology, that the engineers who operate these systems can figure out how best to optimize our reservoirs. Those operations involve things like how much do we worry about floods, how low do we draw our reservoirs down in the spring so that they can capture water and be safe so that you don't have a flood, but also capture the maximum amount of water possible?

Senator CRAIG. Yes, I experienced the reality of an interesting thought here. About a year ago, the Boise River was at near flood stage, hadn't been in quite a while. Of course, in that quite a while period of time people had busily built in the flood plain. I was trying to suggest to many of my constituents that a flood was a good thing because we hadn't had one in a while, which meant we were having an optimum water year. I had never thought of it in that way and oftentimes we think of flood as being a negative event. Out West in the last few years, it really is a positive event, if you're in the right place anyway or haven't chosen to be in the wrong place.

But anyway, gentlemen, thank you.

Senator CANTWELL. Thank you, Senator Craig.

One last question I had, Dr. Udall. You talked about modeling and information. Do we have the ability to do region-specific climate change models? Or Dr. Mote, either one of you.

Mr. UDALL. We certainly have the capability of doing it in the future, and people are taking large general circulation models, the big climate models, and downscaling them nowadays and getting reasonable results. But I think the idea here is, for example in the West, where topography is so important in determining what happens in the hydrological cycle, the smaller you can focus these models on, the better the results you get out. We need to expend more resources on that aspect of climate modeling.

Mr. MOTE. There is—

Senator CANTWELL. Go ahead, Dr. Mote.

Mr. MOTE. Excuse me. There is an effort under way among several modeling groups to do regional modeling for the whole United States, called NARCCAP, which I think is North American Regional Climate Change Applications Program, something like that. So within a few months we'll have national scale regional modeling. It's only at a 50– kilometer, 30–mile resolution, so it's better than the global models, but still not good enough for some resolutions.

We in the Pacific Northwest have a much finer scale model that we've run a couple of times.

Senator CANTWELL. What does that tell us in the sense of helping us to do water management? What data have we acquired from that?

Mr. MOTE. We're still at the early stages of evaluating the results of those modeling experiments. But they suggest, for example, that some of the changes in cloudiness or precipitation in the Yakama Basin versus west side of the Cascades, that these can be differentiated.

Senator CANTWELL. But you think that, given the ecosystem of the State of Washington, that we can defer—I mean, that we can differentiate ecosystems from east and west. But you think this is an investment we should be making for the entire United States?

Mr. MOTE. NARCCAP is an excellent first step. A few years from now we'll need to revisit it on a much higher spatial resolution to support water management and other needs.

Senator CANTWELL. We might pose further questions on this because I think part of the challenge here is if you say that key to the strategy in dealing with this change is the modeling, I think

we need to understand what the modeling will actually deliver for us. So we might pose some further questions to you.

Well, gentlemen, thank you. I think we'll go to panel No. 2 unless my colleagues have any other further questions. Let's hear from some of the actual water users. Gentlemen, thank you for your testimony and your expertise in this area. We look forward to continuing to dialog with you on this important issue.

I'd like to call panel two now. Mr. Patrick O'Toole from the Family Farm Alliance from Wyoming, and I want to mention that Mr. O'Toole served in the Wyoming State Legislature with Senator Thomas, so we're glad that he is here with us today. Jack Williams from Trout Unlimited; Mr. Terry Fulp, who is the Area Manager of Boulder Canyon Operations for the United States Bureau of Reclamation; Mr. Tim Brick, the Metropolitan Water District of Southern California; and Mr. Tim Culbertson, representing National Hydropower Association, from Ephrata, Washington.

Gentlemen, thank you very much. We do have participation across the country, but again a little bit more focused in the West, where water issues are often fought over. So thank you for being here, and, Mr. O'Toole, thank you very much for being here and we'll start with you.

STATEMENT OF PATRICK O'TOOLE, PRESIDENT, FAMILY FARM ALLIANCE, SAVERY, WY

Mr. O'Toole: Thank you, Madam Chairman. When I was asked to be on this panel, Senator Thomas's office contacted me, and I was so looking forward to him introducing me. We worked together in the legislature. He was a colleague. He was a friend and we will miss him.

The last meeting actually that I had with Senator Thomas was at Saratoga, Wyoming, last year when we talked about what is a very graphic manifestation of at least the perception of climate change in the Rocky Mountain States. If you've flown over southern Wyoming and Colorado, you would be stunned to see the effects of the die-off of trees that has happened over the last 3 or 4 years. I was stunned to see what had happened over the last, from last fall to this spring. There were forests with 90 percent of the trees gone, and they will be gone for my lifetime and into my grandchildren's lifetime as we regenerate.

Our conservation was what could we do to enhance water supply in those areas that are so affected. I believe that Family Farm Alliance, which I am currently president of, what I think we bring to the table is the ability to reach out to all of the 16 western States in which we have irrigator members and talk about the specific instances that are happening State by State.

To us it is very graphic, and the reality of the loss of water is affecting virtually every irrigation district in the West. Currently people talk about looking down from 50,000 feet. Well, I live at 7,000 and am surrounded by mountains at 10,000 feet, and I maybe will give you a little bit of what it looks like from the ground.

Last year we had 130 percent snow pack in March. Last summer was the driest summer. It burned up our country just because of the change in climate. This year our basin is at 29 percent, 29 per-

cent of normal, and Wyoming is discussed over the long-term average, possibly as low as 60 percent deliveries to the Colorado River. Those are significant numbers that are going to have effects on our members and, more importantly, on what we perceive as America's food supply and its national security as it relates to that.

We have listed in our testimony a lot of different examples of various things that are happening in various States and various things various States are doing. But we started putting together 3 years ago and I testified and presented in front of the Senate—the House Energy Committee a study that the Family Farm Alliance did on storage. We believe that is one of a toolbox of things that we should be doing in the future, not limited. Certainly we've all talked about big dams already having been built, but in the valley that I live in we have built a project that began delivering water a couple of years ago, 23,000 acre-feet. It saved us in the last 2 years of drought. It also created 25 miles of fishery and the mitigation for it created the largest manmade wetland in Wyoming. Birds went from 30 to 130 in that wetland area.

So what we have learned as farmers and people on the ground is that the uses of water cross such a broad range. In talks I very often say water is life, but I read a book on Africa recently and they talked about water as hope. I've become much more convinced that the ability to know that there'll be water in the system is much more of a hopeful experience and it's one that in this particular case it is very clear that if we do not make decisions, indecision will be decisions in the West.

One thing that Pat Mulvary from southern Nevada and I agree on is that the drought has pushed debate 20 years ahead. So it's our responsibility to come up with solutions that are much further ahead than we thought we were going to have to make as policymakers.

The Family Farm Alliance has, at our yearly convention every State reports what's happening in the particular State. It is a graphic experience the last 3 or 4 years about the transitions of not thousands, but tens of thousands and hundreds of thousands of irrigated acres that are going to fall out of production. It's a food security issue I think that we need to address. We could go on about the impacts of foreign food into the matrix of what we should be looking at. But when you look at the combination of both, the combination of drought, and now the new discussion about ethanol and using water to produce large quantities of ethanol—I know it's an issue that Senator Thomas was aware of. The one example we've used this week while we were here is the billion gallons of ethanol that California has projected out would cost 2.5 trillion gallons of water to produce. That's the water that central California delivers to southern California.

I very much appreciate being able to visit with you today and anything I can do to help and our organization, we'd appreciate.

[The prepared statement of Mr. O'Toole follows:]

PREPARED STATEMENT OF PAT O'TOOLE, PRESIDENT, FAMILY FARM ALLIANCE

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to appear before you to discuss climate change and water supply impacts on Western irrigated agriculture. My name is Patrick O'Toole, and I serve as the president of the Family Farm Alliance (Alliance).

The Alliance is a grassroots organization of family farmers, ranchers, irrigation districts and allied industries in 16 Western states. The Alliance is focused on one mission: To ensure the availability of reliable, affordable irrigation water supplies to Western farmers and ranchers. We are also committed to the fundamental proposition that Western irrigated agriculture must be preserved and protected for a host of economic, sociological, environmental and national security reasons—many of which are often overlooked in the context of other policy decisions.

My family operates a cattle, sheep and hay ranch in the Little Snake River Valley on the Wyoming-Colorado border. I am a former member of Wyoming's House of Representatives and I served on the federal government's Western Water Policy Review Advisory Commission in the late 1990's.

The topic of this oversight hearing is not only tremendously important to the Alliance, it also is immediately relevant to me and other Wyoming water users, and to farmers, ranchers and small communities all over the West.

ALLIANCE INVOLVEMENT WITH CLIMATE CHANGE ISSUES

The Family Farm Alliance Board of Directors at its 19th Annual Meeting in Las Vegas last February established a subcommittee to develop a white paper that addresses the important issue of climate change, its possible impact on Western water supplies and irrigated agriculture, and recommendations on how to plan and provide stewardship for this change. That document will soon be finalized and publicly released, and we will share it with the subcommittee. I think it will once again demonstrate the Alliance's realistic approach to problem solving.

CURRENT AND PROJECTED IMPACTS OF CLIMATE CHANGE TO WESTERN FARMERS AND RANCHERS

In the past six months, the public has been inundated with a flood of new studies that focus on projected climate change impacts to Western water resources. Predictions and conclusions reached about the impacts climate change will have on future water resources availability are as varied as the Western landscape. However, we are increasingly hearing reports that predict dire long-term hydrologic consequences for the West. Several studies further focus on specific regions or watersheds and are briefly discussed below.

Arizona

Experts in Arizona say that climate change is occurring and will likely have more impacts in the future to water resources. A climatic water budget runoff model has been developed for the Salt and Verde River basins of central Arizona[1], which used the outputs of six global climate models to estimate runoff in the future under assorted "scenarios" developed by the Intergovernmental Panel on Climate Change. Due to projected warmer temperatures by the year 2050, projected changes in runoff for the two basins suggest that the runoff from the Salt and Verde will have approximately an 85% chance of being less in the future due largely to warming in the study area. This could have significant impacts for these two basins, which have six dams, a variable hydrology, and a total storage capacity of 2.3 million acre-feet (as compared to the 27 million acre-feet capacity of Lakes Powell and Mead on the Colorado River).

California

A report released in 2006 by the State of California[2] predicts that climate change will result in a drastic drop in the state's drinking and farm water supplies, as well as more frequent winter flooding. The report suggests that warmer temperatures will raise the snow level in California mountains, producing a smaller snowpack and more winter runoff. This means more floodwaters to manage in winter, followed by less snowmelt to store behind dams for cities, agriculture, and fish. By the year 2050, the statewide snowpack would shrink by 5 million acre-feet less water, more than the total capacity of Lake Shasta, the state's largest reservoir.

By 2050, the State study predicts that average snowpack in the Sierra Nevadas is likely to diminish by more than a third, and more precipitation will fall as rain rather than as snow, making it harder for reservoirs to capture for the long summer

[1] CLIMATE CHANGE 2050: IMPACTS ON RUNOFF FROM THE SALT AND VERDE RIVER SYSTEMS. PRESENTATION TO THE FAMILY FARM ALLIANCE ANNUAL CONFERENCE, February 22, 2007, Dr. Robert C. Balling, Jr., School of Geographical Sciences, Arizona State Uuniversity.

[2] OUR CHANGING CLIMATE-ASSESSING THE RISKS TO CALIFORNIA, A summary biennial report from the California Climate Change Center, 2006.

the same amount of water. The dwindling snowpack could reduce deliveries of Sierra supplies to Central Valley farmers by 10%.

According to another recent study developed by the University of California[3], agricultural water users in the Central Valley are also the most vulnerable to climate warming. For the driest climate warming scenario assessed, the predicted hydrology would reduce agricultural water deliveries by about a third. For that dry scenario, the study speculates that, while financial losses to the agricultural community would be compensated by water sales to urban areas, much of this loss would likely result in an uncompensated structural change in the agricultural sector.

Colorado River Basin

A February 2007 report by a National Research Council (NRC) committee[4] says agriculture is the likeliest target for shifting use to urban needs in the fast growing West. But it cautions that "the availability of agricultural water is finite." It adds that rising population and water demands "will inevitably result in increasingly costly, controversial and unavoidable trade-off choices" in managing a shrinking resource. Future droughts may be longer and more severe because of a regional warming trend that shows no signs of dissipating, the NRC report notes. It also states that a preponderance of evidence suggests that rising temperatures will reduce the river's flow and water supplies.

The committee also looked at how a steadily rising population and related increases in water demand will affect Colorado River water management. The population across the western United States has grown rapidly. Despite some successful water conservation efforts, urban water use in the region has increased significantly along with the expanding population. Increasing urban water demands are often met through sales, leases, or transfers of water rights from farm users. Water transfer agreements will be limited in their ability to satisfy growing, long-term demand, according to the NRC committee, and such agreements may also cause problems for third parties, such as downstream farmers or ecosystems. Technology and conservation measures are useful and necessary for stretching existing water supplies, the committee acknowledged, but any gains in water supply will be eventually absorbed by the growing population.

Pacific Northwest

Last April, the Intergovernmental Panel on Climate Change released a report[5] that predicts climate-change related impacts to water resources in the Pacific Northwest. Similar to predictions made in other parts of the West, dwindling mountain snowpack is expected to make summer water scarce especially east of the Cascades, where agriculture is a strong component of rural communities.

Snowpack in the Cascade Range holds two-thirds of the region's stored water. As it melts during the dry summer months, it fills rivers, generates hydropower, and helps meet the water needs of irrigation, fish, recreation and growing urban areas. However, Cascade snowpack has diminished in the past 50 years and is expected to further shrink. Projected warmer winter temperatures will cause snowpack to melt earlier in the spring, which could exacerbate both spring-time flooding and late-summer drought conditions. This prediction does not bode well for irrigation-dependent eastern portions of Oregon and Washington.

Utah

A 2003 study directed by Congress and led by Utah State University professor Frederick Wagner[6] lays out a variety of possibilities if temperatures increase from nearly 4 to 6 degrees Fahrenheit by 2100. The potential scenarios range from increased precipitation (with decreased snowpack and greater downstream flood risks) to decreased precipitation (desertification and a decline in water resources). In all scenarios, water management changes would be required, and the worst-case scenario would likely trigger water transfers from agriculture to urban areas, which would contribute to a sharp decline of farming and ranching. Water resources ex-

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[3] CLIMATE WARMING AND WATER MANAGEMENT ADAPTATION FOR CALIFORNIA, Stacy K. Tanaka et al, Department of Civil and Environmental Engineering, Department of Agricultural and Resource Economics, University of California, Davis 95616.

[4] COLORADO RIVER BASIN WATER MANAGEMENT: EVALUATING AND ADJUSTING TO HYDROCLIMATIC VARIABILITY, National Research Council, Division on Earth and Life Studies, Water Science and Technology Board, 2007.

[5] CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, World Meteorological Organization and the United Nations Environment Program.

[6] Professor emeritus of the Department of Forest, Range and Wildlife Science at Utah State University.

perts in Utah also realize that new surface water storage projects may be necessary to capture more snowmelt or more water from other sourcesg.[7] The Southern Nevada Water Authority—which has essentially used up its share of Colorado River water—is already planning to take groundwater out of aquifers under the Utah-Nevada state line and pipe it to Las Vegas. Ranchers in this area are fighting this proposal.

SUMMARY OF ANTICIPATED IMPACTS TO AGRICULTURAL WATER USERS

The Western Governors' Association (WGA) recently testified[8] in support of a bill that would reorient and fully fund the U.S. Global Change Research Program to make it more user-driven. The WGA testimony mirrors many of the common themes and findings developed in the reports identified above. WGA found that we can expect to see the following general effects and impacts caused by warming future temperatures in the Western U.S.:

- Smaller snow packs and earlier snowmelt will affect reservoir storage and demand for water and impact productivity and value of hydroelectric generation;
- More rain than snow is likely, with uncertain projected impacts to overall precipitation amounts in specific areas;
- Extreme flood events could be more common and larger.
- Droughts and higher temperatures would be more intense, frequent and last longer, which would increase stream and reservoir evaporation, diminish surface water supplies, and stress groundwater supplies and water quality.

Despite the highly variable and uncertain nature inherent with climate change predictions, it can safely be concluded that, in the West, with a warming climate, there will be less water stored in our biggest reservoir . . . the snow pack. More water in the form of rainfall and runoff will come at farmers and ranchers sooner in the season, when it may not be useful and may even present a threat.

WHAT ARE IRRIGATORS, WATER AGENCIES AND BUSINESSES DOING TO ADDRESS CLIMATE IMPACTS?

While a great deal of scientific inquiry and public discourse has been focused on climate change and its possible consequences for the planet's future, Western irrigators and irrigation districts are concerned about the problems threatening their water supplies today—drought and urban population growth. Event without climate change, these factors present an immediate crisis for agricultural water users in the West. If the effects of climate change are anything like those outlined in the research discussed here today, Western irrigated agriculture could be largely eliminated. This is, of course, worrisome to farmers and ranchers and their communities. It ought to be of great concern to nation as a whole because climate change may result in a disruption of food production worldwide. If that is what is in store for us, then this country cannot afford to lose the food production capacity of Western irrigated agriculture.

The response of irrigators and water agencies to current water supply challenges can provide some insight into the possible measures that might be taken to cope with long-term water supply reductions resulting from climate change.

DROUGHT RESPONSE

Much of the West is currently in drought or facing reduced water supplies as a result of environmental regulation. In response, farmers and water agencies are taking creative measures to conserve water and increase the efficiency of irrigation. Here are a few examples.

- In the San Joaquin Valley of California, state-of-the-art drip irrigation systems water some of the most productive farmland in the world.
- Further north, in the Sacramento Valley, producers and local governments are working to develop a regional water management program that will help address not only water quantity challenges, but also water quality and environmental issues. Those same growers 15 years ago were key players in a state-managed drought water bank that temporarily transferred local water to southern California to meet other statewide needs.

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[7] Professor Jack Schmidt, Utah State University, Dept. of Aquatic, Watershed, and Earth Resources, quoted in "Global Warming: What about water?", Salt Lake City Tribune, October 30, 2006.

[8] Testimony before the . . . Western States Governors Association . . .

- In Idaho, water users are working with state and federal agencies and the Nez Perce Tribe to settle longstanding disputes and create more certain water supplies.
- Along the Columbia River, irrigators are developing water exchange programs to increase supply reliability while improving salmon habitat.

PRESSURES OF URBAN POPULATION GROWTH

The West is the most rapidly growing part of the United States. Yet, water supplies there are essentially static. In some areas, urban demand for water—and land—is straining agriculture and rural communities to the breaking point. New environmental water demands imposed by regulatory agencies or courts also first look to agriculture. This is happening in every state, but farmers and ranchers point to some striking examples:

- A report released last year by Environment Colorado found that, from 1987-2002, Colorado lost an average of 460 acres per day of ag land. The report predicts 3.1 million more acres will be lost to development by 2022.
- Arizona's massive Salt River Project (SRP) in a few years will cease to provide water to agriculture in order to meet new demands exerted by development.
- In Las Vegas, Nevada, over 70,000 new residents are moving in every year, and urban water officials are looking to rural areas to satisfy its growing thirst.
- A restoration agreement developed for the Platte River could potentially dry up hundreds of thousands of acres of farmland in Nebraska and Wyoming, in order to reallocate water to meet the perceived needs of imperiled fish and wildlife.
- The California Department of Conservation indicates that more than 1 million acres of farmland in the state was converted between 1988 and 1998. Last year, California's population officially topped 37 million, a growth rate of 1.4 percent, representing 500,000 new residents in the last fiscal year.

Farmers, ranchers and rural communities cannot solve the water supply problem created by the Western population boom. Nor can they be expected to sacrifice their livelihoods for the "greater good" of golf courses, strip malls and housing developments.

Farmland is disappearing at a time when the U.S. needs a stable domestic food supply (just as it needs a stable energy supply). We are concerned that this critical issue—which becomes even more serious when viewed in the context of projected climate-change impacts to water supplies—is being overlooked by our national leaders.

A reliable, safe and sustainable domestic food supply is just as important as a strong military to the protection of our national interests. The post 9/11 world of terrorist threats makes the stability of domestic food supply even more pressing.

WHAT ARE WESTERN IRRIGATORS DOING TO REDUCE GREENHOUSE GASES?

Western farmers and ranchers are already taking actions to reduce greenhouse gases and other possible contributors to climate change. Some of these actions are undertaken consciously with this objective in mind; others have been implemented as part of the broad portfolio of actions that successful farmers have to take to stay profitable in today's economic and regulatory climate. In virtually every Western state, there are examples of activities that agricultural producers are taking that have an overall effect of reducing carbon dioxide emissions, which many policy makers believe are a primary contributor to global warming. These actions include:

- Use of cleaner and more efficient diesel engines;
- Reduction of energy needs on farms;
- Use of biodiesel;
- Low-till practices;
- Involvement in conservation programs, which provide incentives to set aside thousands of acres of farmland for wildlife habitat;
- Selling carbon credits to industries for approved management actions.

Probably most obviously, and most importantly, crops turn carbon dioxide into oxygen. Further, new research suggests that irrigation has kept croplands cool, countering to some extent the rising temperatures caused by greenhouse gas emissions over the last half century.[9]

[9] Kueppers, L. M., M. A. Snyder, and L. C. Sloan (2007), IRRIGATION COOLING EFFECT: REGIONAL CLIMATE FORCING BY LAND-USE CHANGE, Geophys. Res. Lett., 34, L03703, doi:10.1029/2006GL028679.

RECOMMENDED STRATEGIES TO ADDRESS POTENTIAL IMPACTS

Western water supplies are already inadequate to the demands of agriculture, urban growth and environmental enhancement. Global climate change, we're told, will further reduce those supplies.

So how will we meet the ever-increasing demand for water in the West in an era when there will be an ever-decreasing supply? Improved conservation and efficiency by urban and agricultural water users is certainly part of the solution, but only part.

1. Implement a Balanced Suite of Conservation and Supply Enhancement Actions

We believe that it is possible to meet the needs of cities and the environment in a changing climate without sacrificing Western irrigated agriculture. To achieve that goal, we must expand the water supply in the West. There must be more water stored and available to farms and cities. Maintaining the status quo simply isn't sustainable in the face of unstoppable population growth, diminishing snow pack, increased water consumption to support domestic energy, and increased environmental demands.

It is simply ludicrous to believe that conservation alone will supply enough water for the tens of millions of new residents expected to arrive in Western cities during the coming decades. Farmers and ranchers understand that conserved water cannot realistically be applied to instream uses, as it will more likely be put to beneficial use by the next downstream appropriator or held in carryover storage for the following irrigation season.

Many water projects are ready and waiting to be developed in the West[10]. While conservation and recycling programs have done a tremendous job of meeting new growth, still, only a small amount of new water has been developed in the past 30 years. We cannot continue to "conserve just a little more" forever. It's time to start developing and implementing the water infrastructure needed to cope with a changing climate, meet the needs of a burgeoning population, and support a healthy agricultural base in the West.

2. Streamline the Regulatory Process to Facilitate Development of New Infrastructure

Modern, integrated water storage and distribution systems can provide tremendous physical and economic flexibility to address climate transformation and population growth. However, this flexibility is limited by legal, regulatory, or other institutional constraints, which can take longer to address than actually constructing the physical infrastructure[11].

The often slow and cumbersome federal regulatory process is a major obstacle to realization of projects and actions that could enhance Western water supplies. In addition, there exists with agencies a defeatist attitude that no dams or water supply projects will be built. So, there is no commitment to earnestly begin and engage the difficult problems described above. The Family Farm Alliance wants to work with Congress, federal agencies and other interested parties to build a consensus for improving the regulatory process.

3. Prioritize Research Needs

Our country has tremendous, but limited, resources available to fix our problems, so we must prioritize. One priority research items should be a comprehensive validation of West-wide changes in climate change-driven streamflow. This should be followed by quantification of the amount of additional reservoir storage, conservation targets, etc required to re-regulate this change in hydrology. This would quickly illustrate to policy makers the need to start modernizing our water infrastructure. This assessment should be accompanied by a comprehensive study of the collective impacts of agricultural land and water changes in western states over the last 10 years, as well as predicted trends. A study of this sort may provide the type of hard findings that may help wake up policy makers on the "big picture" ramifications of this issue.

CONCLUSION

Climate change could further strain fresh water supplies in the American West. We must begin to plan for that now, and not wait until we are forced to make decisions during a crisis. Relying on agriculture to be a "shock absorber" to soften or

[10] WESTERN WATER SUPPLY ENHANCEMENT DATABASE, Family Farm Alliance, 2005.

[11] CLIMATE WARMING AND WATER MANAGEMENT ADAPTATION FOR CALIFORNIA, Stacy K. Tanaka et al, Department of Civil and Environmental Engineering, Department of Agricultural and Resource Economics, University of California, Davis 95616.

eliminate the impending water shortage is not planning. It is a choice to put our heads in the sand and hope for the best. It is a decision that could worsen the overall impact of climate change on our nation's economy and security.

Millions of acres of barren land have been transformed into the most efficient and productive agricultural system in the world. About 5 percent of the land area of the West is irrigated, and the Bureau of Reclamation provides water to about one-fifth of that acreage. All of this has been done for a total federal investment of $11 billion. A 1998 study found that the economy of the United States receives a greater than 100% return each year on this investment[12].

Now is not the time to retreat from our investment. Now is the time to enact sound policies that encourage continued investment in irrigated agriculture. Allowing water-short cities to absorb farmers' water supplies will significantly diminish domestic food production at exactly the same time global warming is predicted to severely adverse impact food production worldwide.

The U.S. recently became a net importer of food. The U.S., which once fed much of the world, now imports more food than it exports. Food production, like so many of our industries and services, is moving off shore, and a large part of our security is moving with it.

Europeans aggressively protect their farms and food production capability because they still remember the hungry years during and after World War II when they relied on other nations, America in particular, to feed them. The time has come—indeed, it's long overdue—for the United States to similarly adopt an overriding national goal of remaining self-sufficient in food production. Policy decisions on a wide range of issues ranging from taxation to the management of natural resources should then be evaluated to be sure they are consistent with that goal. It's hard to imagine a simpler or more important step to safeguard the American public.

Thank you.

Senator CANTWELL. Thank you again, Mr. O'Toole, for being here.

Mr. Brick.

STATEMENT OF TIM F. BRICK, CHAIRMAN, METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, LOS ANGELES, CA

Mr. BRICK. Madam Chair and distinguished Senators. I too would like to begin by expressing my deepest sympathy to the family and friends of the late Senator Thomas. He was a great friend of western water and we will miss him.

I'm Tim Brick, the Chairman of the Board of the Metropolitan Water District of Southern California. For about 80 years we've been supplying water to a population that is now 18 million people through the coastal plain of southern California. Our two main sources of supply have been the Colorado River and the California State Water Project from northern California.

I'd like to say that I guess my main message really is that in order to meet our reliability goals we've had to start changing and transforming the way that we approach water planning and to emphasize a diversification of supply and resources. A lot of the lessons for this we really learned from the drought that occurred in the late 80's and early 90's, which hit our region very hard.

But the current situation in southern California is that we are in the driest year on record. Los Angeles, which typically has 15 percent—15 inches average rainfall, this year has 3.2 inches of average rainfall. In the 9 most recent years, it has fallen to 11 inches, which is 27 percent below normal, and that included one of the highest rainfall years on record as well. My community of Pasa-

[12] That report and associated data was produced by Darryll Olsen, Ph.D. of the Pacific Northwest Project in Kennewick, Washington and Houshmand Ziari, Ph.D. of IRZ Consulting in Hermiston Oregon. The report was prepared for the Family Farm Alliance.

dena 3 years ago had 58 inches of rainfall. This year it had 3.5 inches of rainfall.

This pattern throughout the West is largely typical of the West, in which we're experiencing record low precipitation and runoff. This is the first time in Metropolitan's history in which critical dry conditions exist locally and on all of our supply watersheds.

You've heard estimates of great concern with regard to the long-term adequacy of supplies on the Colorado River and estimates that it's likely that runoff will decline in the near future from 10 to 15 percent, and some would even say substantially more. On our State Water Project entitlement and supply, there has been some extensive study by the government, by the State Government, to look at the key issues with regard to runoff, water quality, and extreme weather conditions related to the State Water Project, with some very disturbing kinds of conclusions.

Our response really has been to move toward a diversification of supplies and the development of a buffer beyond even that basic goals that we set for future supply. It includes storage, both surface storage and groundwater storage. We've spent more than $450 million in recent years on groundwater storage and more than $2 billion on surface storage.

It includes a very substantial commitment to conservation and increased conservation programs, even including trying to change how southern Californians view landscaping and developing a California-friendly landscaping program which emphasizes natives and appropriate vegetation. We made a major investment in recycling and groundwater recovery as well, with 85 programs that we've spent $215 million on that now supply about 128,000 acre-feet of supply per year. That's about enough water for 600,000 people.

We also now manage imports for ecosystem health and competing needs, shifting the timing of deliveries to wetter years or wetter periods when there's less impact on fish and the environment. It's important to know that that's particularly important because the effects of climate change are going to create great stress on the ecosystems and the watersheds that supply southern California and the rest of the West.

In the next year there's going to be some critical decisions made that we need Federal help and support on. The first is with regard to the basin State recommendations to the U.S. Bureau of Reclamation on how to manage shortage on the Colorado River Basin. The second is with regard to the Sacramento-San Joaquin River Delta System. Key decisions need to be made and the basic message that we would offer is that we cannot afford to wait. We need to partner with the scientific community, implement no-regrets actions, undertake aggressive conservation steps, and we need imperative decisions regarding the California Bay Delta System and the Colorado River Basin States Initiative.

Metropolitan stands ready to work cooperatively and collaboratively with you and with the Federal agencies you oversee. Thank you very much.

[The prepared statement of Mr. Brick follows:]

PREPARED STATEMENT OF TIMOTHY F. BRICK, CHAIRMAN, METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, LOS ANGELES, CA

Chairman Bingaman and Members of the Subcommittee, thank you for this opportunity to testify regarding the impacts of climate change on water supply and availability in the U.S. My name is Timothy Brick, and I am the Chairman of the Board of the Metropolitan Water District of Southern California.

For more than 75 years Metropolitan Water District has provided imported water to the Southern California region from the Colorado River and the State Water Project originating in Northern California. Our mission has been to be the wholesale provider of high quality, reliable drinking water supplies primarily for municipal and industrial use. In recent decades, we have begun to diversify our resources and commit to contingency planning in order to live up to our mission.

Metropolitan Water District is the nation's largest provider of imported water to an urban area. The population today in our service area is more than 18 million, and it is projected to rise to 22 million by 2030. Metropolitan is comprised of 26 member public agencies that service an area spanning 5,200 square miles and six southern California counties.

CLIMATE CHANGE

Metropolitan's latest challenge is one shared by not only the water community, but also the global community as a whole. California's history shows us that change in climate and weather, both natural and human-induced, are inevitable.

This climate change will have a dramatic impact on water supplies and demands and will necessitate a strong ethic of water use efficiency in our communities as well as the aggressive development of innovative, alternative water supplies to meet growing water needs.

Southern California is currently experiencing its driest year on record. Since July 1st 2006, Los Angeles has received only 3.21 inches of rainfall as compared to the normal of 15 inches per year. This year seems to be a continuation of a critically dry weather trend. In the most recent nine years, Los Angeles has averaged only eleven inches per year, 27% below normal.

On a larger scale, most of the western United States is experiencing record low precipitation and runoff. For the first time in Metropolitan's history, there are critical dry weather conditions occurring concurrently in our service area of Southern California as well as in the watersheds for our Colorado River and State Water Project water supplies. These regional climate trends are shown in the recent drought outlooks provided by the National Oceanic and Atmospheric Administration.

COLORADO RIVER WATER SUPPLIES

A report released by the National Research Council in February 2007 looked at past climate and streamflow conditions in the Colorado River and raised concerns regarding the long-term adequacy of Colorado River water supplies.

The western United States, particularly the region that depends on Colorado River supplies, has been experiencing drought conditions since the late 1990s. Years 2002 and 2004 are among the 10 driest years on record in the upper basin states of Colorado, New Mexico, Utah and Wyoming. Correspondingly, water storage in the basin's reservoirs has dropped sharply and now is at the lowest level since their initial fillings many decades ago.

It is now known that water allocations between the upper and lower Colorado River basin, as governed by the Colorado River Compact of 1922, were based on a short record of relatively high annual flows of 15 million acre-feet annually on the Colorado River. Recent patterns as well as reconstructed river flows based on tree-ring data dating back several centuries indicate that the past water management decisions on river water allocations and use may be overly optimistic of future water availability as annual flow could be 10 to 15 percent less than the 1922 estimate. Some experts would say even more.

Temperature records across the Colorado River basin and the western United States document a warming trend over the past century. Most recent climate model projections suggest that temperature across the region will continue to rise in the foreseeable future. Higher temperatures will result in less snowfall, increased evaporation losses, and shifting of snowmelt to earlier in any given year. The preponderance of scientific evidence suggests reduced Colorado River streamflow and water supplies, as well as increasing severity, frequency, and duration of future droughts.

In addition, the western United States is experiencing rapid population growth, further increasing the pressure for Colorado River water supplies. For example, pop-

ulation grew 66% in Nevada, 40% in Arizona, and 30% in Colorado from 1990 to 2000; these three states ranked number 1, 2, and 3 in terms of highest percentage population growth during the last Census.

Better understanding of past climate and streamflow conditions of the Colorado River, rapid population growth and increasing water demands in the region, an apparent climate warming, and warnings from many climate model simulations have cast great uncertainty in the reliability of future Colorado River supplies to southern California and the Southwest.

CALIFORNIA STATE WATER PROJECT

Last year the California State Department of Water Resources released a report titled "Progress on Incorporating Climate Change into Management of California's Water Resources." The report was prepared in response to Governor Schwarzenegger's Executive Order S-3-05 establishing California greenhouse gas emissions targets.

This report utilized four climate scenarios from two global climate models and downscaled potential ranges of change to the State Water Project watershed to analyze potential impacts. While the report does not represent a comprehensive assessment of the climate change impact, it does reveal at least three major potential impacts that constitute growing concerns for water managers.

Runoff

The first concern is related to the timing of snowmelt runoff. Studies suggest that warmer temperatures during the past half-century have brought significant changes in the seasonal timing of runoff. Smaller spring snow packs are a very real possibility and earlier melting of these natural reservoirs. When warmer temperatures in the winter translates into more rain and/or less snow in our Sierra Nevada mountains, it will severely lessen the ability to store water for peak summer water needs, avoid costly flooding, and otherwise manage fresh water—an increasingly scarce resource.

Water Quality

Water quality is also a concern linked to climate change. A higher sea level would likely bring increased salinity levels intruding on the freshwater system that is already vulnerable to salt water intrusion, and could further jeopardize levee stability, possibly leading to larger and more frequent failures like one that happened last year. Long periods of dry weather can also bring water quality challenges as contaminants typically accumulate on land surfaces. When the rain returns, it carries these contaminants in the runoff, making water treatment more difficult.

Extreme Weather Conditions

The third concern is linked to the possibility of extreme weather events that change the frequency of storm and drought conditions. Extreme weather conditions bring about many challenges, water quality being only one. Storage becomes another challenge as managers are caught in a tradeoff between storing water for future dry periods and lowering reservoirs before the onset of a flood season to protect downstream communities.

Climate change impacts further accentuate the variability and uncertainties surrounding water supplies from the State Water Project system.

METROPOLITAN'S POLICY ON CLIMATE CHANGE

In March 2002, our board adopted policy principles on global climate change as related to water resource planning. The principles stated in part that "Metropolitan supports further research into the potential water resource and quality effects of global climate change, and supports flexible "no regret" solutions that provide water supply and quality benefits while increasing the ability to manage future climate change impacts."

METROPOLITAN'S RESPONSE

The policy principles are reflected in Metropolitan's Integrated Resource Plan (IRP). Metropolitan and its member agencies have developed an IRP water resource portfolio that emphasizes diversification and adaptability of supply sources to manage current and future uncertainty. The IRP has also placed an increasing emphasis on local supplies such as conservation, water recycling and groundwater recharge.

Metropolitan built a new storage reservoir in the late 1990's in order to store water when it is plentiful during wet years for use in dry periods. In addition, Metropolitan is completing a large project called the Inland Feeder that will also expand

our ability to obtain water from the Colorado River and State Water Project when it is available and to provide greater system reliability and flexibility.

Metropolitan has also forged many agreements in the past few years to store water in groundwater basins within and outside of southern California. Our cumulative investment in groundwater storage through 2006 was more than $400 million for groundwater storage augmented by $45 million of state grants.

Metropolitan also recognizes that importing water requires a large amount of energy. For example, importing an acre-foot of water via the State Water Project requires 3,200 kwh, and an acre-foot of Colorado River supplies requires 2,000 kwh. The IRP places increased emphasis on less energy consuming local water resources.

The greatest concentration of effort and resources in recent years has been in the area of conservation. Metropolitan has made a cumulative investment of $251 million in conservation. Metropolitan has long been an advocate and supporter of water conservation providing financial incentives to member agencies to grow conservation programs in their service areas through a variety of programs and rebates. Conservation has occurred in both residential and business sectors with Metropolitan offering guidance and financial incentives to use more water-efficient technologies. The most recent push has been in the area of outdoor conservation. Our California Friendly® program is an umbrella for many different programs that promote waterwise lifestyle choices.

Today, the California Friendly umbrella extends over a wide area of Metropolitan-sponsored programs that include retail partnerships to encourage of native and California Friendly plants in the product mix of large home improvement stores; a bewaterwise.com Web site that hosts as many as 3,000 visitors a day; and a landscape rebate program for new homes and a model home program with incentives for new home builders to install more efficient water saving devices in their model homes.

In recent years, Metropolitan has helped to bring about more than 85 water recycling and groundwater recovery programs by providing financial incentives to member agencies. Metropolitan has invested about $215 million through 2006 into these projects, which produce 128,000 acre-feet per year, equivalent to the water needs of over 600,000 people.

Metropolitan's diverse water resource portfolio continues to include imported supplies from the Colorado River and California State Water Project. To better manage the water systems for ecosystem health and competing needs, Metropolitan has shifted the timing of deliveries from these sources to wetter years or wetter periods when there is less impact on the fisheries and environment. To further efforts towards proper management of these supplies, Metropolitan has been participating with the other Colorado River basin states to provide recommendations to the U.S. Bureau of Reclamation on how the river system should be managed. Similarly, Metropolitan is a participant with other interests within the State of California on improvements to the Sacramento-San Joaquin River Delta system, which is the hub of water deliveries for the State Water Project. The goal is to more effectively manage water supply, water quality, and environmental needs. Both the efforts on the Colorado River system as well as the State Water Project Delta system will face critical decisions in the coming year.

CONCLUSION

The great challenges presented by the uncertain effects of climate change and increasing demands on the scarce freshwater supply mean we cannot afford to wait. Metropolitan, and the water community as a whole, needs to partner with the scientific community to conduct further research in assessing risks and integrating them into water management decisions. Metropolitan will continue to implement "no regrets" actions that incorporate climate change into our planning and investments in infrastructure, energy management and water supply development. Importantly, aggressive conservation and water use efficiencies must be practiced within California's communities and businesses to use our limited water supplies wisely and to protect the environment and ecosystems that will be stressed by climate change.

To support Metropolitan's continued supply diversity, and better adapt to climate change and other impacts, it is imperative that decisions regarding the Delta's ecosystem, levee and other infrastructure improvements. In addition, the Colorado River basin states initiatives and water management programs must be implemented to assure proper management of Colorado River resources during this extended drought.

Finally we need greater collaboration and partnerships with governmental agencies, non-governmental organizations, and other entities to implement solutions that

provide benefits in multiple areas such as water quality and quantity, ecosystem health, and reduced energy usage. The federal government should play a key role in addressing uncertainty with regard to climate change by being a direct participant in the State of California's efforts on the Delta, Colorado River, and local water management. Metropolitan stands ready to work cooperatively and collaboratively with you and the federal agencies that you oversee.

Senator CANTWELL. Mr. Williams. Thank you, Mr. Brick.

Mr. Williams.

STATEMENT OF JACK WILLIAMS, SENIOR SCIENTIST, TROUT UNLIMITED, ARLINGTON, VA

Mr. WILLIAMS. Yes. Madam Chairman, members of the committee. I appreciate the opportunity to appear before you today to provide Trout Unlimited's perspective on the impacts of climate change on our Nation's water supply and related impacts to salmon and trout populations.

My name is Jack Williams. I'm the Senior Scientist at TU. Trout Unlimited is the Nation's largest cold water fisheries conservation organization dedicated to the protection and restoration of our Nation's trout and salmon and the watersheds that sustain them.

Trout Unlimited is very concerned about the impacts of climate change on our water and fisheries resources. During the past 2 years we have modeled the impacts of climate change on coldwater fisheries and developed a set of strategies that, if implemented, will build resistance to climate change impacts and help maintain our Nation's important salmon and trout resources.

I have four main points that I would like to make this afternoon. These points are described in detail in my written testimony and are as follows:

First, climate change will have a major negative impact on trout, salmon, and the stream systems that support them.

Second, despite these concerns, we believe there are strategies that can be implemented now to build resistance to climate change into our fish populations and river systems.

Third, these actions must strategically target populations where we can achieve immediate and lasting impacts.

Finally, the long-term health of our rivers and watersheds must have priority over any quick fixes.

Let me briefly elaborate. First, climate change will have a major negative impact on trout and salmon and the river systems. Most models predict salmon populations to decline by 20 to 40 percent by the year 2050 in the Pacific Northwest and by larger amounts in California and Idaho. In some regions trout populations will decline by more than 50 percent. Our Nation's streams and rivers will be impacted by more pollutants, lower flows, reduced snow packs, and a greater likelihood of floods, drought, and wildfire. Erosion rates will increase, as will polluted runoff from our cities and agricultural areas.

The negative impacts of climate change are already upon us. Two quick examples to that effect. One, off the coast of the State I live in in Oregon we've had a dead zone that's appeared off the coast every year since 2002 that appears to be caused by changes in ocean currents that are in turn controlled by weather patterns. In 2006, this dead zone covered an area the size of Rhode Island.

Another sign. Because of warmer stream flows and earlier runoff, May flies and other aquatic insects are emerging earlier in Rocky Mountain streams. Earlier emergence of aquatic insects means that females are smaller in body size and produce fewer eggs than would insects that emerge later. Such changes may seem minor, but they have cascading implications to fish populations that depend on May flies, caddis flies, and other aquatic insects as their primary foods.

This brings me to my second point. Despite these concerns, we believe there are strategies that can be implemented now to build resistance to climate change into our fish and river populations. But unless immediate action is taken, stream conditions will degrade and more of our native trout and salmon may warrant the protection of the Endangered Species Act. Our strategies can be summarized as the protect, reconnect, restore model of fishery sustainability. This process emphasizes protection of our best remaining habitats and populations, reconnection of stream systems by removing in-stream barriers and reestablishing in-stream flows, and restoration of main stem river habitats.

In many ways the impacts of climate change will bring additional stress to stream systems and watersheds that have already been pushed to their ecological limits. We may not be able to slow the immediate impacts of changing climate, but we can identify and remove or mitigate existing sources of stress. Watersheds that are in a healthy condition will be better able to withstand the stresses of climate-imposed impacts and rebound from floods and drought.

Third, as I mentioned, these actions must be strategically—target populations where we can achieve immediate and lasting impacts. We must plan and coordinate our efforts to focus where we can get the most bang for our buck.

Last, the long-term health of our rivers and watersheds must have priority over any quick fixes. We are highly skeptical of any attempts to channelize streams or dam headwaters in an effort to control flows on floods. Rather, we advocate healthy streams and flood plains that are more able to absorb the higher energies associated with floods and also more likely to slowly release water and maintain flows to minimize drought.

Thank you again for the opportunity to testify today and I'll be happy to answer any questions.

[The prepared statement of Mr. Williams follows:]

PREPARED STATEMENT OF JACK WILLIAMS, SENIOR SCIENTIST, TROUT UNLIMITED

Mr. Chairman, Members of the Committee, I appreciate the opportunity to appear before you today to provide Trout Unlimited's perspective on the impacts of climate change on our nation's water supply, related impacts to trout and salmon populations, as well as strategies that we believe can be important in responding to the very serious threat that climate change poses to these valuable resources.

Trout Unlimited (TU) is the nation's largest coldwater fisheries conservation organization dedicated to the protection and restoration of our nation's trout and salmon, and the watersheds that sustain them. Our goal is to restore robust populations of native and wild coldwater fishes so that future generations can enjoy these resources. TU has more than 160,000 members organized into 450 chapters across the country. Our members generally are trout and salmon anglers who give back to the resources they love by voluntarily contributing substantial amounts of their personal time and energy to fisheries habitat protection and restoration on public and private lands. The average TU chapter donates 1,000 hours of volunteer time on an annual basis.

My name is Jack Williams and I serve as Senior Scientist for Trout Unlimited. Prior to working for TU, I was privileged to serve in a number of research and management positions in the federal government, including Endangered Species Specialist for the U.S. Fish and Wildlife Service, National Fisheries Program Manager for the Bureau of Land Management (BLM), Science Advisor to the Director of the BLM, Deputy Forest Supervisor on the Boise National Forest, and Forest Supervisor on the Rogue River and Siskiyou national forests. I have also served as a Professor at Southern Oregon University and retain the title of Adjunct Professor at that institution.

Trout Unlimited is very concerned about the impacts of climate change on our water and fisheries resources. During the past year, a team of TU scientists and geographic information specialists have modeled the impacts of climate change on coldwater fishes, reviewed available scientific literature, and prepared articles on the impacts of climate change for our members. In addition, TU has polled hunters and anglers across the country to determine their level of interest and concerns about how climate change is likely to impact their recreational pursuits. Furthermore, we have developed a series of strategies, that if implemented, we believe will substantially increase the resistance and resilience to climate change impacts in our nation's salmon and trout streams.

I would like to briefly describe the impacts from climate change on our trout and salmon resources and their habitats and then proceed to describe our strategies to increase resistance and resilience to these impacts.

IMPACTS TO TROUT AND SALMON RESOURCES

There is a clear scientific consensus that climate change will have major and negative implications to our nation's hydrology and river systems. Numerous peer-reviewed studies have predicted broad declines in trout and salmon populations as well. U.S. Forest Service scientists have predicted that between 53 and 97% of wild trout populations are likely to be eliminated from the Appalachian Mountains because of warming climate. Losses of western trout populations may be as high as 64%. Most studies of Pacific Coast salmon predict losses of 20-40% by the year 2050. The bad news about the salmon models is that they may actually be optimistic predictions because they focus on freshwater conditions and do not consider the complexity and uncertainty of changing ocean environments.

Although some regions will fare better than others and the timing and severity of impacts is somewhat uncertain, the overall need for concern should be clear. Based on review of the relevant literature and research, the following impacts from climate change are likely to occur: increased stream temperatures, increased evaporation rates, earlier spring runoff, reduced snowpack, higher winter flows and lower summer flows in most streams, greater storm intensity and increased frequency of floods, drought and wildfires, and rising sea levels. Erosion rates will increase as will polluted runoff from our cities and agricultural areas. One of the most significant bottom lines for fisheries and other water users is that stream flows are likely to be even lower during future summers than they have been in the past.

While some consequences of climate change are highly predictable others are not. Beginning in 2002, a "dead zone" of very low dissolved oxygen has appeared each year off the Oregon coast. Unlike other oceanic dead zones, this one is not attributable to pollution or other human impact that has been identified. Rather, it is caused by changes in ocean currents and upwelling that is in turn, controlled by weather patterns. In 2006, the dead zone covered 1,235 square miles, an area the size of Rhode Island. According to Oregon State University Professor Jane Lubchenco, "we are beginning to think there has been some sort of fundamental change in ocean conditions off the West Coast." The changes appear consistent with wind patterns modified by climate change.

The Oregon coast changes bring up another important concern: climate change is not just a problem of the future, but is a growing concern of the present. Our climate already is rapidly changing and we currently are seeing impacts to our stream systems and aquatic communities. For instance, because of warmer stream flows and earlier peak runoff, mayflies and other aquatic insects are emerging earlier in Rocky Mountain streams. Earlier emergence of aquatic insects means that females are smaller in body size and produce fewer eggs than would insects that emerge later. Such changes may seem minor but could have cascading implications to fish populations that depend on mayflies, caddisflies, stoneflies and other aquatic insects as their primary food supplies.

At TU we have modeled impacts of climate change on Colorado River cutthroat trout in Utah, Wyoming and Colorado; Bonneville cutthroat trout in Idaho, Utah, Wyoming and Nevada; and westslope cutthroat trout in Idaho, Montana, Oregon

and Washington. In 5 of the 8 major river drainages where Colorado River cutthroat trout occur, most populations already are below adequate habitat thresholds and will be further stressed by climate change impacts. The same situation is true for 2 of 4 geographic management areas of Bonneville cutthroat trout. Most remaining populations of both subspecies are restricted to small, headwater streams, which will feel the brunt of climate change impacts due to declining snowpacks, drought and wildfire. Westslope cutthroat trout fare somewhat better because of existing strongholds in National Forest wilderness areas. Nonetheless, populations of westslope cutthroat continue to be invaded by non-native rainbow trout that hybridize with the cutthroat and eliminate the native gene pool.

Depending on the climate model used, most salmon populations in the Pacific Northwest are expected to decline by 20 to 40% by the year 2050. In California, where temperatures already pose a significant source of stress for fisheries, greater declines are likely.

Unless immediate action is taken to restore resistance and resiliency to climate change impacts, stream conditions will degrade and many more of our native trout and salmon may soon warrant the protection of the Endangered Species Act. Let me outline what can be done to alleviate at least some of the adverse impacts of climate change on the nation's trout and salmon populations.

STRATEGIES TO INCREASE THE RESISTANCE AND RESILIENCE TO CLIMATE CHANGE IMPACTS

Trout Unlimited works primarily to implement what we refer to as the Protect-Reconnect-Restore model of fishery sustainability. This process emphasizes protection of our best remaining habitats and populations, reconnecting stream systems by removing instream barriers and reestablishing flows, and restoring vital lower-elevation rivers. I will describe six strategies for dealing with a rapidly changing climate that fit this model. These strategies are consistent with the best available science and have been proven to be effective in on-the-ground application. Our primary goal in suggesting these strategies is to increase the resistance to climate change impacts in our natural systems and to enable fish populations and their habitats to rebound more completely once they are disturbed by flood, drought and wildfire that will accompany a warming environment.

Furthermore, it is important to realize that these actions must be implemented strategically to achieve success. That is, for each evolutionarily significant unit of salmon, or each large river basin with trout, we need to identify the best subset of opportunities for protection, reconnection, and restoration. We must carefully choose those areas for restoration where we can make the most immediate and lasting impact.

Strategy 1: Protect remaining core habitat areas.—It is vital that remaining salmon and trout strongholds as well as watersheds that produce reliable supplies of cold water be protected from additional disturbance. Watersheds that currently support large and robust populations of native fisheries should be protected from new dam and road development. Simply stated, it is more biologically sound and cost effective to protect existing population strongholds than attempt to restore them once they have been disturbed.

Strategy 2: Maintain genetic and life history diversity.—Higher levels of genetic diversity enable populations to better adapt to future environmental change. For example, scientists at the University of Washington have demonstrated that large numbers of separate spawning populations of sockeye salmon in Alaska's Bristol Bay have been the key to maintaining that robust fishery in the face of changing freshwater and marine conditions. Under certain conditions, one set of stocks will be favored and produce abundant offspring; when conditions shift, a different group of populations will be favored. It is simply a matter of maintaining all the genetic pieces to maximize adaptability.

Life history diversity also is critical. In western cutthroat trout, for example, most populations are resident stream forms that are restricted to single tributaries. But, restoring migratory populations expands habitat options, produces bigger fish, and allows remaining individuals more opportunities to find suitable habitats as stream conditions and flows change.

Strategy 3: Increase size and extent of existing populations.—Currently, many populations of native trout in the West have been pushed into upper elevation streams as non-native species have been introduced downstream. We know that at least 5 miles of continuous high quality habitat are necessary to ensure the likelihood that each trout population will persist for many generations. The populations already are being squeezed from downstream reaches. Climate change will squeeze them from upstream as snowpacks diminish and precipitation patterns change. The options for

these fish are to expand into remaining downstream habitat or perish. But for downstream expansion to be possible, non-native fishes must be removed and habitats restored.

Strategy 4: Minimize outside stressors.—In many ways, the impacts of climate change will bring additional stress to stream systems and watersheds that already have been pushed to their ecological limits. We may not be able to slow the immediate impacts of a changing climate, but we can identify and remove or mitigate existing sources of stress. Too many roads, poorly constructed culverts, and poor livestock practices are a few examples of existing stressors that can be fixed. Watersheds that are in a healthy condition will be better able to withstand the stress of climate-imposed impacts and rebound from disturbances.

We know basic improvements in water quality, restoration of riparian habitats, and restoration of stream channel complexity will improve habitats and create refuges from warm water by forming deeper and more shaded pools of cool water. This appears just as true for small mountain streams in New Mexico or Montana as it does for larger river systems in coastal areas of Oregon and Washington.

Strategy 5: Manage at watershed scales to reconnect stream systems.—Many existing stream systems have been disconnected by construction of dams, water diversions, and other dewatering processes. We should identify and reconnect the hydrology in those areas that are most likely to provide for long-term survival of trout and salmon. In some cases, this may be as easy as replacing poorly designed culverts with small bridges that allow upstream and downstream movement of fish and spawning gravels.

Strategy 6: Monitor, evaluate and employ adaptive management.—As noted earlier, our ecosystems are complex and some impacts of climate change are difficult to predict with certainty. Therefore, it is important to adequately fund monitoring programs and maintain the ability to modify our management approach in the face of changing conditions and new information. We must listen to what the land is telling us as climate shifts.

CONCLUSION

In conclusion, we find that climate change poses a serious and imminent threat to our nation's water and stream resources and to the trout and salmon populations they support. Further, we believe that the impacts of a rapidly changing climate are already manifesting themselves through changes in precipitation regimes and snowmelt patterns, warmer weather and increasing drought, reduced snowpacks and earlier stream runoff, reduced stream flows in the summer, and a greater threat from disturbance processes such as drought, flood and wildfire.

Despite these significant challenges posed by a rapidly changing climate, we believe there are many reasonable and proven actions, such as the strategies described herein, that can be taken immediately to reduce the threats to our coldwater fishery resources. We strongly believe that our actions must be based on the principles of conservation biology and restoration ecology.

The long-term health of our rivers and watersheds must have priority over any quick fixes. We are highly skeptical of any attempts to channelize streams or dam headwaters in an effort to control flows and floods. Rather, we advocate healthy streams and floodplains that are more able to absorb higher energies associated with floods and also are more likely to slowly release water and maintain flows during summer and autumn.

Many of our existing trout and salmon face an increased risk of extinction. It is important to make investments in protection and restoration of our streams, riparian areas and watersheds during the current and coming years while the debates and discussions concerning our energy policies and carbon footprint move forward. By making such basic investments in the health of our watersheds, we will insure the persistence of our most valuable salmon and trout populations and buy the time needed to deal with the larger problem of reducing our carbon footprint.

Thank you again for the opportunity to testify today. I look forward to answering any questions that you may have.

SUPPLEMENTAL TESTIMONY

ELEMENTS OF A CONTINGENCY PLAN TO SAVE COLDWATER FISH COMMUNITIES FROM THE IMPACTS OF CLIMATE CHANGE

Background.—Climate change is predicted to have severe impacts to stream systems and water supplies in the United States (see Philip W. Mote, June 6, 2007 testimony and references therein). Populations of trout and salmon are projected to decline accordingly with corresponding impacts to recreational and commercial inter-

ests that depend on these resources for their livelihood. Improving the condition of habitats and expanding target populations can improve the likelihood that important fisheries will persist in the face of additional stress imposed from climate change. For example, recent studies on Washington's Snohomish River Basin found that habitat restoration could offset salmon declines predicted by all but the most dire climate models (James Battin et al. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences 104:6720-6725).

Goals of contingency plan.—1) to identify a representative sample of stream and lake habitats throughout the United States that support the best remaining coldwater fish communities, 2) to restore resistance to climate change impacts to this representative sample through ecological restoration, and 3) to protect these habitats from additional stressors. This will maximize the likelihood that the natural diversity of coldwater fishes will persist until such time that site-specific impacts of climate change are more fully understood.

Steps in development of a contingency plan.—The initial step to completing such a strategy is to identify watershed-scale representatives of the best remaining habitats in each river basin containing trout and salmon resources. This could be accomplished through a broad-scale status tool such as Trout Unlimited's Conservation Success Index (see http://tucsi.spatialdynamics.com). Trout and salmon make appropriate surrogates for the broader aquatic biodiversity because their habitat requirements are relatively well known, they are sensitive to habitat disturbances and require cold and clean water, and they are broadly distributed across the country. If the trout and salmon are protected, it is likely that other native components of the aquatic communities within these drainages will be well protected.

The second step is to determine needed action to restore resilience and resistance to climate change impacts in each selected system and implement these measures. These actions would be based on ecologically sound and proven strategies of stream restoration and population expansion (see testimony of Jack E. Williams, June 6, 2007). These actions include, among other actions, restoration of instream flows, removing barriers to fish movement, and restoring life history diversity in target sites.

The final step would be to provide interim protection to these areas while additional research is conducted to revise and focus our understanding of the local impacts of climate change on stream systems. By minimizing outside stressors, these Combined range of Bonneville cutthroat trout and Colorado River cutthroat habitats and their fish trout in the western United States. Results of Conservation Success Index communities would be analyses for these two species illustrate how habitat and population integritymore likely to withstand can help identify target populations in each major river basin. Subwatersheds additional stress from with the highest total scores would be compared with climate change models to find the best remaining populations that should be least impacted by climate change impacts.

Senator CANTWELL. Thank you, Mr. Williams.

Mr. Culbertson, thank you for being here.

STATEMENT OF TIM CULBERTSON, ON BEHALF OF THE NATIONAL HYDROPOWER ASSOCIATION, EPHRATA, WA

Mr. CULBERTSON. Madam Chairman, members of the subcommittee, I'm Tim Culbertson, General Manager of Grant County Public Utility District No. 2, located in the central part of the State of Washington. I appear before you today to testify on behalf of NHA, a nonprofit national association dedicated exclusively to advancing the interests of the U.S. hydropower industry, including new water power technologies, ocean, tidal, and in-stream hydrokinetic power. Along with NHA, I greatly appreciate the opportunity to speak to you on the importance of recognizing the critical role hydropower plans to help combat climate change, the potential effects to hydropower resources resulting from climate change, and planning that is under way, particularly in Washington State and the Pacific Northwest, in preparation of these changes.

Grant County PUD is a consumer-owned utility in a rural, predominantly agricultural section of the State. Grant PUD's energy

portfolio is diverse and expanding, which is consistent with Grant PUD's focus on renewable energy, including hydropower. Combined, Grant County PUD's two dams, Priest Rapids and Wanapum on the Columbia River, have a rated capacity of around 2,000 average megawatts. In a typical year, our hydroelectric projects generate enough power to serve over 8,000 homes with clean, reliable, and affordable electricity. That is enough to power the entire Seattle area.

This power is also a driving force not only for the Washington State economy, but for the entire Pacific Northwest region, as Grant PUD provides electricity at cost to 22 other utilities throughout the Northwest, providing power to millions of consumers in Washington, Idaho, Oregon, Montana, Utah, Wyoming, and California.

Senator Cantwell, members of the subcommittee, our message to you today is simple. Congress needs to fully consider hydropower and its many benefits as it debates and develops climate change policy for the United States. Too often hydropower is overlooked or taken for granted in these discussions. This is unfortunate because hydropower is a clean, renewable, and domestic resource and has a significant role to play in combating climate change.

Not only is hydropower the largest source of renewable power in the United States, but there is a tremendous growth potential that remains untapped. A new report released by the Electric Power Research Institute conservatively estimates the potential increase in hydropower generation capacity at 23,000 megawatts by 2025. The overall resource potential based on resource assessments conducted by the U.S. Department of Energy, EPRI, and the industry is estimated to range from 85,000 to 95,000 megawatts. This represents a doubling of hydropower's current contribution to the Nation's energy supply.

However, the industry realizes that the benefits hydropower brings to the table are threatened if climate change is left unchecked. Changes in local conditions caused by reduced snow pack, earlier spring runoff, and affected peak flows will impact the timing, availability, and amount of water power for generation. This will in turn create challenges in meeting the country's increasing need for electricity, as well as have significant consequences to downstream water uses such as irrigation, recreation, fish migration, and water supply resources.

These effects to all of these resources will have significant economic impacts and affect consumers both regionally and nationally. As a result, the hydropower industry and others are beginning to examine these potential impacts and have begun planning for them.

Grant PUD recognizes that as climate impacts to the Nation's rivers unfolds steps will need to be taken to address them. For its part, the PUD has begun to optimize its existing water resources with installation of more efficient generating equipment, with the utilization of advanced hydropower turbines at Wanapum Dam. The PUD is currently in design for new turbines and generators at Priest Rapids Dam for additional efficiencies. Installing more efficient equipment will provide more power with the same amount of water.

However, variability in the amount of water and timing of the water from year to year is not unusual for the hydropower industry. Grant County PUD participates in a coordination agreement with Federal and non-Federal dam operators on the Columbia and Snake River systems. In addition, long and short-term water planning of the system is discussed with regional operators as often as weekly throughout the runoff season.

In addition to Grant PUD's investment in equipment and river coordination agreements, hydropower in general is an excellent flexible resource. During drought or excess water years, hydropower's built-in flexibility helps to address changing water conditions and the many pressures on the system. While there are several things that can be done to help plan for the future impacts, hydropower's unique ability to adapt, an attribute unmatched by other energy resources, again highlights its role as part of the climate change solution.

Beyond the hydropower industry's efforts, all around the country State, regional, and local initiatives are under way to investigate the impacts of climate change. Washington State in particular is taking aggressive steps to address climate change. The Washington Climate Change Challenge, which has engaged business, community, and environmental leaders over this year, will culminate in specific recommendations both to the Governor and the State legislature.

Washington is also working closely with other western States, California, Oregon, New Mexico, and Arizona, and together they have established the Western Regional Climate Action Initiative to collaborate on identifying, evaluating, and implementing ways to reduce greenhouse gas emissions.

However, there is also an important role for the Federal Government to play. NHA encourages the Congress not only to work with the industry to develop a better understanding of climate change impacts to the resource, but to provide the policy support necessary to realize the industry's substantial growth potential.

Senator CANTWELL. Mr. Culbertson, we want to definitely hear your recommendations, but could you summarize those?

Mr. CULBERTSON. Sure. Which ones?

Senator CANTWELL. Whatever recommendations to the Federal Government that you have.

Mr. CULBERTSON. One is to consider the benefits that hydropower plays to the region and the fact that there is a huge potential. There's an awful lot of talk about renewable standards and I hope that the Federal Government adopts a Federal standard. It would be helpful I think to all the States to have some consistency.

But one of the roles I think the Federal Government can do is understand that behind the renewables there needs to be some other resource that stands behind these renewable resources to firm them, because they're intermittent generation resources. As we look at our requirements as a utility to operate control areas and provide a reliable system, we have to have a resource that we can count on for capacity. So we believe the resource of choice to stand behind these other renewable resources is hydrogeneration.

So I think considering hydrogeneration is a viable resource not only in conjunction with renewable standards, but it also serves well when we talk about climate change.

[The prepared statement of Mr. Culbertson follows:]

PREPARED STATEMENT OF TIM CULBERTSON, ON BEHALF OF THE NATIONAL HYDROPOWER ASSOCIATION, EPHRATA, WA

INTRODUCTION

Good afternoon, I am Tim Culbertson, General Manager of Grant County Public Utility District No. 2 located in the central part of the state of Washington. Grant County PUD is a long time member of the National Hydropower Association (NHA)[1] and I appear before you today to testify on behalf of NHA.

The association greatly appreciates this opportunity to speak to you on the importance of recognizing the critical role hydropower plays to help combat climate change; the potential affects to hydropower resources resulting from climate change; and the planning that is underway, particularly in Washington state and the Pacific Northwest, in preparation for these changes.

Senator Cantwell, members of the Subcommittee, our message to you today is simple—Congress needs to fully consider hydropower and its many system benefits as it debates and develops climate change policy for the U.S. Too often hydropower is overlooked or taken for granted in these discussions. This is an unfortunate oversight because hydropower, a clean and domestic resource, has a significant role to play to combat climate change.

Not only is hydropower the largest source of renewable power in the United States, but there is tremendous growth potential that remains untapped. In fact, a new report released by the Electric Power Research Institute (EPRI) conservatively estimates the potential increase in hydropower generation capacity at 23,000 Megawatts (MW) by 2025.[2] This same study also acknowledges that 90,000 MW of hydropower remains undeveloped. With the right government policies a significant portion of this clean homegrown energy could be captured.

However, the industry realizes that the benefits hydropower brings to the table are threatened if climate change is left unchecked. Changes in local conditions, such as the timing and availability of water for power generation, will create challenges in meeting the country's increasing need for electricity, as well as have significant consequences to irrigation, recreation and water supply resources. All of which will have a significant economic impact to this growing region and affect consumers both regionally and nationally. As a result, the hydropower industry and others are beginning to examine these potential impacts and have begun planning for them.

In order to fully meet the challenges posed by the effects of climate change, the industry requests that Congress partner with the private sector to develop the needed strategies and responses. Federal investment in new advanced hydropower technologies—through economic incentives and research and development funding—is critical to assist the industry in its planning and preparation for the impacts climate change will impose on the resource. It is critical that we apply best practices and technological advances to optimize water resources for the benefit of all users. Smart use of policy, planning and technology application is the best path forward.

BACKGROUND

Let me take a few moments to provide some information about Grant County PUD; its hydropower resources; and the importance of those resources to Washington state and the Pacific Northwest.

Grant County PUD is a consumer-owned utility, created in 1938 by a popular vote of county residents who struggled for 20 years to receive electricity. Grant County is a rural, predominantly agricultural region. Electricity provided by Grant PUD supports the county's important role in the agricultural sector of Washington state,

[1] NHA is a non-profit national association dedicated exclusively to advancing the interests of the U.S. hydropower industry, including the new water power technologies—ocean, tidal and instream hydrokinetic power. It seeks to secure hydropower's place as an emissions-free, renewable and reliable energy source that serves national environmental and energy policy objectives. Its membership consists of more than 140 organizations including; public utilities, investor owned utilities, independent power producers, equipment manufacturers, environmental and engineering consultants and attorneys.

[2] Assessment of Waterpower Potential and Development Needs. EPRI, Palo Alto, CA: 2007. 1014762.

which accounts for a fifth of the state's annual gross product and employs 173,000 people—more than any other sector in the state.

Grant PUD's energy portfolio is diverse and expanding, which is consistent with Grant PUD's focus on renewable energy, including hydropower. Combined, Grant County PUD's two dams, Priest Rapids and Wanapum on the Columbia River, have a rated capacity of around 2,000 average megawatts (actual generation varies depending on river flow and other factors). In a typical year, 2005, our hydroelectric projects generated enough power to serve over 800,000 homes with clean, reliable and affordable electricity. That is enough to power the entire Seattle area.

This power is also a driving force not only for the Washington state economy, but for the entire Pacific Northwest region. Grant PUD provides electricity at cost to 22 other utilities throughout the Northwest, providing power to millions of consumers in Washington, Idaho, Oregon, Montana, Utah, Wyoming, and California. Combined, Grant PUD's dams allow the Northwest to avoid 942,000 tons of carbon emissions annually.[3]

IMPACTS ON HYDROPOWER RESOURCES AND THEIR EFFECTS

In 2004, hydropower made up approximately 7% of the electricity generation in the United States. Focusing on the state of Washington, hydropower represents 72% of its electricity generation. As such, the state clearly understands that the potential impacts due to climate change on hydropower resources will have a significant effect on its economy, the lives of its residents, and the environment. As a result, Washington has begun to closely examine those impacts and their effects.

This year, Governor Christine Gregoire signed Executive Order 07-02, which among other things, created the Washington Climate Change Challenge, an initiative designed to consider the full range of policies, strategies and specific steps the state of Washington should take to prepare for the impact of global warming.

As part of the initiative, impacts to hydropower resources were examined. Specifically, effects on mountain glaciers, snow pack and peak flows were analyzed utilizing data summarized in a November 2006 report titled, "Impacts of Climate Change on Washington's Economy."

The report states that mountain glaciers in the North Cascades have lost a significant percentage of their total volume since 1983; that average mountain snow pack in the North Cascades, which is critical to summer stream flows, has declined at a majority of mountain sites studied causing spring runoff to occur earlier in the year; and finally, that stream flows have been affected resulting in peak flows occurring earlier in the year throughout the state, including the Columbia River Basin.

These impacts are creating changes in the availability of water and the timing and amount of flows. This increases the stress on the hydropower system and affects power output, as well as poses challenges and creates secondary effects on downstream uses such as fish migration, recreation, irrigation, and water supply.

For hydropower, output may be affected as changes in water management become necessary. Simulations of the power market by the University of Washington indicate a possible revenue impact of 5 percent or less, which at today's rates totals $165 million per year.For salmon and other fish, changes to peak river flows may affect rearing, migration and spawning. Low flows in spring and summer could result in warmer water, which holds less oxygen and can stress fish. In addition, increased temperatures in summer streams may exceed the tolerable limits for coldwater fish.

In the end, all the additional uses of the water—recreation, irrigation, water supply—for which hydropower projects provide, will be affected in one way or another by changes in the amount and timing of flows.

For a hydropower system that is as highly regulated as that in the state of Washington, the additional stress brought on by climate change will exacerbate tensions between the competing water users and their needs. The challenge we face is ensuring our current policies, particularly regulatory frameworks, are flexible enough to withstand the additional stress and result in the appropriate balance of these competing needs.

PLANNING FOR IMPACTS

Grant County PUD recognizes that as climate impacts to the nation's rivers unfold, steps will need to be taken to address them. For its part, the PUD has begun to optimize its existing water resource with the installation of more efficient generating equipment with the utilization of the advanced hydropower turbine at

[3]Natural gas combined-cycle turbines are the predominant backup generation source in the Pacific Northwest.

Wanapum Dam. The PUD is currently in design for new turbines and generators at Priest Rapids Dam for additional efficiencies. Installing more efficient equipment will provide more power with the same amount of water.

Variability in the amount of water and timing of the water from year to year is not unusual for the hydropower industry. Grant County PUD participates in a coordination agreement with federal and non-federal dam operators on the Columbia and Snake Rivers. In addition, long and short term water planning of the system is discussed with regional operators as often as weekly throughout the runoff season.

In addition to Grant County PUD's investments in equipment and river coordination agreements, hydropower, in general, is an excellent adaptor. During drought or excess water years, hydropower's built-in flexibility helps to address changing water conditions and the many pressures on the system. While there are several things that can be done to help plan for future impacts, the advantages contained in hydropower's flexibility and ability to adapt once again highlight its role as part of the climate change solution.

Beyond the hydropower industry's efforts, all around the country, state, regional and local initiatives are underway to investigate the impacts of climate change. From the work of the Northeast states participating in the Regional Greenhouse Gas Initiative (RGGI) to California's passage of its greenhouse gas emissions bill, governments, industries, and the public are actively engaged in climate change planning and preparation.

As mentioned earlier, Washington state in particular, is taking aggressive steps to address climate change. The Washington Climate Change Challenge, which has engaged business, community and environmental leaders over this year, will culminate in specific recommendations to both the Governor and the state Legislature.

Currently, a Climate Advisory Team composed of about 30 leaders from business, labor, and local jurisdictions, is hard at work reviewing policies and potential strategies for slowing climate change. They are working with Technical Working Groups to analyze impacts and actions focusing on the agriculture, energy supply (including hydropower), forestry, transportation, and residential, commercial and industrial sectors.Washington is also working closely with other western states—California, Oregon, New Mexico and Arizona—and together they have established the Western Regional Climate Action Initiative to collaborate on identifying, evaluating and implementing ways to reduce greenhouse gas emissions.

The work underway, from that of individual utilities to regional groups, is important in order for the hydropower industry to prepare for climate change and other impacts on water—from regulation to transportation, and from fish needs to irrigation needs. Coordination of runoff planning for the many uses of water will be more difficult as the predicted events of climate change unfold. Additional long term planning for water storage and support for hydropower operations is necessary to address the future uses of the hydropower system.

HYDROPOWER'S ROLE IN COMBATING CLIMATE CHANGE

Hydropower should be encouraged and supported to play an important part in solving the climate problem. Reducing greenhouse gas emissions will require the use of all of the climate-friendly technologies currently available, as well as new technologies.

Hydropower provides significant benefits and potentially even greater benefits in the future, if properly supported. Beyond the fact that it is renewable, climate friendly, and domestic, hydropower offers some advantages over other resource options.

Hydropower provides significant generation, peaking capacity, and ancillary services to bolster the reliability, stability, and resilience of the nation's transmission system. This includes frequency control, regulation, load following, spinning reserve, supplemental reserve and blackstart capability. The August 2003 blackout on the east coast was a testament to these benefits, where hydropower projects in New York and elsewhere remained online and were critical in restoring power to the area.

In addition, as the U.S. significantly increases the amount of renewable resources in its overall portfolio, hydropower offers one other significant advantage. Hydropower is one of the few resources suited to "firming" intermittent or non-dispatchable resources such as wind. As the development of wind, solar and other intermittent resources grows, as is widely expected, the need for "firming" resources will become even more important. Without these "firming" resources, the value of intermittent or non-dispatchable resources is greatly reduced.

Today, hydropower accounts for approximately 77% of the actual renewable electricity generation and 83% of the nation's renewable energy capacity. As robust a resource as hydropower is today, there remains tremendous growth potential for the industry. As stated earlier, a new EPRI report finds the potential increase in generation capacity at 23,000 MW by 2025. To put this in perspective, the total installed generating capacity for wind is approximately 9000 MW.

The EPRI estimate includes: 2,300 MW capacity gains at existing conventional hydropower (incremental hydropower); 5,000 MW of new conventional hydropower at existing non-powered dams[4]; 2,700 MW of new small and low power conventional hydropower (<30 MW installed capacity); 10,000 MW from ocean wave energy; and 3,000 MW from hydrokinetic technologies.

The EPRI report also states that these estimates could be significantly increased if economic incentives and regulatory processing for the industries are enhanced. The overall resource potential, based on resource assessments conducted by the U.S. Department of Energy (DOE), EPRI, and industry is estimated to range from 85,000 to 95,000 MW. This represents a doubling of hydropower's current contribution to the nation's energy supply.

If the U.S. is serious about its response to the effects of climate change, then federal support for the development of this untapped potential is necessary.

Hydropower resources should be treated as fairly and equitably as any other renewable energy resource under any proposed national renewable portfolio standard, which should include incremental hydropower, hydropower at existing non-powered dams and the new hydropower technologies—ocean, tidal and instream hydrokinetic power.

Economic incentives, such as the Production Tax Credit and the Clean Renewable Energy Bonds program should be extended long term, fully funded, and expanded to include more resources such as additional hydropower at non-powered dams and the new technologies. Credit parity, so that all new renewable resources brought online receive the same credit amount, should also be adopted.

To that end, NHA applauds Senator Cantwell for proposing 5.1370, the Clean Energy Investment Assurance Act of 2007, and for her continuing support of the hydropower resource. The bill, co-sponsored by Senator Gordon Smith and Senator John Kerry, addresses these needed changes to the PTC and CREBs programs, resulting in increased clean renewable hydropower being brought online throughout the U.S.

Finally, the hydropower research and development program at the Department of Energy should be reinstituted and expanded to include initiatives for both the conventional industry and the ocean, tidal, and hydrokinetic technologies. Advanced turbine designs for conventional hydropower have shown promising first round results. Grant County PUD utilized the DOE R&D program as a private-public partnership in developing the advanced turbine now being deployed at Wanapum Dam. Seeing the program to completion and supporting the necessary studies for the development of the new technologies are crucial if these advancements are to succeed and gain acceptance.

With the proper support outlined above, the hydropower industry will be able to responsibly develop the identified growth potential, thus significantly contributing to the climate change solution.

CONCLUSION

Members of the Subcommittee, let me conclude with these final thoughts. The hydropower industry must remain actively engaged in the discussions on climate change. We have begun, along with state and local partners, to undertake an examination of the issues; to review policies to address them; and to take steps to mitigate potential effects.

However, there is also an important role for the federal government to play. NHA encourages the Congress not only to work with the industry to develop a better understanding of climate change impacts to the resource, but to provide the policy support necessary to realize the industry's substantial growth potential.

Most important, the federal government must step up and reinvest in hydropower and new waterpower technologies, which allow us to maximize the water resource with the application of new advancements. The DOE program must be reinstated and the federal hydropower system should cooperate with the non-federal sector to study and deploy new advanced technologies to achieve this goal.

Senator Cantwell we commend you for your leadership in holding this hearing on the interplay between climate change and the hydropower resource. Climate issues are some of the most complex of our time. NHA and the hydropower industry look

[4] Currently only 2 percent of U.S. dams have hydropower facilities.

forward to working with you and other policymakers and we offer ourselves as a resource for future climate hearings or other events.

Thank you.

Senator CANTWELL. Thank you again for being here and thank you for your testimony.

Mr. CULBERTSON. You're welcome.

Senator CANTWELL. Dr. Fulp, thank you.

STATEMENT OF TERRY FULP, PH.D., AREA MANAGER, BOULDER CANYON OPERATIONS OFFICE, BUREAU OF RECLAMATION, DEPARTMENT OF THE INTERIOR

Mr. FULP. Good afternoon, Madam Chair and members of the subcommittee. My name is Terry Fulp and I'm the Area Manager of the Boulder Canyon Operations Office for Bureau of Reclamation. We operate Lake Mead and Hoover Dam and our other facilities down to the Mexico border.

I'm pleased to be here today alongside my colleagues and others to discuss the Bureau of Reclamation's operations and the state of the science on global climate change. I have submitted a written statement for the record. Additionally, I'd like to just start off by saying that in my job with Reclamation my primary responsibility is related to the management of the lower Colorado River. If you have specific questions outside my area, I'd be happy to respond to those in writing for the record.

As you know, there is extensive interest, as we've heard today, in the scientific as well as the water communities with regard to the potential impacts of climate variability and climate change on water resources in the western United States. Fortunately, Reclamation already possesses great operational flexibility to respond to hydrologic variability in order to fulfil our mission in the West. Droughts, floods, and wide climate variability in the West are a fact of life and something we've been adapting to for over 100 years.

However, that flexibility may be challenged in the future. Our understanding of climate change and the capabilities of climate change models to provide information on the scales that we need is improving, as we have heard today, and will continue to improve. We are preparing now to be able to determine how and where to incorporate that new information into our water management decisions.

We have several collaborative efforts ongoing and I'd like to just touch on a few of those for you. Our primary partnership is with our sister agency the U.S. Geological Survey, with which Reclamation is working to define the impacts of climate variability and climate change on western water resources. Dr. Milly mentioned several areas we're focusing on that will better help us predict future water availability.

As I also mentioned, we need information with regard to these potential impacts of climate change on relatively detailed temporal and spatial scales. We're collaborating with the Department of Energy's Lawrence Livermore National Laboratory to develop and evaluate climate model output at the level of individual Reclamation drainage basins. The result of this effort will essentially be an archive of what is called down-scaled climate data from numerous

climate models that we as Reclamation managers can then use to assess our operational risks.

Turning to specific basins, we are partnering with the California Department of Water Resources to conduct joint research to assess the risk of shifting climate on Reclamation's water and power operations in California. This research may also be applicable to all of our basins. Additional partners in this activity include the Army Corps of Engineers, of course the Geological Survey, the Scripps Institute, and Santa Clara University.

We're also collaborating with NOAA and the University of Colorado, as represented by Mr. Udall, to assist in better understanding the science surrounding climate variability. Specifically, my office is working directly with Mr. Udall, from whom you heard from earlier and other climate scientists to assess current abilities to analyze the potential impacts of climate change specifically on Colorado River water supply.

We're also working very closely with the University of Arizona to understand what tree ring records can tell us with respect to past hydrologic variability on the Colorado River.

Reclamation and the Department of the Interior will continue to develop these collaborative efforts in order to understand and incorporate climate information into our water resource planning and operations efforts. I do want to take this opportunity to point out that we do not believe that real-time operational changes to release patterns or storage levels at our major facilities are warranted at this time. As I stated in the beginning, we possess great operational flexibility at our major facilities that can respond to hydrological variability.

We need more specific real-time hydrologic indicators at the basin scale that show how inflows change, both in terms of timing and volume, and how those changes fall outside the historical ranges that our operations currently can handle. We'll continue to actively pursue seeking this information with our collaboration and we'll of course incorporate it in our operational schemes as appropriate.

In summary, together and with the support of Congress and our customers, we believe that this and other collaborations will equip Reclamation with the necessary information and tools to adapt to potential climate change impacts in the future.

Thank you and I'd be happy also to address any questions you might have.

[The prepared statement of Mr. Fulp follows:]

PREPARED STATEMENT OF TERRY FULP, AREA MANAGER, BOULDER CANYON OPERATIONS OFFICE, BUREAU OF RECLAMATION, DEPARTMENT OF THE INTERIOR

Madam Chairwoman and Members of the Subcommittee, my name is Terry Fulp, and I am the Area Manager at the Boulder Canyon Operations Office at the Bureau of Reclamation. It is a pleasure to be here today alongside the U.S. Geological Survey (USGS) to discuss the Bureau of Reclamation's operations, and the state of the science on global climate change.

There is extensive study, and discussion, within the scientific community about whether the West is experiencing warmer temperatures, longer growing seasons, earlier snowpack runoff, and more precipitation occurring as rain rather than snow. As the predictive capabilities of climate change models improve, western water resource management is looking to where and how to incorporate new climate change information.

A report released earlier this year from the National Academies of Science on Colorado River Basin Water Management concluded that "higher temperatures will result in less upper basin precipitation falling as snow, increased evaporative losses, and will shift the timing of peak spring snowmelt to earlier in the year." Reclamation is evaluating methodologies for incorporating climate change information into its west-wide operations.

Fortunately, Reclamation already possesses operational flexibility to respond to hydrologic change and fulfill its mission to deliver water and power in the West. Drought, flood, and wide climate variability are all common occurrences in the western United States. Given its mission, Reclamation must manage with this variability in mind. However, solutions and strategies for incorporating climate change science into water project operations is an emerging effort being undertaken by all western water management interests, not just Reclamation. Identifying the information needed will require coordinated participation from all the organizations that can provide expert climate and hydrologic sciences.

Reclamation works with its many partners to better understand and incorporate climate information into western water resource management. These partnerships include:

- Department of the Interior—United States Geological Survey (USGS)—The Reclamation Research and Development (R&D) Office is working with climate change experts in the USGS to help define the impact of changes in climate variability and climate change on western water resources. USGS and Reclamation management met in April 2006 to discuss collaboration and coordination efforts.
- Department of Energy (DOE)—Reclamation is working with DOE on evaluating general circulation climate models at the level of individual Reclamation drainage basins, and use of the resulting model information by Reclamation Regions.
- Department of Commerce—National Oceanic and Atmospheric Administration (NOAA)—Reclamation is in the early stages of collaboration with NOAA Regional Integrated Science and Assessments Centers in the western U.S. to assist in data selection, interpretation, and understanding. These centers include the University of Washington Climate Impacts Group, the California Applications Group, the Western Water Assessment, and Climate Assessment for the Southwest. We are also collaborating with NOAA Earth System Research Laboratory to assist Reclamation to better understand the science surrounding climate variability and climate change.
- National Science Foundation (NSF) Funded Science Centers—These research centers include the National Center for Atmospheric Research and the National Center for Sustainability of Semi-Arid Hydrology and Riparian Areas. NSF also funds the Consortium of Universities for the Advancement of Hydrologic Science Inc., which has developed a Hydrologic Information System that may be of use to Reclamation as we seek to have better access to critical Hydrologic data. Reclamation plans to work with individuals in these centers and to utilize the available data to understand the impact of climate variability and climate change on western water resources.
- State of California—Department of Water Resources (DWR)—Reclamation is conducting joint research with DWR on assessing the risks of shifting climate on Reclamation's water and power operations This effort focuses on the Central Valley and State Water Projects. Additional partners include the U.S. Army Corps of Engineers, USGS, Scripps Institute, and Santa Clara University.
- U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS)—NRCS's Snowpack Telemetry (SNOTEL) network provides an extensive, automated system designed to collect snowpack and related climate data in Alaska and the western United States which can be used to produce water supply forecasts. NRCS's Soil Climate Analysis Network (SCAN) is an information system designed to provide data on soil moisture and climate information from a number of different sources.

Secretary Kempthorne has convened a Climate Change Task Force chaired by Deputy Secretary Lynn Scarlett. In testimony delivered April 26, 2007, the Deputy Secretary spoke about the Task Force to the House Interior Appropriations Subcommittee. She explained that uncertainties persist on the timing, scale, and site-specific incidence of climate change impacts. Widely respected models differ in their projections about precipitation patterns, changes in vegetation, extent of sea level rises, and so on. Moreover, global climate modeling is just beginning to provide descriptions and projections at the regional and smaller scales that are needed to be useful for land managers on the ground.

To address this, the Task Force has designated three subcommittees. The first is currently reviewing the legal and policy issues associated with reviewing climate

change effects in land-use planning. The second subcommittee focuses on land and water management, and cataloguing impacts relevant to Interior managed lands and waters. And the third subcommittee will focus on whether modeling might be developed at regional scales to better project more location-specific changes to the landscapes we manage. The three subcommittees will evaluate information needs and whether new types of monitoring might strengthen our understanding of on-the-ground trends in water availability and timing of flows, vegetative patterns, movement of species and so on.

Reclamation will continue to develop these partnerships to better understand and incorporate climate information into western water resource management. However, we do not believe that operational changes to release patterns or storage levels at major water facilities are warranted at this time. In order for new operational regimes to be warranted, Reclamation would look for much more specific, real-time hydrologic indicators at the basin level than currently exist, to show that runoff and inflows are occurring far outside the normal range. In some locations, methods may be available for linking climate change information to actual runoff. But more specific data to inform those methods is needed, and Reclamation would look for a dramatic change in the timing and volume of inflows beyond the capability of current operations and flood plans before implementing substantial changes in operations.

We also continue to work with our water users to institute improved water management and conservation in order to be better prepared for any possible future impacts associated with climate change. Our Water 2025 and Water Conservation Field Services Program, as well as current processes to analyze shortage sharing and coordinated water operations in the Colorado River Basin, all are important in this effort.

Together, and with the support of Congress and our customers, we believe that these activities will make Reclamation well-equipped to adapt to climate change impacts if and when they bring about new hydrologic regimes within the river basins of the West.

This concludes my written statement. I am pleased to answer any questions the subcommittee may have.

Senator CANTWELL. Thank you, Dr. Fulp, and thank you to all the panelists for being here and for your testimony. I'll remind you again that you can submit longer statements if you have them for the record and that the subcommittee has received additional testimony, statements, and exhibits and we'll make those part of the official record today. Again, my colleagues I'm sure may ask additional questions and we'll submit them to the panelists.

Mr. Fulp, are you saying in your testimony that you're going to continue on the path that you're on now—given that the projections for temperature increases will be in the magnitude of several times greater than what they have been over the last 50 years, don't you think we ought to have a contingency plan?

Mr. FULP. Well, again I believe we see that as maybe a two-part question. First of all, that temperature, those temperature effects, we need to understand clearly how that relates to the water supply, particularly the precipitation inflow in our specific basins; and then from that we can understand how any operational regime changes or scheme changes need to be made.

So we believe that's exactly the path we should be on, is get the science further along in order to provide us that specific information.

Senator CANTWELL. Has the Bureau done any analysis on the impact?

Mr. FULP. We have several efforts that I didn't talk about in the verbal remarks that are listed in the testimony. The one that I did mention here with the Department of Water Resources in the State of California, we are looking at potential impacts to both water and power in our Central Valley operation.

Similarly, in Colorado we believe that recent research is going to be fruitful and we'll be able to look at also potential water flow impacts on the Colorado River Basin.

Senator CANTWELL. But would you say the Bureau has changed its priorities, given data and information about climate change?

Mr. FULP. I believe our priority remains the same in the sense of our mission and that's to deliver water and generate hydropower. We obviously want to do that in the most safe, efficient way possible, and so certainly this new information we are pushing very hard to get it and we are very anxious to see what it tells us.

Senator CANTWELL. Mr. Culbertson, does that sound like a contingency plan?

Mr. CULBERTSON. I don't know for the California river systems, but I do know that the Bureau in the Northwest is looking at the question you asked earlier that addresses incremental storage. I think you're probably well aware that the Bureau and others are looking at incremental storage in the State of Washington. One is the Black Rock Project, which would pump water out of the headwaters of our Wanapum—Priest Rapids Dam. But also the Bureau is in the final stages of looking at one of four projects. The most feasible project we believe at this time is in the Lower Crab Creek area, which is right in the center of the county of Grant and is twice the size of Black Rock.

So if you look at the shapes of water and the surplus years that we have, it may make some real viable sense to think about building some incremental storage projects to capture some of the water, especially in the spring time when we have a fair amount of surplus water that we end up spilling even in below average water years because of the shape of the flows. So incremental storage may actually make some sense depending on the size of the projects. But the Bureau is looking at those as we speak today.

Senator CANTWELL. I think, Dr. Fulp, I'd be more comfortable if the Bureau was proposing some changes as it related to our strategy in delivering and protecting water in the West, given climate change. The fact that you don't have the data, and we heard from our previous panelists the importance of data to the specific approaches and solutions. I'd feel more comfortable if the agency was advocating, even within its budget, this amount of money to make sure that we are on track with modeling and impacts.

But not having the data shouldn't be a substitute for not having a strategy. If step No. 1 is let's get the data, then I'm happy to hear that.

Mr. FULP. Well, I don't mean to imply that we aren't doing other things. Let me give you an example perhaps—

Senator CANTWELL. Just so I can bring in Mr. Culbertson's comment, my comment was I think you won't stop getting recommendations from the panelists who are here. You won't stop getting local governments who are in search of solutions and asking for Federal dollars. So it'd be better if the Bureau had its own proposal as it relates to this.

Mr. FULP. Okay, yes. Let me maybe make two points. Certainly we have an active research program and we will continue to do that and we are funding that.

Second, I think I also want to point out we are doing other things. One that Mr. Udall mentioned is the adoption of additional operational guidelines for the Colorado River. What that does for us is implement a shortage strategy. If in fact the reservoirs continue to decline, we would then have a strategy by which we reduce water deliveries.

Another key aspect of it, however, though, is in very active conservation program. If these guidelines go into place as we think in December, if would allow our water users to conserve water and store it in Lake Mead for use later. So that will be quite a new tool that will give us flexibility to allow our users essentially to trade water. So we believe that's going to really be a good addition to our management scheme in the lower basin.

Senator CANTWELL. Thank you.

Senator Corker.

Senator CORKER. Thank you, Chairwoman.

Mr. Brick, when you look at the issues that you have to deal with of water supply and you have to weigh the threats, if you will, that you're dealing with, how would you allocate them from the standpoint of just natural weather changes, population growth, and forced climate change? How would you rate the threat, if you will, to the water supply in your particular area?

Mr. BRICK. Well, it's very difficult to separate out what is kind of natural hydrologic variation and the new impact of climate change. But I would say that the planning that we've done to respond to drought conditions coming irregularly has served us well, has positioned us well, really, to be able to deal with the kind of uncertainty and risk that climate change presents.

It's not clear what the impacts are going to be, but it's clear that we can't wait to find out and that we need to take hopefully kind of no-regrets kind of actions immediately in order to deal with both hydrologic uncertainty in general as well as with the added layer of complexity that climate change adds to that.

Senator CORKER. What about the population growth piece as it relates to the other issues?

Mr. BRICK. Well, population growth is certainly critical, and in the Colorado River Basin this is a very rapidly growing area, and in the 90's Nevada grew by 66 percent, Arizona grew by 40 percent, Colorado grew by 30 percent. This is the most rapidly growing area in the Nation.

So we're faced with a situation in which the allocation of Colorado River water was based upon a relatively wet period of time and the division of 15 million or 16.5 million really acre-feet of water on the Colorado River when that is not considered to be the realistic normal flow of the Colorado River at this point.

With estimates from climate scientists who say that climate change is likely to induce a variation of 10 to 15 percent, and some of the estimates go as high as 41 percent reduction in the stream flow on the Colorado River in the future, it creates a great deal, a great deal of concern, Senator, as to what we're going to have to do on the Colorado River.

I would like to say that the statements by our friend from the Bureau of Reclamation are important and the basin States have responded to this and do have some action steps that we are all

united in asking the Bureau of Reclamation to pursue with regard to shortage sharing criteria on the Colorado River and also with regard to the creation of what's being called intentionally created surplus, which is the ability to bank water on the Colorado River, which is a very important management step for us at a very reasonable cost, a lot less than building other reservoirs and other things like that. We will be able to manage and trade water in the future based on these recommendations from the basin States.

So we encourage congressional oversight of that and support for the basin States' recommendations.

Senator CORKER. But back to the population growth issue, it seems to me that we know we have a lot of contributing factors to sort of magnify the problem, but with the tremendous population growth that's taking place without these other factors, you have serious issues. Is that correct?

Mr. BRICK. That's absolutely correct. Even in our service territory, we're now at 14 or 18 million people, rather. It was 12 million when I first came on board with the Metropolitan Water District. So it's changed that much, from 12 to 18 million, and we expect it's going to go up to 22 million by 2030.

Senator CORKER. Are there things happening at the State and local level? I mean, the things that we are talking about in this panel are semi-more difficult to deal with. They're based on modeling and all of us as a world, if you will, have to work together to address that issue. It sounds like that in your particular area that's a very definable thing to deal with through zoning and working with State and local governments, and that's a much more tangible, easily handled problem that sounds like it's of greater magnitude in many ways than what we're talking about today as it relates to water supply.

So are there things happening at the State and local level to deal with the huge magnitude of growth that is using up this water?

Mr. BRICK. Well, two-thirds of the growth in southern California is coming, is internally generated. But you're absolutely right, the local land use planning and a lot of the important decisions that get made about the density of developments are very important. Moves toward mixed use development in urban areas and concentrating growth in urban areas and protecting green belts or other zones outside of cities are very important. More dense housing in urban areas is very preferable to carpet bombing the desert with new subdivisions.

Many steps like that are being taken, but I think that you're right that there is a need for much more action in that area in order to really assure that the needs of southern California and other regions in the West are met in the future.

Senator CORKER. Again, I was with the chairman last week in Brussels working with others, the European Commission, and looking at global warming, and it seems to me that again to have such a tangible way of dealing with it at the local and State level might be a great first step with some of the issues that are coming up.

Mr. Culbertson, and I thank you all for your testimony. But on the renewable portfolio standard that we're going to be dealing with I think very soon in the next 3 weeks, I know one person on this committee plans on putting forth an amendment. Talk to me

a little bit about new opportunities for hydropower, the investment? Talk to me a little bit about the possibility of—I know that's one of the renewables that is included per this person's proposed amendment. But talk to me about the opportunities there?

Mr. CULBERTSON. There are a number of potential opportunities. Unfortunately, in the utility industry many times we tend to put all of our eggs in one basket. Currently I think that the utility industry—and I've been around 30–some years in the utility business out West. The resource of choice right now is basically two. One is wind and that's predominantly the renewable resource of choice. The other is gas-fired generation.

However, there are multiple hydro projects around the United States, especially the Northwest, that, at least under the State of Washington, qualify potentially as a renewable resource, and hopefully a Federal standard will include hydro resources as renewable generation. We recently filed—I'll give you an example—on a small project known as the Klee-Ellen Project about halfway between where I live in the center part of the State and Seattle. It's an existing storage project, flood control primarily.

We have filed that preliminary permit application to add incremental generation to that project. It's a cost- effective resource. It is considered a renewable resource. We believe there are a number of those kind of projects around the country that could be retrofitted. There are canal systems that have low drops on the canal systems. We have a number on our system. We're going to go back and retrofit, I believe, a number of those drops. They're not huge, but every little bit of generation, incremental generation, is a benefit to the system.

Technology is rapidly changing. Microturbines in canal systems and low-flow stream systems. We are watching that technology as it rapidly advances. We believe that our canal system and low-flow streams—not too far in the future—we'll be able to put little microturbines in there and generate off of those microturbines.

But when you look at all of that, if you have rapid growing areas, I guess I'll sit here and say before you I believe all hydro generation is renewable. It's a renewable resource, always has been. There are other projects across the West and across the country where you could do exactly the same thing as we talked about about the Klee-Ellen Project, only on a larger scale. You have existing large storage projects where you could retrofit to put generation capacity on those storage projects. We're looking at some of those. They're larger scale, but at this point in the State of Washington and the standard adopted—it's going through its rulemaking process—would not be included as renewable. That's not going to stop us from looking at those, at those projects, because right now I think they're some of the most cost effective projects that can be developed when you look at the scope of projects that utilities are able to look at right now.

If you take coal off the table, put nuclear back on the table, which some are doing, but when we look at what the potential is for renewable projects I think it's large-scale and small-scale hydro projects. That's where we're going to focus a lot of our efforts. We're going to look at biomass. We are the largest producer of biomass in the State of Washington, so we're going to look at methane di-

gesters at dairies. But they're very small. You're not going to get large-scale generation. We're going to probably develop a wood products biomass facility. Senator, if you haven't heard we've signed a new agreement with the Yakama Nation. I think your staff will be briefed about it tomorrow.

But you have to look at all of those things and you can't put all of your eggs in one basket. I believe that we've got to diversify our renewable portfolio. But I think a good portion of that is also then developing the incremental hydro resources that we have available to go along with those other renewable resources.

Senator CORKER. I know the body language in the back with people standing suggests that it's time for this hearing to come to a close. But just if you will, what is your mix, your portfolio mix at present?

Mr. CULBERTSON. At present we have 2,000 plus megawatts of hydrogeneration.

Senator CORKER. Do it in percentages, if you will.

Mr. CULBERTSON. Hydro is 95 or 96 percent of our generation, wind is probably 2 percent, and other is the remaining percent—whatever it is.

Senator CANTWELL. All States should be so lucky as to have a Grant County PUD. I should tell you that.

Mr. CULBERTSON. Yes, we're very fortunate.

Any more questions?

Senator CORKER. I want to thank all of you for your testimony and traveling so far to be with us. All of this is very helpful. I know in many cases there's not many Senators here up at the dais, but we do get your written testimony and our staffs all do look at that.

I want to thank the chairwoman for having this hearing and for all of you being here.

Senator CANTWELL. Well, Senator Corker, thank you for attending and being here this afternoon. I think your questions were right on. Having jointly chaired the San Joaquin hearing a few weeks ago, we definitely see how the impacts of local decisions play into this. I personally think the Energy committee and this subcommittee should take a much more aggressive role at looking at these water issues throughout the country, but certainly impacting the West, and promulgate more ideas about what we should be doing in a proactive sense, given the level of frustration.

I don't think I've seen a more contentious issue than water except for fish and, Mr. Williams, often fish and water go together. The lack of fish and water has caused a great deal of debate in western States in the last several years, and oftentimes they end up right at our doorstep. So I would suggest if we could think about being a little more proactive maybe we can deal with those issues in advance of court cases and court decisions and coming to us with last resort agreements.

So anyway, thank you very much for your testimony and the subcommittee is adjourned.

[Whereupon, at 4:10 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX I

Responses to Additional Questions

RESPONSES OF TIM BRICK TO QUESTIONS FROM SENATOR CANTWELL

Question 1a. Your testimony identifies an impressive array of investments that Metropolitan has made in groundwater storage, conservation, and water reuse projects. It appears that Metropolitan's approach is to make itself as diversified as possible with respect to water supply, and as efficient as possible in its operations, as the way to meet the long-term water supply challenges posed by climate change and other factors.

If that correct? Is it your view that implementing strategies for good water management is the best strategy for dealing with the impacts of climate change will have on water supply?

Answer. Good water management by diversifying water resources and practicing demand management is key to handling current and future uncertainties, including climate change, for the southern California region.

Since the adoption of its first Integrated Resources Plan (IRP) in 1996, the diversified water supply strategy has proven to work well for Southern California. The region was able to withstand a 40% reduction in Colorado River supply beginning in 2003 (due to the on-going drought on the River and the Quantification Settlement Agreement). Furthermore, 2004 was one of the driest years on record for California. Southern California managed without water rationing.

Southern California relies on four different hydrologic basins for its water supplies, and integrating the management of these sources provides greater overall capability to handle hydrologic variability of these basins. In addition, Metropolitan has worked to integrate the resources of its member agencies and agencies outside Metropolitan. The region has benefited from storing water to help meet both seasonal swings in water demand and year-to-year variation in water supply.

Metropolitan also works with other water agencies to purchase transfer water during dry periods. In 2003 and 2005, it acquired over 125,000 acre-feet of options to purchase transfer water supplies from agricultural water districts in the Sacramento River Basin. In 2004, Metropolitan entered into a 35-year program with Palos Verde Irrigation District that provides Metropolitan with up to 111,000 acre-feet of Colorado River water annually, depending on Metropolitan's needs.

Metropolitan provides incentives for strong conservation practices and water recycling, which enhances local supply and conservation for the region.

It is important to note that none of these actions alone is enough; that only a mixture of these management actions maintains a reliable water supply for Southern California.

Question 1b. Does Metropolitan, as part of its Integrated Resource Plan have specific actions it is taking solely due to impacts expected due to climate change?

Answer. At this time, Metropolitan is implementing 'no regrets' actions and projects to prepare for climate change; that is, projects which provide water supply and quality benefits now, because they make overall water management sense, while increasing the ability to manage potential climate change impacts when they occur. Our IRP is revised every 5 years and plan implementation is reported annually to track progress, changes in resource status or assumptions, and anticipated implementation challenges. The last version of the IRP, released in 2004, included a ten percent buffer to provide for uncertainties about water supply and management programs and for uncertain developments such as climate change.

MWD staff is currently preparing a new, major revision of the IRP that will be released in 2008. This revision will incorporate specific responses to potential climate change impacts.

Question 2. You mentioned that Metropolitan, and the water community as a whole, needs to partner with the scientific community to conduct further research to assess the risks of climate change on water, and integrate appropriate responses into water management decisions. We heard a similar recommendation from the first panel that there needs to be better integration between the science community and the water user community.

Do you have any suggestions on how we might accomplish a better integration of scientists and water users on the issue of climate change and water? Is there an existing program or structure that can be used to facilitate that integration?

Answer. Metropolitan supports a close collaboration between climate scientists and water resource planners and engineers on applying the science of climate change. Water resource planners and engineers use previous experience to predict the future, and the climate scientists say the past may no longer predict the future. Hence, a planned structure for interaction is needed. The communication needs to be two-way; engineers and planners would convey their needs to climatologists—key parameters for determining risks-tolerance levels including magnitude and frequency of impacts, and scale to be of use. And climatologists need to convey to planners and engineers tools to predict the future.

Answer. Metropolitan believes that we need a joint determination of indicators for adjusting strategies for water resource planning and emergency preparedness. Funding from the Regional Integrated Sciences and Assessments (RISA) and Climate Change Science Program (CCSP) need to be earmarked for this exchange. Funding needs to be reinstated for USGS stream gage monitoring and weather station data collection programs, which have suffered declining budgets in recent years and have curtailed the collection of invaluable data.

Metropolitan recommends that Congress earmark part of the National Science Foundation grant funding for climate research for projects that partner academics and water industry practitioners. Metropolitan also supports NASA's program for satellite monitoring of the Earth's climate, and NASA's CCSP budget needs to earmark the aggressive development of actual application of satellite data.

Response of Tim Brick to Questions From Senator Salazar

Question 1. Are the existing reservoir storage capacities capable of handling the early snowpack melts?

Answer. While the operations of existing storage facilities are being adjusted to capture the earlier snow melts, additional surface and groundwater storage will be required to manage future impacts of climate change for more intense runoff, less snow pack, and longer droughts. Existing reservoir storage volume and operating guidelines were developed based on historical runoff patterns and storm intensities. Changes predicted to occur with climate change would require revising flood management and water conservation and recycling strategies. With the possible impact of higher storm intensities, it is likely that more storage space would need to be reserved for flood control thereby reducing the ability to capture runoff for consumptive use by people. Additional surface and groundwater storage may be required in certain watersheds to compensate for the reduced capture ability.

In addition, water use efficiency gained through water conservation and recycling enhances the ability to meet water demands. Each acre-foot of conservation savings or recycling water would lessen the need to utilize stored water during dry periods. Finally, climate change would likely impact fish and wildlife, and hence the reservoirs may be called upon to regulate the quantity and temperature of streamflow, further limiting the ability to store water for consumptive needs.

Question 2. What are the best options you believe are available to adapt to global warming impacts on water supplies in the West?

Answer. Metropolitan believes that the water agencies should incorporate options that include both mitigation and adaptation to climate change in their water resource management plans. For example, Metropolitan is examining its operations, including reduction of greenhouse gas emissions, to mitigate climate change. It also supports the Governor Schwarzenegger Executive Order S-3-05 and recently enacted state legislature AB 32 by state assembly speaker Nunez to reduce the extent of climate change and associated impacts to water supply.

For adaptation, Metropolitan has diversified its resource mix and created additional water storage opportunities. It has developed conservation and recycling incentives for local agencies to develop these programs. It has worked with industry associations and legislatures for stricter plumbing codes (e.g. low flow showerheads)

and stricter appliance efficiency standards (e.g. clothes washing machines). Metropolitan also supports streamlining regulatory requirements for water transfers and water recycling.

Question 3. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

Answer. Because of the investments the region has made in storage, conservation, recycling and groundwater recovery, Southern California uses the same amount of imported water today as the region did in 1990, even though the region has grown by more than 3 million people.

For Metropolitan's service area, conservation efforts have reduced the daily per person consumption by 36 gallons. Our projections anticipate that by 2025, conservation efforts will reduce per person daily water use by 54 gallons. In more fully developed areas such as the City of Los Angeles, the region's largest city, with four million people, water use has been stable for 25 years despite the addition of one million people. Retrofitting older, less water efficient devices and appliances delays the need for new water supplies.

Water demands in more rapidly developing areas would increase with population and economic growth, since the newer housing and development have already incorporated more water-efficient features through the use of stricter plumbing codes in place. However, Metropolitan strives to increase water use efficiency in the newer areas through partnerships with local, regional and national homebuilders, with support from the California Building Industry Association and U.S. Bureau of Reclamation, to increase the awareness by home buyers and remodelers of water-efficient landscapes and devices. Through its California Friendly® Home Program, Metropolitan currently offers incentives to builders to offset the costs of equipping model and production homes with water-efficient fixtures and landscapes that exceed plumbing code requirements. Homes built with California Friendly® specifications are designed to use 30 percent less water than conventional homes.

Question 4. Do you believe that climate change impacts on water supplies will have to be considered when making commitments about future water deliveries?

Answer. Climate change is an important consideration for water agencies in the planning and implementation of water management strategies. Water agencies, such as Metropolitan, must consider ranges of water supply and demands in their planning for future water deliveries, including supply uncertainties due to climate change and other factors (such as population and economic growth, endangered species and ecosystem needs, more stringent water quality requirements, etc.) In addition, recent state legislation requires local governments to demonstrate sufficient water supply for 20 years when approving new developments exceeding certain thresholds. The federal government could hold oversight hearings to ensure state and water agencies are taking into account potential impacts of climate change on investment decisions, and future water rights and appropriations. Climate change considerations should also be incorporated into decisions regarding federal water contracts and system operations that directly affect water apportionments to individual states.

Regarding water resources to southern California, the federal government plays a key role in making decisions regarding ecosystem, operations and infrastructure improvements for the Colorado River and the San Francisco Bay and Sacramento and San Joaquin River Delta. It is important that those decisions would result in sustainable water delivery systems from the Colorado River and the Delta to meet urban, agricultural and environmental water needs.

RESPONSES OF PATRICK O'TOOLE TO QUESTIONS FROM SENATOR CANTWELL

Question 1a. You mention the need for expanding the water supply in the West through new storage projects that will make water available to farms and cities.

What type of storage projects has the Alliance and its members been contemplating?

Answer. The Board of Directors of the Family Farm Alliance in 2005 launched a forward looking project that pulled together a master data base of potential water supply enhancement projects from throughout the West. Our goal was to gather together ideas from around the West and put them into one master data base.

The types of projects contained in the resulting Western Water Supply Enhancement Study database are not monstrous dams like China's Three Gorges project. Instead, they are supply enhancement projects that range from canal lining and piping, to reconstruction of existing dams, to integrated resource plans. There are also some very feasible new surface storage projects. The benefits from these projects in-

clude providing certainty for rural family farms and ranches, additional flows and habitat for fish, and cleaner water.

Along with basic information included on a CD-ROM, the database that was generated from the compilation of the survey has a Global Information System (GIS) element and includes pictures, maps and a description of up to 500 words for each project or proposal. New GIS format technology is embedded that permits viewers to see a map of 17 Western states and then "drill down" to see map details of a project area. If you would like, we can make copies of the CD-ROM available to your committee. We welcome all constructive comments.

The Initiative shows that, in most areas of the West, water resources are available and waiting to be developed. However, the policies of the federal government make development of that water nearly impossible. Water wars are being fought throughout the West simply because we have not had the vision to develop new, environmentally sound, sources of water.

Question 1b. Can you give some examples?

Answer. There are more than 100 projects included in our data base. Some specific projects include:

- *Water for Irrigation, Streams, and Economy Project (WISE),* a collaborative effort in Oregon to improve the health of the Little Butte Creek and Bear Creek systems and increase the effectiveness and efficiency of local irrigation districts. The WISE Project utilizes a combination of strategies including: piping and lining canals, increasing the storage capacity of selected reservoirs, and installing a pumping system that will provide access to water that has been allocated for agricultural purposes. Collectively, more water will be available for management for irrigation and environmental instream purposes.
- *Sites Reservoir* in has been identified by the California Department of Water Resources and the CALFED Program as one of the most cost-effective and environmentally beneficial new facilities under consideration in California. The Sites project would enhance water supply reliability for environmental, urban and agricultural uses throughout the state. Sites would provide water supplies in average and dry years for urban, agricultural and environmental purposes, increase San Francisco Bay-Sacramento/San Joaquin Delta outflows during critical times, improve flood control, enhance groundwater recharge, bolster fish flows, and improve flexibility for existing projects, such as Shasta Reservoir. Sites reservoir can greatly increase reliability of water supplies by reducing water diversions on the Sacramento River during critical fish migration periods.
- *Strawberry Valley Rehabilitation and Betterment Projects* (Utah) are proposed to decrease the water seepage and losses in the Strawberry Valley Project, as well as provide gravity pressure for the continued migration toward sprinkler irrigation systems, which would then provide additional water savings. These projects could save approximately 15,000 to 20,000 acre-feet of water per year in an agricultural area that is rapidly urbanizing.
- *Farmington Groundwater Recharge Program*. This $33.5 million effort is lead by Stockton East Water District (California) in partnership with the U.S. Army Corps of Engineers to contribute to restoration of local aquifers and to repel saline water intrusion. The Program seeks to rotate water with other land-uses via short-and long-term agreements with landowners, and develop permanent recharge facilities. The recharge facilities also provide seasonal habitat for migratory waterfowl. This will provide an additional water supply yield to the region of approximately 17,000 acre-feet annually.

Question 1c. Obviously, there will be environmental concerns associated with any new surface water storage projects. Moreover, increasing temperatures means more reservoir evaporation, resulting in some loss of the water supply that storage might otherwise make available. In your opinion, is it possible to address those issues and move forward with storage projects that will ultimately have broad support from a number of different stakeholders?

Answer.

Environmental Impacts

Individual surface storage proposals must be evaluated and the associated benefits and risks must be viewed in a net, comprehensive manner. While some environmental groups focus on perceived negative impacts associated with new facility construction (e.g. loss of habitat, disruption of stream flow patterns, and potential evaporative losses), these perceived impacts must also be compared to the wide range of multi-purpose benefits that storage projects can provide. Properly designed and constructed surface storage projects provide additional water management flexibility to better meet downstream urban, industrial and agricultural water needs, improve

flood control, generate clean hydropower, provide recreation opportunities, and—yes, create additional flows that can benefit downstream fish and wildlife species.

Evaporation

Potential increasing temperatures and associated increased evaporation must also be evaluated for new storage projects on a case-by-case basis. Evaporation is a function of several variables, including temperature, wind and the surface area of the reservoir. Sometimes, new reservoirs might actually result in lower evaporative losses than is the current case.

Consider, for example, Oregon's Long Lake basin, located just west of Upper Klamath Lake, the principal reservoir for the Klamath Irrigation Project. Putting in earthen dams in the mostly dry Long Lake could create a reservoir with about the same storage capacity as Upper Klamath, but with only about 10 percent of the surface area. It would be about 160 feet deep, compared to an average depth of just 8 feet for Upper Klamath Lake. Upper Klamath's annual water loss to evaporation is 290,000 acre-feet. The projected annual loss from a Long Lake Reservoir would be 8,000 acre-feet. That's a huge difference—and a huge benefit. So is the fact that the water from such a reservoir would be much colder than water from Upper Klamath.

Stakeholder Support for New Projects

Some people and organizations oppose dams as a matter of dogma. They have no flexibility when it comes to surface storage. But experience teaches us that solving complex problems requires a great deal of flexibility. It also requires the collective efforts of reasonable, well-intentioned people who may come at the problem from entirely different perspectives. Surface storage isn't the solution in all cases, but dismissing it out-of-hand serves no good purpose.

Creative, successful solutions can be found by motivated, unthreatened parties. The holders of water rights approach the Western water supply problem with much at risk, and with much to offer in the form or practical experience managing the resource on a daily basis. Incentives that create reasons to succeed will do more good for the environment in a shorter period of time than actions that rely on threats of government intervention.

Question 1d. Given the cutbacks in water supply funding over the last several years, do you envision that water users will be able to pay for a majority of any new water supply infrastructure?

Answer. Those who benefit from new water supply infrastructure should help pay for that infrastructure. For the most part, new water supplies are not being proposed to meet the expanding needs of agriculture. On the contrary, we are seeing a move in the opposite direction, where agricultural lands are going out of production and being lost to expanding urban development. Water that was originally established for agriculture and the communities it supports is now being reallocated to meet new growing urban and environmental water demands. The growing numbers of urban water users in the West and the public interest served through improved environmental water supplies should naturally be part of equitable financing schemes.

The President and Congress will prioritize whatever federal funds are available to meet existing and future needs. As for the rest of the capital, it must come either from state and local governments or from the private sector. If the federal government cannot fund the required investments, it should take meaningful steps to provide incentives for non-federal entities to fill the void, and remove barriers to the new ways of doing business that will be required.

In this time of tight budgets and huge overseas spending, the federal government must adopt a policy of supporting new projects to enhance water supplies while encouraging state and local interests to take the lead in the implementation of those projects.

Question 2. Your testimony identifies as a priority, the need for research that would validate projected climate-driven changes in streamflow; and which would then be coupled with a plan addressing the new storage and conservation targets essential to compensate for the changed hydrology. You also suggest the need for a comprehensive assessment of changes in agricultural land and water use over the last decade.

In your opinion, should the Federal government lead such a research effort? If so, who should take the lead? Is any one agency equipped to carry out such a large task?

Answer. No. Rather, this type of study lends itself well to a private-public partnership that would add non-governmental farming organizations, state agencies and academic institutions to a team of federal agencies like the Natural Resources Con-

servation Service, Bureau of Reclamation, U.S. Geological Survey. For example, the Family Farm Alliance has partnered with Colorado State University and recently developed a proposal to the U.S. Department of Agriculture for a project that would assess public attitudes and perceptions regarding agricultural water use in the West. A similar type of proposal—one that involves producers, state and federal agencies, and academia—could be developed to create a partnership of the above agencies and other entities to collaboratively lead a climate change/hydrology research effort. We would be happy to further coordinate and detail such a proposal.

RESPONSES OF PATRICK O'TOOLE TO QUESTIONS FROM SENATOR SALAZAR

Question 1. Are the existing reservoir storage capacities capable of handling the early snowpack melts?

Answer. There are several reports that suggest existing reservoirs will not be capable of safely accepting the earlier, more intense snowmelt. As noted in our written testimony, a report released last year by the State of California predicts that climate change will result in a drastic drop in the state's drinking and farm water supplies, as well as more frequent winter flooding. The report suggests that warmer temperatures will raise the snow level in California mountains, producing a smaller snowpack and more winter runoff. This means more floodwaters to manage in winter, followed by less snowmelt to store behind dams for cities, agriculture, and fish. Water resources experts in other parts of the West also realize that new surface water storage projects may be necessary to capture more snowmelt or more water from other sources.

Some Western water managers believe there will likely be a "rush" to re-operate existing multi-purpose projects to restore some of the lost flood protection resulting from the changed hydrology associated with climate change. These projects were designed to provide a certain level of flood protection benefits that will be reduced because of more "rain flood"-type of events. There will be a call to reduce carryover storage and to operate the reservoirs with more flood control space and less conservation space. If this is done, it will even further reduce the availability and reliability of agricultural water supplies.

Further, many water users are located upstream of existing reservoirs. These users must then rely on direct or natural that is primarily fueled by snowmelt. In the Rocky Mountain West, snowmelt traditionally occurs during the onset of the irrigation season. Since conveyance systems are never 100% efficient, water is diverted, conveyed and spread on the land in excess of the net irrigation demand. This surplus returns to the stream and recharges groundwater aquifers, which augments water supplies for all users located downstream from the original diversion. If more runoff were to occur during warm cycles in winter before the onset of the irrigation season, this would impact the utility associated with these return flows.

One priority research item should be a comprehensive validation of West-wide changes in climate change-driven streamflow. This should be followed by quantification of the amount of additional reservoir storage, conservation targets, etc required to re-regulate this change in hydrology. To optimize beneficial use, storage should be spaced through the drainage and locate at high and low elevations to regulate and subsequently re-regulate the water supply to maximize beneficial use.

Question 2. What are the best options you believe are available to adapt to global warming impacts on water supplies in the West?

Answer. In our written testimony, we elaborated on general actions that should be prioritized to allow us to mitigate climate impacts to Western water supplies:

a) Implement a Balanced Suite of Conservation and Supply Enhancement Actions;
b) Streamline the Regulatory Process to Facilitate Development of New Infrastructure; and
c) Prioritize Research Needs.

Also, many of the West's Reclamation projects are nearly 100 years old and are badly in need of repair. Rehabilitation measures should focus on maximizing the conservation effort through increased delivery efficiencies, construction of re-regulation reservoirs to prevent operational waste, and construction of new dams and reservoirs in watersheds with inadequate storage capacity to increase beneficial use and provide operational flexibility. Conjunctive management of surface and groundwater supplies should be encouraged. Installation of additional stream gauges, water meters, groundwater monitoring wells and better estimates of consumptive use are of paramount importance for the equitable management of available water supplies.

Question 3. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

Answer. Yes, conservation efforts have been effective, but it strains credibility to believe that conservation alone will supply enough water for the tens of millions of new residents expected to arrive in Western cities during the coming decades. Also, conservation does not work in many cases, especially where the desire is to increase in-stream flow. Water that is conserved tends to be used by the next junior downstream appropriator and the flow remains the same.

In our written testimony, we provided several examples from throughout the West, where creative measures have been taken to develop and efficiently manage water resources for irrigation. These examples represent just a handful of the creative water management programs that Western irrigators are working on. Efforts to conserve water in urban areas have also been impressive, particularly in the Southwest.

The experience of the City of Las Vegas may provide the best response to Senator Salazar's question. The Southern Nevada Water Authority (Authority) has imposed dramatic conservation measures in the areas it serves in and around Las Vegas. Consider the following:

- As of March 2006, a program developed to pay customers $1 per square foot to remove lawns had already spent $56 million.
- New restrictions were imposed on landscaping.
- Use of recycled water was stepped up dramatically.
- Casino-hotels along the Las Vegas Strip have made significant investments in water features, capturing and treating grey water and using recycled water.
- A stiff four-tier rate structure was imposed, as were high connection charges.

With conservation measures in place, southern Nevada reduced water use by 65,000 acre-feet in two years. However, despite these aggressive conservation actions, the Authority is moving with equal determination to develop new water supplies in other parts of the region, since probabilities of shortages on the Colorado River are likely going to increase over time. As noted in our written testimony, the Authority is already planning to take groundwater out of aquifers under the Utah-Nevada state line and pipe it to Las Vegas.

So, this particular example—which describes some of the most innovative and aggressive conservation measures undertaken in the West—suggests that even the highest level of conservation is insufficient to keep up with new demands caused by new residents moving to Las Vegas.

Question 4. Do you believe that climate change impacts on water supplies will have to be considered when making commitments about future water deliveries?

Answer. Yes, with qualifications. Proper planning of any water resources project includes thorough hydrologic assessments and modeling of potential future scenarios. These scenarios can include a range of variables, including population projections, financial predictions, and weather/climate scenarios. However, caution should be employed when making commitments about future water deliveries, especially where climate change is concerned. Policy makers must understand the incredible uncertainty and high range of variability inherent in climate change predictive models before considering using these models as a basis for commitments.

It often appears that agency modelers will expend seemingly endless amounts of funding based on their hope to create predictive tools, even though we are decades or more away from models that will have enough reliability to commit money or other resources. Climate scientists love their models, but when asked if they have enough confidence in them to make irreversible commitments of resources, the message becomes a more subdued "no, but we hope to get there".

RESPONSE OF PHILIP W. MOTE TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Subcommittee staff have been looking at putting together a National Water Science Initiative that would focus on expanding, standardizing, and modernizing data acquisition for streams, groundwater, lakes, and reservoirs. Hopefully, this effort would lead to the development of better hydrologic models which would improve overall water management. I would also hope that these models could be coupled with atmospheric models to improve our ability to assess the impacts of climate change on water supplies.

What do you think of such an initiative? It sounds as if the focus has been on streamflows in most of the research. What about other parameters affecting water supplies such as groundwater recharge; soil moisture; reservoir evaporation; and

evapotranspiration? Would it help to increase our knowledge base about these parameters to use in conjunction with more streamflow data?

Answer. Such an effort is vitally needed in order both to understand the details of how climate change will affect water resources in different watersheds and to improve streamflow prediction on timescales from a week to a year. At the University of Washington, the hydrology group headed by Prof. Dennis Lettenmaier developed the VIC (Variable Infiltration Capacity) hydrologic model, which unlike conventional hydrology models balances both water and energy fluxes and hence is more physically realistic and more suitable for estimating how streamflows, soil moisture, and evapotranspiration will change in a changing climate. This model has been used in numerous studies of climate change and also for shorter-term forecasting. Better data, especially naturalized streamflows, would improve this and other models' ability to accurately simulate streamflows and other aspects of the hydrologic system.

The National Integrated Drought Information System, which Congress and the President authorized and funded in 2006, is a trailblazing step in the direction you suggest. It is among other things intended to harmonize data collection and distribution efforts among the various federal agencies. The National Weather Service's Historical Climate Network Modernization effort is also relevant for the effort you propose.

Question 2. It's been my understanding that the climate change scientific community has relied heavily on data made available from satellites; and also made significant investments in trying to develop new remote sensing technologies. Unfortunately, I recently read a news report indicating that the Administration is drastically scaling back the use of satellite based data collection, which is critical to refining our understanding of the implications of global warming.

Your testimony noted the importance of additional data and analysis in tracking and understanding the implications of climate change on water. Are you aware of these planned cutbacks in satellite data, and if so, how do you think it will affect ongoing science programs in this area?

Answer. I believe you are referring to the NPOESS, National Polar Orbiting Environmental Satellite System, which is intended to make better use of planned satellites in both the Department of Defense and Department of Commerce. I understand that the NPOESS schedule has slipped considerably and that the instrument packages on the various satellites have been reworked, and there is considerable risk now that the first NPOESS satellite will not launch until the demise of NASA's Terra and Aqua satellites. Satellites are primarily used for process studies, and they have a role to play in climate monitoring but generally their design lifetime is too short to constitute monitoring, so overlapping series of satellites are needed.

Response of Philip W. Mote to Questions From Senator Cantwell

Question 1. Your testimony states that "warming in the West can now be confidently attributed to rising greenhouse gases and are not explained by any combination of natural factors". Researchers at the University of Washington have recently debated the trends being observed in snowpack in the Pacific Northwest, and whether those trends were attributed solely to global warming or more closely related to the natural variations in weather patterns.

How do you discern between the two causes and how might we improve in understanding and addressing this distinction in the future?

Answer. Implicit in the question are two separate logical steps. The first is whether snowpack has changed in a manner that can be explained by warming, regardless of the cause of the warming. The second is whether western warming can be explained by natural factors or whether the buildup of greenhouse gases is involved.

For the first question, as one of the primary parties in that discussion of snowpack, I am very familiar with the issues discussed. I and colleagues at several other institutions have published about 8 or 9 peer-reviewed papers demonstrating that snowmelt-driven hydrology in the West has changed in the last 50-60 years and that warming is clearly involved. Our papers considered about 1,000 locations where snow has been monitored and about 300 locations where streamflow has been monitored, as well as detailed hydrologic modeling that substantially corroborated the observations. The "debate" arose after a colleague at UW, on the basis of cursory analysis with a handful of snow monitoring sites and without the scrutiny of peer review, challenged the findings of these 8-9 far more detailed and peer-reviewed studies, referring to the notion of declining snowpack as a "myth". However, an independent review panel of four faculty at UW examined the evidence on both sides and wrote a short report affirming the basic conclusion that snowpack in the Cascades had declined some 30% since the mid-twentieth century largely in response to warming.

The second question was addressed in a paper by Peter Stott in 2003, which showed that the warming in western North America could not be explained solely by natural variability but could be explained by the buildup of greenhouse gases. An easy way to see that is by considering trends in temperature and how they relate to the primary pattern of western climate variability, which is a north-south seesaw associated with Pacific basin climate patterns. That is, the Northwest tends to have winters that are wetter and cooler than average when the Southwest has winters that are drier and warmer than average, and vice versa. But in the past 50 years all regions of the West have warmed, illustrating that rising greenhouse gases have dominated the natural see-saw.

Question 2. In talking about predicted future changes, you discussed climate models being used by the IPCC, and that those models tended to agree that precipitation will likely increase in the north and decreases in the Southwest. Mr. Udall and Dr. Milly's testimony seem to be in sync with those conclusions. A recent story in USA Today, though, entitled "Climate change models overstate droughts", talks about a new study entitled "How Much More Rain Will Global Warming Bring", which finds that climate change will result in increased global rainfall which may be 3 times greater than currently predicted. The story concludes by stating that "climate modelers are overstating how much rainfall will dry up in a warmer climate".

Are you familiar with this new study, and if so, does it have implications for the modeling results that you've all discussed today?

Answer. I have read the paper in question by Mears et al., and I believe its results were somewhat overstated in the USA Today article. The last two sentences of the paper says that it raises more questions than it answers: "The observations reported here suggest otherwise, but clearly these questions are far from being settled." [emphasis added]

The authors studied variability in precipitation from satellite data over about the last 20 years, and the relationship between temperature and precipitation that they reported was predominantly a tropical relationship and was dominated by the 1997–98 El Nino event and the changes in rainfall and wind that occurred then; it uses the relationships derived from the past 20 years to test the models, and extrapolates from that behavior to the future. Furthermore, what their paper showed outside the tropics was that the pattern that global climate models project for future changes—drying in the subtropics and more precipitation in higher latitudes—are correct, but the intensity is underestimated. In other words, if they are correct that models underestimate the intensity of the hydrologic cycle are correct, the projection of increased drought in the southwest is also an understatement. Heavier precipitation in the tropics goes along with less rainfall in the desert areas.

Question 3. You discuss the need to produce information on a regional basis as opposed to a global scale, including the development of regional climate models. It's my understanding that a great deal of the projections currently being made are the result of "downscaling" global climate models to assess climate change impacts in specific regions.

It's my understanding that you have a paper in the works on this subject. What are your views on the issues associated with "downscaling" and the prospects for regional models? What will regional models be able to do better than global models?

Answer. Thank you for noticing that paper. We believe that regional models are a useful tool for studying climate change, sometimes illustrating how large-scale changes in circulation can interact with small-scale topography to produce interesting results. In some respects global model changes can be considered to be uniform across a large region—for example, the factors producing a 3°F warming or 10% decrease in summer precipitation would be largely the same in central Washington as in eastern Idaho, even though the baseline temperature and precipitation in each place is different. However, for other aspects like the interaction between snow cover and surface temperature, getting the details of the location correct (for example, whether it has snow cover) are very important for determining the rate of warming. Regional models can be useful tools for such details. There are a number of technical challenges in using regional models, not least the computing power required to do long simulations and to improve their numerics.

Response of Philip W. Mote to Questions From Senator Salazar

Question 1. What studies do you believe would be most beneficial to understanding the potential impacts from global warming on water supplies?

Answer. First, estimating future flows using a combination of global climate models, regional models, and physically-based hydrologic models. Ideally this approach would include a range of scenarios of future climate. Second, each water management agency that has a water resources model should run the model on a range

of future flows to investigate the impacts. For example, the Northwest Power and Conservation Council has used flows produced using the VIC hydrologic model (mentioned in my responses above) in its Genesys hydropower model to investigate what climate change could do to future hydropower production.

Question 2. Are the existing observation networks, e.g., for measuring streamflows, snowpacks, etc., adequate to understanding the observed impacts from global warming? Are there additional observation networks we should be putting in place?

Answer. None of these networks was originally designed for monitoring climate changes. Monitoring long-term climate and hydrology requires greater consistency in instrumentation, observing practices, and surrounding landscape than most sites have achieved. Using these networks to deduce changes over time therefore requires some efforts to estimate the effects of these non-climatic factors, for example the effects of changing a thermometer type. A serious problem of attrition is reducing the number of long-term weather stations, stream gauges, and snow courses, and, as the American Association of State Climatologists and various panels of the National Academy of Sciences have said, Congress should reverse this decline so that we can at least maintain the level of monitoring capability that we have now. Improving real-time reporting capability and data access are another high priority. Adding sensors like soil moisture, groundwater, and solar radiation to existing networks would further improve their value. These various tasks are in my opinion more urgent and more valuable than establishing new networks, with the exception that the Climate Reference Network (which is currently being installed) should certainly be completed.

RESPONSE OF BRADLEY H. UDALL TO QUESTIONS FROM SENATOR BINGAMAN

Question 1. Subcommittee staff have been looking at putting together a National Water Science Initiative that would focus on expanding, standardizing, and modernizing data acquisition for streams, groundwater, lakes, and reservoirs. Hopefully, this effort would lead to the development of better hydrologic models which would improve overall water management. I would also hope that these models could be coupled with atmospheric models to improve our ability to assess the impacts of climate change on water supplies.

What do you think of such an initiative? It sounds as if the focus has been on streamflows in most of the research. What about other parameters affecting water supplies such as groundwater recharge; soil moisture; reservoir evaporation; and evapotranspiration? Would it help to increase our knowledge base about these parameters to use in conjunction with more streamflow data?

Answer. The answer is, without qualification, yes. I would encourage you to include the NRCS, USGS, and NOAA in this effort. I think it is possible for these three entities to collaborate much better than they currently do and synergies should result. The USGS is currently beginning a necessary and overdue effort to combine groundwater and surface water models; more innovative efforts of this type need to be pursued. In my experience there is a knowledge gap between the atmospheric scientists and the hydrologists that needs to be bridged; each discipline would be well served to learn from the other.

In the context of climate change there is very little research on groundwater recharge and evapotranspiration, somewhat more has been done on soil moisture and reservoir evaporation but all four are lacking focused research efforts. There is very little soil moisture data. The NRCS is in the process on installing soil moisture sensors at some of its SNOTEL sites, and elsewhere. This is a start, but much more is needed. There is anecdotal evidence that the record low 2002 runoff occurred because of low soil moisture prior to the runoff season that year. But given current datasets, it is impossible to test this hypothesis. If true, this would increase our capability to issue accurate streamflow forecasts.

Question 2. It's been my understanding that the climate change scientific community has relied heavily on data made available from satellites; and also made significant investments in trying to develop new remote sensing technologies. Unfortunately, I recently read a news report indicating that the Administration is drastically scaling back the use of satellite based data collection, which is critical to refining our understanding of the implications of global warming.

Your testimony noted the importance of additional data and analysis in tracking and understanding the implications of climate change on water. Are you aware of these planned cutbacks in satellite data, and if so, how do you think it will affect ongoing science programs in this area?

Answer. Yes, I am very aware of these issues. The American Association for the Advancement of Science felt strongly enough to issue a policy statement on this problem this year on April 28.

There are likely two causes: (1) the mismanagement of the NPOESS satellite programs by NASA, NOAA and DOD; (2) the ill-conceived and focus on sending a human to Mars.

I categorically state that this will impact climate science.

The AAAS Statement is worth reading in its entirety, and I agree with it completely, but here are some selected extracts:

> The network of satellites upon which the United States and the world have relied for indispensable observations of Earth from space is in jeopardy. These observations are essential for weather forecasting, hurricane warning, management of agriculture and forestry, documenting and anticipating the impacts of global climate change, and much more.
>
> Maintenance of an adequate constellation of Earth-observing satellites and the instruments they carry is now threatened by budget cuts and reallocations in the two federal agencies that share the primary responsibility for them, the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA).
>
> The situation is already causing harm, and it will become rapidly worse unless the Congress and the Administration take prompt action to reverse the recent trends.
>
> The new NRC report finds that [T]he United States' extraordinary foundation of global observations is at great risk. It also concludes that the sensors planned for the next generation of U.S. Earth observing satellites are 'generally less capable' than their counterparts in the current, now rapidly diminishing generation.
>
> These declines will result in major gaps in the continuity and quality of the data gathered about the Earth from space.
>
> As noted in the new NRC study and elsewhere, this trend of sharply diminished U.S. capacity in Earth observations from space has been the result not only of tightening constraints on NASA and NOAA budgets but also of an explicit redirection of NASA's priorities away from Earth observation and toward missions to the Moon and Mars. The goals in NASA's mission statement formerly began with 'To understand and protect our home planet . . . ' Those words have now been replaced with 'Pioneering the future . . .'. The aim of better exploring the moon and Mars has attractions, but we agree with the sentiment expressed by the former chairman of the House Science Committee, Representative Sherwood Boehlert (R-NY), who observed at a hearing on this topic in April 2005 that 'The planet that has to matter most to us is the one we live on.'
>
> The result of the change in NASA priorities is that the funds needed to sustain critical space-based observations are now declining precipitously, even as the agency's total budget grows. budgets and currently fall far short of U.S. needs The NRC study offered detailed recommendations for restoring U.S. capabilities in Earth observations from space to acceptable levels, including:
>
> - reconstituting specific key observation capabilities that have recently been deleted from scheduled NOAA satellite series;
> - accelerating NASA's current launch schedule to shrink the data gaps implied by current plans; and
> - committing to the 17 highest-priority new Earth-observation missions, out of more than 100 candidates evaluated for the 2010-2020 time period.
>
> The study concluded that its recommendations could be funded until 2020 by returning the Earth-science budget at NASA to its FY 1998-2000 level and stabilizing the budget of NOAA's National Environmental Satellite Data, and Information Service at only slightly above the FY2007 level, adjusted for inflation. This is a blueprint for a program that will bring immense returns for modest costs. The Congress and the administration ought to implement it.

RESPONSE OF BRADLEY W. UDALL TO QUESTIONS FROM SENATOR CANTWELL

Question 1. In talking about predicted future changes, you discussed climate models being used by the IPCC, and that those models tended to agree that precipitation will likely increase in the north and decreases in the Southwest. Mr. Udall and Dr. Milly's testimony seem to be in sync with those conclusions. A recent story in USA Today, though, entitled "Climate change models overstate droughts", talks

about a new study entitled "How Much More Rain Will Global Warming Bring", which finds that climate change will result in increased global rainfall which may be 3 times greater than currently predicted. The story concludes by stating that "climate modelers are overstating how much rainfall will dry up in a warmer climate".

Are you familiar with this new study, and if so, does it have implications for the modeling results that you've all discussed today?

Answer. I am familiar with this study and have had several discussions with scientists about it. Here's what I've discovered:

1) Like all science, this article will take some time for people to digest.

2) The new 2007 IPCC WG1 Summary for Policy Makers says the following about the observations for heavy precipitation and droughts:

> "More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying linked with higher temperatures and decreased precipitation have contributed to changes in drought. Changes in sea surface temperatures (SST), wind patterns, and decreased snowpack and snow cover have also been linked to droughts. {3.3}"

and

> The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. {3.8, 3.9}

Wentz's article focuses on heavy precipitation events and barely discusses droughts. Theory predicts both heavier precipitation and more drying due to atmospheric physics as the planet warms. These two concepts, contrary to perception, are tied together and one does not preclude the other. In fact, they are related.

3) There is a very short dataset associated with the article. Data from only 20 years is frequently too short to be able to detect and quantify trends. For example, the early satellite temperature record showed very little tropospheric warming. Today, we now know that the methods used to analyze that data were in error, and after many discussions and publications, science finally got it right.

4) The science of more floods and more droughts' associated with climate change is quite robust. It bothers me that the authors did not cite what is one of the most important articles on the topic, Kevin Trenberth's "Changing Character of Precipitation" published in 2003 in the Bulletin of the American Meteorological Society.

5) The satellite data for the study only covers the oceans, not continents. Continental data was assumed to be a constant.

6) In summary, this was a study done with a short dataset, looks only at oceans, focuses on precipitation and not droughts, and seems to disagree with the most recent observations on drought as reported by the IPCC. I suspect many of these issues will be discussed in papers that respond to this article.

7) With regard to models, there is much work to be done on many fronts. Please see my response below to Senator Salazar.

Question 2. You discuss the need to produce information on a regional basis as opposed to a global scale, including the development of regional climate models. It's my understanding that a great deal of the projections currently being made are the result of "downscaling" global climate models to assess climate change impacts in specific regions.

Udall—What is "downscaling" and is it the best way to evaluate trends in specific regions? Do we have the capability to develop region-specific climate models and, if so, will they be likely to produce better predictive results?

Answer. The current generation of global circulation models operates with very large scale grid boxes—on the order of 200km per side. In areas of complex topography like mountains, these large grid boxes do not do a good job of simulating climate. In addition, some weather and climate processes operate on scales much smaller than 200km, and these processes are, grossly speaking, estimated, rather than precisely calculated. These large grid boxes are due to computer limitations—in order to make the grid boxes half the current size and process data at the same rate, computers need to be 16 times faster. (one grid box turns into four grid boxes, the four boxes are then divided vertically making 8 grid boxes, and the model time step is cut in half meaning that 16 solutions are required where previously only one solution was needed.) As computer power increases following Moore's law, every 4

years we can halve the grid box size. In order to get grid boxes on the order of 25km, we need 3 halvings' or about 12 years.

Until models get to much smaller grid boxes, the only way to get more accurate regional level information is to take the large scale output and downscale' it. There are 2 ways to do this: (1) find statistical relationships between the computer model and known historical conditions, and use those relationships to convert future model data into downscaled' data ("statistical downscaling"); and (2) use a regional computer model (or nested model') to take the large scale model and put it into a similar model but one with small grid boxes("dynamical downscaling"). The statistical method is generally quite fast; the regional model is much slower.

Both techniques have strengths and limitations: the statistical method can downscale output from many different computer models and even different runs of the same model with ease while the regional model is believed to be more representative of the actual physics at work and hence offers the opportunity for more realistic representations. The statistical technique is, however, constrained by the statistics of the past events while the dynamical technique is very slow.

In answer to the question, we now have both of these capabilities. The statistical technique have been more widely used. We need to encourage groups doing statistical downscaling to do large parts of the country in addition to their particular region, and store the output in a common location. In the case of dynamical downscaling, these efforts are just beginning. The North American Regional Climate Change Assessment Program (NARCCAP) is such an effort. More needs to be done on the dynamical downscaling front.

Question 3. You describe in your testimony a host of problems facing water managers in the Colorado River basin—for example—over-consumption; population growth; and uncertainty as to the extent of legal entitlements.

Do those issues dwarf the issues likely to be posed by climate change? Should our focus be primarily on better water management and increased efficiencies on the theory that improvements in these areas will also serve the water supply challenges posed by climate change?

Answer. This is a great question. Yes, in the short term, we should certainly focus on these areas because better water management and increased efficiencies do offer some significant solutions for now that will carry over into the future climate change problems. With respect to planning for climate change on a longer term horizon, I believe we need to begin building capacity now in water management organizations to deal with the unique problems of climate change. This will take time—engineers, managers, boards of directors all need to learn about the state of the science, including the limitations, and begin to think about how to incorporate this knowledge into operations. I believe this will take several years, by which time I hope our regional modeling capabilities will improve such that we can begin to obtain future more reliable future projections, especially with respect to precipitation. Should the models not be available at this time, I still very much believe this effort will generate returns by having water providers begin to reanalyze their entire operations.

Response of Bradley W. Udall to Questions From Senator Salazar

Question 1. What studies do you believe would be most beneficial to understanding the potential impacts from global warming on water supplies?

Answer. The more I talk to scientists, the more I think that the US's three computer modeling groups need to be directed to fix known problems in their general circulation models before introducing new complexity. This may or may not require additional resources. When upgrading and enhancing these models it is too easy to direct new effort into increasing model complexity, when more value could be obtained from doing model intercomparisons, identifying problems, and then fixing known issues. The draft report from the Climate Change Science Program for Synthesis and Assessment Product 3.1, Climate Models: An Assessments of Strengths and Limitations for User Applications, covers many of the known problems with these models. A good start would be to encourage these modeling groups to address known problems before adding new features.

Question 2. Are the existing observation networks, e.g., for measuring streamflows, snowpacks, etc., adequate to understanding the observed impacts from global warming? Are there additional observation networks we should be putting in place?

Answer. The networks are clearly not adequate. We are losing important streamgages with long periods of records regularly. USGS Cooperators and not happy with the high fees being charged by the USGS to handle data collected by the cooperators, and as such are not willing to pay for their portion of the co-op sta-

tion. Meta data, that is the data that describes the particulars of real data, is frequently non-existent. I had a discussion with a high level person in the NRCS recently about the meta-data associated with SNOTEL and he was very concerned about the quality of the data. Without the metadata it is difficult to obtain accurate studies on snow trends. This is a resource question. Very little is known about soil moisture because the soil moisture network is so sparse. Additional sites are needed. It would be very interesting to have the NRCS, USGS and NWS provide a joint report on how these networks could be improved in a cost-effective manner to provide reliable data for water management and research. Encouraging these entities from three different federal agencies to work together could potentially identify interesting synergies. All of these networks need sets of stations that are relatively clean' of aberrations so that long-term trends can be deduced. While the USGS and NWS supposedly have these data sets, many scientists complain that these sets have significant problems that hinder long term trend analysis.

RESPONSE OF JACK WILLIAMS TO QUESTIONS FROM SENATOR CANTWELL

Question 1. You cite to several studies predicting broad declines in trout and salmon populations as a result of climate change. You also mention a range of impacts that will likely occur—from reduced streamflows to changes in insect hatches.

In the studies predicting broad declines, is there any consensus on what factor, in particular, will negatively affect coldwater fisheries? Is it reduced streamflows, warmer temperatures, changed timing in streamflows or some other specific impact?

Answer. We do not believe there is any consensus regarding a single factor that would primarily be responsible for predicted declines. However, we believe that the following two factors will be the most influential in predicted declines of trout, char and salmon.

- Reduced streamflows as a result of reduced snowpack, earlier runoff, drought and increased evaporation rates.
- Increased flooding as a result of more intense and frequent storm events, and resulting impacts from flood-control activities such as dam construction and stream channelization.

Of course, the causal factors are complex and often synergistic. For example, drought may reduce streamflows but is also likely to cause more frequent and larger wildfires.

We also are very concerned about potential impacts of well-meaning but ill-advised attempts exert more artificial control on streamflows, floods and drought. Dams, for example, may appear a tempting way to address water supply shortages but have been shown to cause negative impacts downstream and actually increase risk of larger flood events as dam capacities are exceeded or reservoir capacity is used for other purposes besides flood control. We encourage measures that improve the long-term health of our watersheds rather than quick fixes.

Question 2. In recommending strategies to increase the resilience of fisheries to Climate Change, you talk about the need to protect remaining core habitat areas, as well as the need to expand the range currently available through habitat restoration projects.

Is there any coordinated set of federal programs to address the habitat protection and restoration activities that you envision? It seems that most of the activities that I'm aware of on the federal level are ESA-driven. Is that indeed the case, and if so, will that be too late if the impacts of climate change are rapidly accelerating?

Answer. I do not believe that there is a coordinated federal effort to address the habitat protection and restoration activities that we envision. However, there are several important pieces at the federal level, which if adequately funded and coordinated, could achieve the desired result. For example, the Western Native Trout Initiative is an effort of the U.S. Fish and Wildlife Service in cooperation with other federal and state agencies and non-governmental organizations, to develop a multi-species approach to conservation of coldwater fish habitats. TU will be encouraging adoption of a climate-driven contingency plan to protect aquatic diversity at their next meeting in Phoenix, Arizona.

Of course, much of the restoration work must take place on private lands. The Farm Bill provides $4 billion annually to help pay for conservation and restoration efforts on private lands, including water conservation and riparian and stream habitat restoration. The Farm Bill programs, administered by the Natural Resources Conservation Service, can help pay for activities to help avoid ESA listings or recover species so that they can be taken off of the list.

We are concerned that if preventative action is not taken soon to improve the condition of our fisheries that additional species will require ESA protection. The ESA would likely improve protections for important fish species but its provisions would be invoked only after substantial declines occurred.

RESPONSE OF JACK WILLIAMS TO QUESTIONS FROM SENATOR SALAZAR

Question 1. Are the existing reservoir storage capacities capable of handling the early snowpack melts?

Answer. We believe that changes in dam operation have limited ability to offset water supply changes anticipated by climate change. Most existing reservoirs are located far downstream of mountain areas that will be most influenced by changes in snowpacks. Many existing dams are multipurpose facilities that could not handle significant additional storage needs.

We also are concerned about attempts to build new dams to offset climate impacts. Steep, mountainous terrain most affected by snowpack changes offers few good dam sites. Any new dams constructed in such areas would cause significant disruption to stream systems and aquatic biodiversity.

Question 2. What are the best options you believe are available to adapt to global warming impacts on water supplies in the West?

Answer. We believe that there are a number of conservation actions that could readily be taken to reduce demand for water supplies. In particular, numerous efficiencies could occur through improved irrigation practices, such as replacing flood irrigation with sprinklers, restricting sprinklers to morning and evening hours when evaporation is less, and installing drip irrigation where feasible.

Improving the condition of our riparian areas and watersheds will improve the natural storage capacity of our lands, mitigate impacts of floods and drought, and insure that runoff is metered out throughout as much of the year as possible.

Question 3. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

Answer. While conservation efforts have been effective in reducing water demands, their overall influence on water supplies is seldom realized because of increasing population growth, particularly in larger urban centers in the West. Nonetheless, we believe that water conservation efforts, in municipal, agricultural, and industrial areas, should be a critical part of our response to climate change. We also believe that restoration of our watersheds will improve their natural storage ability and metered delivery of runoff throughout the year. Restoration efforts also should be a critical part of our response to climate change.

Question 4. Do you believe that climate change impacts on water supplies will have to be considered when making commitments about future water deliveries?

Answer. We believe that changes in water supplies that are predicted from a changing environment should be considered when making future commitments for water delivery. Already throughout the West, we have many river and groundwater systems that are over allocated, which causes protracted legal disputes, disrupted streamflows, and loss of fisheries.

RESPONSE OF TIM CULBERTSON TO QUESTIONS FROM SENATOR CANTWELL

Question 1a. Your testimony talks about the additional stress and competition that climate change will bring about for limited water resources—a point reiterated by the testimony of other panelists. You also mention the opportunities that exist for additional hydropower development in the U.S.

In the face of the potential new conflicts that climate change may cause in the competition for limited water resources, do you think it will be possible to move forward and develop the hydropower potential that you discuss in your testimony?

Answer. Yes, we do believe that the projected growth opportunity for hydropower can be realized despite the fact that some areas of the country will experience additional water constraints. The estimates of new hydropower generation are conservative. Additionally coal, nuclear and natural gas facilities also consume fairly large quantities of water during the production of electrical energy and also have a stake in the use of our water resources.

Some existing hydropower facilities will lose a portion of their current output due to shrinking snow pack, etc., while other regions will experience an increase in rainfall or snow pack. Projections are showing that the issue will be more of a transfer of water availability from particular regions to perhaps another area of the country, or a significant change in the timing of the water availability and the form in which it is received. Rather than melting snows, some rivers will be fed by significant

rains. These rains may, or may not, arrive in spring. As a result, the issue becomes one of managing the water received, the timing of that receipt, and addressing the form (rain versus snow), rather than an issue of no or too little water.

As a result, we believe that new strategies will be developed to address the water management issue. These strategies will address the form in which the water is received and the timing to ensure that enough water is available for the many competing interests and uses. This may require the building of additional water storage facilities on which hydropower could be built. In addition, it is especially important to develop new hydropower potential at existing dams that are currently without generation facilities. It is simply good public policy to ensure that our Nation's infrastructure, whether newly planned or existing, provides the greatest societal benefit to the consumer. Otherwise, the overall value of hydropower relative to other, more GHG-producing resources will not be fully realized.

Another important strategy to address these impacts is increased research and development funding. As important as this research is, the Department of Energy has not funded a hydropower R&D program to any large degree. In fact, over the last two years the administration has not proposed any funding at all. A robust DOE R&D program, as is under consideration for FY 2008, would support: resource assessments for both conventional hydropower and new waterpower technologies, such as ocean, tidal and instream resources; environmental impact studies; RD&D for advanced technologies; and importantly, new turbine designs.

New turbines, in particular, could address the timing issue with variable speed designs and other improvements that result in greater efficiencies. Underfunding research is shortsighted given the need to design and deploy turbines that can produce the same amount of energy with variable water supply. The National Hydropower Association calls on Congress to consider the important need for a reinvestment in hydropower to help prepare for the effects of climate change.

Question 1b. Of all the impacts to water supply discussed in the hearing, what is the most troubling to the hydropower industry? Is it the change in timing of streamflows, the potential overall reduction in water supply or some other factor?

Answer. Both the timing question and the supply are equally important concerns. Some regions may be troubled more on the timing issue depending on their ability to store water. Not all facilities have storage capability, and many industry members are constrained by FERC license requirements as to the amount of water they can store. What will be important to future planning will be a willingness to be flexible and provide the appropriate tools for industry to address the issue. More flexibility on the part of FERC and the resource agencies to store additional water or change release schedules could be something for future consideration, but it is too early as yet to determine exactly what tools will be necessary and under what circumstances they might be needed. We believe that it will require the cooperation of FERC, industry, the resource agencies and the stakeholders to work through the issues presented by the storage question.

Question 1c. Will the ultimate impacts likely be different in different river basins? For example, will it depend on the amount of reservoir storage capacity that's available relative to the overall streamflow?

Answer. Yes, as indicated in the response to the earlier question, regions of the country will be affected differently. Some areas already rely on spring rains, rather than large mountain snow packs and are well equipped to store water, timing releases over the drier summer months. Other regions have relied heavily on a consistent melting snow pack to feed rivers over the drier summer periods.

Not all regions have studied the projected impacts climate might have on their water supply issues. The Northwest, California and some of the other western states have just recently begun to look into the issue. Well versed in the scarcity of water issues, western states have begun to understand the importance of the issue and, as a result, are working to develop a plan of action. While eastern states have experienced localized periodic droughts over the years, these regions of the country have generally been blessed with an abundant water supply system. Just the same, most industry members, despite their regional location, have addressed water management issues in the past and have the ability to plan for the future. The question is more one of providing the support to industry and the sharing of information from national, state and regional perspectives, as industry works to address climate change's affect on water management issues. This support should be in the form of information sharing, regulatory cooperation and financial support of research and development.

RESPONSE OF TIM CULBERTSON TO QUESTIONS FROM SENATOR SALAZAR

Question 1. Are the existing reservoir storage capacities capable of handling the early snowpack melts?

Answer. The short answer regarding storage capacities is that some reservoirs are equipped, while others may not be capable to store large additional supplies of water. This is a site specific issue and depends on the original design and plan for the storage facility, the FERC license terms and conditions, and how projects are managed on the same river or within the same river basin.

Some facilities will be engineered to handle the additional water, but may be constrained from a FERC license or a regional management perspective to hold the additional water. Projects may have a FERC license that requires that no water be stored, forcing the owner to operate the project as run-of-river. Under such a scenario, all the water will be required to be passed down the river system. Run-of-river operations are more of a trend under relicensing over the last five years as the preferred operation mode by many of the stakeholders engaged in the relicensing process. As such, the region could be subject to energy shortages when rains end and no additional rains are received during the hot summer months because the backup battery—the storage facility—has been eliminated. With no snow pack constantly feeding the river over these drier months, energy shortages could occur.

Industry has the knowledge and the engineering ability to address these issues. However, it will require cooperation, support of R&D, and regulatory flexibility to address the problem and provide the tools to successfully manage the water resource.

Continuing to provide support for research and the development of new turbines that allow for greater water efficiencies and variable speeds will be an important and critical step forward. Variable speed turbines that allow industry to address a more flexible water resource will be key to maintaining energy supply under the uncertainties presented by climate. Congress needs to support a hydropower research and development program within the DOE well beyond its current strategy of providing little to no funding. Significant new dollars should be invested in this program to ensure that industry has the tools necessary to address the climate issue and climate's affect on water supply.

Question 2. What are the best options you believe are available to adapt to global warming impacts on water supplies in the West?

Answer. First, we need to continue to study and plan for impact. Federal support should be provided for cooperative efforts to prepare for the impact on water supply. Second, the issue may very well drive states to reconsider new water supply storage facilities; the addition of clean, climate friendly hydropower should be considered to maximize the full benefit of these facilities should the states proceed with such a plan; 3) development of new clean, non or low emitting generation should be pursued to lower the carbon emissions and reduce the threat of global warming; this will include the development of ocean, tidal and hydrokinetic or damless waterpower technologies; 4) most important, a reinvestment in research and development, with a particular emphasis on turbine efficiencies and variable speed designs, will provide the necessary hardware tools to address the problem; 5) cooperation and sharing of information between the levels of government and industry regarding impacts and operation best practices would be extremely helpful; and finally 6) regulatory flexibility that would permit the issue of climate's impact to be considered regarding operation terms under existing licenses and inclusion of this equation as new licenses or relicensings are considered would be an important step forward.

Question 3. Have conservation efforts been effective in reducing water demand or have increases in population in the West negated the savings from conservation?

Answer. Increases in population will always affect water planning strategies, including conservation. Despite this issue, many regions have found water conservation programs effective. The question is not so much whether conservation works in the context of growth, but whether regional cooperation exists within a river basin to ensure the effectiveness of the program.

Question 4. Do you believe that climate change impacts on water supplies will have to be considered when making commitments about future water deliveries?

Answer. While most hydropower projects do not "deliver" water, the issue of water availability for all of the competing interests is of great concern to the hydropower industry. The terms under which a hydropower plant must operate are set in the license agreement. These agreements set flows and timing of releases as well as the amount of water that can be held back in a reservoir.

Obviously, climate considerations should become an issue that is addressed as the license terms are set since water availability could change over the term of the license, which generally last for 30-50 years. With some regulatory flexibility built in

to the license, operators would be able to plan for and address climate change's impact on water availability. All stakeholders should understand that need and expectations for water allocations should be governed with a willingness to remain flexible in future or out years.

Despite the need for flexibility and the anticipated effect climate change will have on water availability, with proper planning and support, the hydropower industry will be able to address these impacts. At the same time, it is critical that the federal government move forward in addressing the climate change issue. One important strategy that must be considered as part of this national campaign is the nation's hydropower system which sits, along with its sister renewable technologies, as our best hope for the future. Yet, too often, hydropower is not recognized for the role it could play and is left out of incentive plans to spur growth.

As mentioned, hydropower is primed for significant growth in the areas of both conventional hydropower and new technologies. A new Electric Power Research Institute report has found that 23,000 MW of growth potential could be developed by 2025 utilizing conventional hydropower and new ocean, tidal and instream hydrokinetic technologies. This potential will require that hydropower receive the same incentives currently provided wind, solar, geothermal and biomass.

Long term extension of the production tax credit, credit parity with the other renewables, recognition of new technologies under the eligibility definition within the PTC and modifications on the statute addressing eligibility of non-powered dams for consideration under the credit are all key policy changes that should be part of our plan to address climate change. In addition, a federal renewable portfolio standard should consider new technologies and non-powered dams as eligible renewable resources. By taking these simple acts, Congress could be adding substantially to our clean energy portfolio and reduce the nation's reliance on carbon producing generation. We urge Congress to give greater consideration to hydropower as part of its national plan to reduce our carbon footprint and lessen the impact of climate change on our planet.

NHA once again expresses its appreciation to the Committee for the opportunity to testify at the June 6 hearing and to demonstrate hydropower's growth potential and role as part of the solution to climate change. If there are any further questions regarding NHA's testimony or these questions, please feel free to contact us.

APPENDIX II

Additional Material Submitted for the Record

STATEMENT OF DAN GEARY, NEVADA REPRESENTATIVE, NATIONAL ENVIRONMENTAL TRUST

We appreciate the opportunity to submit testimony regarding impacts of climate change on water supply and availability in the United States, and related issues from a water use perspective. The National Environmental Trust is a non-profit, non-partisan organization established to inform citizens about environmental problems and how they affect our health and quality of life.

Few issues have as dramatic an impact on our communities in Nevada than the urgent concern of global warming and a changing climate.It is no secret that water is the lifeblood of the American West. A frequent expression used to describe water and the West is the old phrase attributed to Mark Twain, "Whiskey is for drinking, water is for fighting over."

Nevada's communities are completely dependent on the rivers and natural aquifers of the West. Booming Clark County, which contains metropolitan Las Vegas, receives its water from the Colorado River, with our primary reservoir stored behind Hoover Dam in one of the largest man-made lakes in the world. The Colorado River Compact is the instrument by which the waters of the Colorado River basin are distributed to all of the upper and lower basin states. The Colorado River is fragile and stretched to the breaking point. Although it once stretched to the Pacific Ocean from its headwaters in Colorado, the river now ends in an empty riverbed miles east of its natural terminus in Baja, Mexico. Nevada's northern counties, along with much of California, are dependent upon the snowpack contained in the mighty Sierra Nevada Mountains. Nevada's own jewel, Lake Tahoe, is entirely fed by the snowpack of the Sierras.

The tale of the American West is a tale of coping with scarcity. The harsh reality is that water in the West is not only scarce; it is scarcest where and when it is most needed. Much of policymaking for western states is driven by this scarcity and the use of water, whether in cities or on farms and ranches. Most of the West's precipitation falls in the mountains. When air rises to pass over mountains, its moisture is forced out as precipitation. Man could not have devised a more efficient water storage and distribution system than the natural connection between snowpack in the mountains and the distribution system of the West's rivers. The cycle of winter snowfall and spring runoff provides nearly three-quarters of the West's water.

Through extensive engineering along the arid Colorado River basin, we can hold four times the river's annual flow, and pipelines deliver the water where it is needed, including my home of southern Nevada. Water from the Colorado River is also diverted under the Continental Divide and through an aqueduct across the California desert to meet the needs of cities and farms and ranches at the edge of the Great Plains. Even with these marvels of engineering, the largest reservoir of water is the annual snowpack, which delays the runoff until spring, delivering water where and, most importantly, when it is needed most.

That human activities are already changing the nature of water in the West is well documented. Regional snowpack, which acts as a natural reservoir system that stores water until needed, has been shrinking in recent years and releasing fresh water earlier than usual. There is a growing body of evidence documenting these changes, including the following specific findings:

- Higher temperatures: Increases in annual temperatures have been greater in the West than in other regions of the contiguous states, according to National Weather Service Data.[1]
- Less snow, more rain: Since 1949, less winter precipitation is falling as snow and more as rain, according to a 2006 analysis of National Climatic Data Center records from 200 western mountain weather stations.[2]
- Less snowpack: Most snowpack levels are declining, according to an exhaustive analysis of 824 western snowpack-measurement records spanning the period 1950 to 1997.[3]
- Earlier snow melt: Snowpacks are now melting earlier in the year. For a majority of 279 snowmelt-dominated western rivers and streams, the timing of peak flows advanced over the period 1948 to 2000, with the peaks coming 10 to 30 days earlier.[4]

Unfortunately, western states can look forward to a continuation of this trend. As one expert testified before Congress in 2004, "losses in the West's total April 1 snowpack are likely to exceed 40% by the 2050s."[5]

The Intergovernmental Panel on Climate Change (IPCC) found in its 2007 report on the current and projected impacts of global warming that: "Climate change is very likely to constrain North America's already intensively utilized water resources, interacting with other stresses." The panel found that "projected warming in the western mountains by the mid 21st century is very likely to cause large decreases in snowpack, earlier snowmelt, more winter rain events, increased peak winter flows and flooding, and reduced summer flows." Coupled with increases in demand, climate-driven water scarcity is likely to complicate management of heavily utilized water resources.

In some cases, the panel's projections are quite stark. For example, the IPCC states: "In the case of the Sacramento-Joaquin River and the Colorado River basins in the western USA . . . streamflow changes . . . are so strong that beyond 2020, not all the present-day water demands (including environmental targets) could be fulfilled even with an adapted reservoir management."[6]

Many circumstances are responsible for the complexity of water concerns throughout the United States, and particularly in the West. Some of these are within our control and some are not. Two that are in our control are diminished water availability due to global warming and increased water consumption due to the energy choices we make. It will be more important than ever to consider how choices about climate and energy will affect future economic growth, agriculture, wildlife, and recreation.

NATIONAL ACTION

The United States can produce substantial, near-term reductions in domestic greenhouse gas emissions. An effective near-term climate policy would:

- Enact comprehensive emissions reduction requirements that include a carbon cap,
- Enact simple-to-implement policies to expand production of electricity from renewable sources,
- Adopt a stronger federal fuel economy standard to improve light-vehicle fuel efficiency, and

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[1] Climate Prediction Center, National Weather Service, National Oceanic and Atmospheric Administration, U.S. Temperature and Precipitation Trends: Annual, <www.cpc.ncep.noaa.gov/anltrend.gif>.

[2] N. Knowles, M. D. Dettinger, and D. R. Cayan, "Trends in Snowfall versus Rainfall for the Western United States, 1949-2004," Journal of Climate, September 2006

[3] P. W. Mote, A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier, "Declining Mountain Snowpack in Western North America," Bulletin of the American Meteorological Society 86(2005): 39-49.

[4] I. T. Stewart, D. R. Cayan, and M. D. Dettinger, "Changes in Snowmelt Runoff Timing in Western North America Under a 'Business as Usual' Climate Change Scenario," Climatic Change 62(2004): 217-232.

[5] The West's Snow Resources in a Changing Climate, Testimony before the U.S. Senate Committee on Commerce, Science, and Transportation, May 6, 2004, Philip W. Mote, PhD, Joint Institute for the Study of the Atmosphere and Ocean Climate Impacts Group, University of Washington. <www-jisao.atmos.washington.edu/cig/outreach/presentfiles/Mote—SenateTestimony—050604.pdf>.

[6] Barnett, Malone, Pennell et al. cited by Intergovernmental Panel on Climate Change, "Chapter 3: Technical Summary," Working Group II: Impacts, Adaptation and Vulnerability, Fourth Assessment Report, 2007, <http://www.ipcc-wg2.org/index.html>.

- Aggressively implement existing federal authority to set equipment and build energy efficiency standards and codes.

In addition, the United States should begin to lay the groundwork for much deeper reductions in global warming emissions. These actions should include:

- Replacing the highest emitting sources with cleaner sources, such as renewable energy or advanced fossil energy systems with low or no greenhouse gas emissions,
- Researching and developing technologies that permanently capture and sequester carbon from commercial fossil-fueled energy sources,
- Developing action plans for significantly reducing several non-carbon dioxide greenhouse emissions or concentrations (methane and ozone formation), along with emissions of black-carbon aerosols, and
- Reengaging in the international dialogue to effectively construct an international policy to address climate change worldwide.

STATEMENT OF THE PACIFIC NORTHWEST NATIONAL LABORATORY

Using a unique approach to model climate and hydrologic processes and their linkages, scientists and engineers at the Pacific Northwest National Laboratory have been investigating the impacts of climate change on water resources in mountain watersheds and river basins for over a decade. These investigations have been in support of missions for multiple federal agencies including Department of Energy, NOAA, NASA, and EPA.

Early studies at Pacific Northwest National Laboratory focused primarily on assessing cumulative impacts of climate change. Since the mid-1990's, however, our focus has increasingly been on developing approaches to adaptive response to climate change. Since water resources are one of the primary sectors directly impacted by climate change, adaptive water resources management has long been a focus.

Climate change will affect water resources. Water resources are critical to nearly every aspect of human endeavor. The impacts of climate change on goods and services that directly or indirectly rely on water propagate in ways that our understanding can only allow us to crudely postulate. While water is generally a regional resource, many of the goods and services water provides are global. For example, hydropower generated by rivers in the Northwest provides electrical power to the nation through the power grid, and numerous irrigated crops grown in eastern Washington State are exported worldwide.

Over the past century the nation has made vast investments in the water related infrastructure such as dams, canals, groundwater wells that is specifically required to mitigate the impacts of seasonal patterns and inter-annual variability of water supply and water demand. Reservoirs help mitigate the impacts of drought and flood. Water law provides a framework to prioritize the allocation of water in periods of drought. This existing infrastructure provides a capacity for some degree of adaptation to changes in climate.

While climate models forecast only minor changes in the average quantity of precipitation in the Pacific Northwest, scientists at PNNL predict significant changes in the seasonal patterns of water availability. This change is due to the shift toward increasing fraction of precipitation occurring as rainfall than as snow as the climate continues to warm in the future following the observed trend over the past half century due to the buildup of greenhouse gases in the atmosphere. Historically, the snowpack in the Pacific Northwest represents the largest "reservoir" of freshwater in the region. Reduction of this virtual reservoir due to reduced mountain snowpack will management of already stressed water resources even more difficult

A priority research need identified by scientists and engineers at Pacific Northwest National Laboratory is to significantly advance the methods that water mangers use to forecast and mitigate potential impacts of extreme events including catastrophic floods and sustained droughts. Our studies have suggested an increased likelihood of intense precipitation and winter floods in the Northwest, with the latter caused primarily by an increased frequency of rain-on-snow events. Water mangers must continuously balance the need to draft reservoirs to provide adequate storage for flood protection against maximizing water storage to mitigate drought impacts. It will be important for scientists to advance and validate their methods to simulate the observed frequency and intensity of extreme events and predict how they will shift in the future, and for water managers to assess adaptation approaches to manage the extremes under the climate-changed regimes.

Another area that Pacific Northwest National Laboratory is currently investigating to help mitigate climate change impacts is improved conjunctive manage-

ment of groundwater and surface water. Many regions overlie groundwater reservoirs that can be utilized to provide reliable backup water supplies during drought. Climate change may alter the rates at which these subsurface reservoirs are recharged. For example, in a warmer climate, reduced subsurface discharge would likely result from more precipitation falling as rain rather than snow, favoring surface runoff over subsurface recharge and higher evaporation from the surface during summer. Withdrawing from the subsurface reservoirs in excess of the recharge rate will cause potentially non-renewable water table decline and a variety of associated adverse impacts. The conjunctive use of surface water and groundwater must be assessed in the larger context of climate change, its impacts on water and the ecosystems, and water use.

Meeting these challenges within individual states, regions, and across regions will require increasingly sophisticated and integrated modeling and analysis tools to understand complex earth system processes at a variety of spatial and temporal scales and to model the potential outcomes of various management alternatives. Further, we will need to integrate these new tools into a decision framework that will harness the most comprehensive data sets and advanced earth systems models related to regional climate, hydrology, and demand analysis, and will translate our improved understanding of the system into more efficient and sustainable water resource, ecosystem, and economic operations and practices.

STATEMENT OF WESTERN RESOURCE ADVOCATES

BACKGROUND

In the western United States the availability and development of water resources has shaped the pattern of human settlement. So important is water in these arid lands of the west that inscribed in the rotunda of the Colorado State Capitol is the saying "Here is a land where life is written in water."[1] The ability of mankind to survive where rainfall is infrequent and evaporation rates high is wholly dependent upon the availability of water and we have produced enormous dams and water conveyance structures to bring water to mines, farms, and metropolitan areas.

But our manipulation of western waterways has not come without consequence. Over the past 150 years we have seen ecosystems dry up and many native species die as the water that once supported them has been diverted for urban, industrial, and agricultural needs.

Our ability to conquer and harness the energy of natural resources is unparalleled. However, these actions have also had dramatic increases in combustion of fossil fuels. Emissions from this combustion have been found to alter the chemical composition of Earth's atmosphere and unabated continued production will bring changes in the global climate, influencing temperatures and precipitation patterns.

Human influenced climate change will have a tremendous impact on water resources. Experts agree that we are at the dawn of a new era in which greater and more frequent fluctuations in water availability will exist.[2] Due to heavy human reliance upon water in the western United States, it is critical that westerners prepare for the changes that may come and adopt management strategies to decrease per capita energy and water use.

CLIMATE CHANGE & THE GREENHOUSE EFFECT

Since the industrial revolution, humans have been using fossil fuels in large quantities to heat homes, fuel vehicles, produce electricity and manufacture goods.[3] The burning of carbon based fuels, such as oil and coal releases a large amount of carbon dioxide and other greenhouse gases into the atmosphere. Once in the atmosphere these gases act alongside their naturally occurring counterparts trapping and reradiating heat back to the surface of the earth. The increase of trace greenhouse gases in the atmosphere causes more heat than would naturally be trapped to remain in the atmosphere; this phenomenon is known as global warming or climate change.[4] The balance between retaining and releasing heat is delicate and even the slightest alterations can have monumental impacts.

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[1] The Honorable J. Steven Griles, Deputy Secretary of the Interior, Address to the Colorado River Water Users Association, Las Vegas, NV, December 17, 2004.

[2] US Environmental Protection Agency, "Clean Water After Climate Change, Inside the Greenhouse," Global Warming Web Page, Fall 2001, Available at: http://www.epa.gov/globalwanning/greenhouseigreeenhouse15/water.html.

[3] Ibid.

[4] McKinney, Michael L. Environmental Science: Systems and Solutions, 3rd Ed. Jones and Bartlett. Sudbury, MA. 2003. 419

One impact of climate change that is of particular concern is the impact on water resources and how people living in the Western United States need to modify behavior and re-structure their management approaches to dramatically change how water is used.

PRECIPITATION & STREAM FLOW

Studies have shown that even a slight 1.7 degree Celsius increase in temperatures alone could result in an 18 percent decrease in annual runoff within the Colorado River Basin, one of the primary water arteries of the west.[5] [6] Should precipitation also decrease, the annual run off could be reduced anywhere between 14-44%.[7] Moreover, the storage capacity of the river could drastically decrease due to increased evaporation, potentially reducing the reservoirs by 40 percent in the next 50 years.[8]

Impacts such as this are not isolated to the Colorado River but are real concerns for all rivers throughout the Western United States. A recent Intergovernmental Panel on Climate Change Report projected that average annual runoff from rivers and the availability of water would "decrease by 10-30% over some dry regions and mid latitudes" by the middle of this century.[9] Another report stated that "Reduction in snow pack will very likely alter the timing and amount of water supplies, potentially exacerbating water shortages and conflicts, particularly throughout the western US."[10]

Increased temperatures in the western United States are likely to lead to changes in precipitation patterns that could have great impacts on residents. It is predicted that as temperature increases, more precipitation will fall in the form of rain rather than snow in higher altitudes of the West. This will result in a decline of the alpine snow pack that feeds many of the major western rivers. The soils of this semi-arid region are not able to absorb large amounts of water rapidly; therefore, increased rain may also lead to an increase in large-scale floods.

In the West precipitation type has a close relationship to runoff. Many major river systems throughout the west are heavily reliant upon snowmelt runoff; in fact in the Colorado River basin, 70% of runoff comes from melting snow pack,[11] which in turn feeds the basin during the arid summer months.[12]

Moreover, a change in the type of precipitation falling, such as increased rain to snow ratio,[13] would alter the hydrograph of rivers, shifting when water is available for use. This is also problematic in that water rights are currently issued based on the flow of the river over a specified time. If the timing of river flow were to change dramatically with an increase in winter runoff and a decrease in summer runoff, it could lead to less water being available for junior water right holders, even if the overall annual runoff remains the same.[14] Additionally, many of the flows that benefit the environment fail to have any water rights at all. As a result, many flows that benefit fish species, the aquatic environment, and recreation, will be the first to be affected as flows decrease.

Increased temperatures will also result in higher rates of evaporation in rivers, lakes, reservoirs and soils. Increased evaporation will lead to reduced stream flow and runoff, which will carry serious implications for river basins and those species dependent upon their resources.[15] Cold water fish such as trout and salmon are especially vulnerable as they will be unable to survive in streams with high temperatures. The endangerment of these species could have a spiraling effect on other or-

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[5] Christensen, N.S., et al., "Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin," 347, 350.

[6] Ibid, 350.

[7] Nash, "The Implications of Climatic Change for the Stream Flow and Water Supply in the Colorado Basin, "171.

[8] Christensen, "Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin," 348.

[9] Intergovernmental Panel on Climate Change, Impacts, Adaptation, Vulnerability Summary for Policy Makers, Working Group II Contribution to the Intergovernmental Panel on Climate Change, Fourth Assessment Report. 2007.

[10] Jerry Melillo et al. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change.

[11] Kenneth M. Strepek, David N. Yates. "Assessing the Effects of Climate Change on the Water Resources of the Western United States," Water and Climate in the Western United States, 2003, 102.

[12] ibid, 102.

[13] Ibid, 340.

[14] Strepek, "Assessing the Effects of Climate Change on the Water Resources of the Western United States," 102.

[15] Christensen, "Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin,", 350

ganisms within the river that would otherwise not be as impacted by changes in water temperature. Additionally, increased temperature will lead to increased levels of salinity within western rivers.[16] This will not only impact aquatic species ability to survive but it may also lead to treaty violations between the United States and Mexico.

POPULATION GROWTH

Over the last fifteen years nearly all western states have seen dramatic population increases. For major cities like Las Vegas, Phoenix and Los Angles the major source of water is a single river—the Colorado. Since 1990 the population of Las Vegas, Phoenix and Los Angeles has increased a combined 228%. Las Vegas alone grew over 140%. In the last six years the population of the Southwest has increased by 4,500,000 people an average increase of 14.15%.[17]

In addition to increased water demands as population soars, land use patterns are changing to accommodate homes for all these people. This can result in forests being heavily degraded. Deforestation for croplands as well as expanding cities will impact both water quality and supply. It has been found that forests play a critical role in precipitation patterns and that sudden loss of forested land can quickly lead to desertification, only exacerbating the aridity that the Western United States currently faces.[18]

ENERGY DEMANDS

One repercussion of increased temperatures and higher evaporation rates could be a drastic decrease in storage, due to an already over allocated stream flow. Relatively small fluctuations in stream flow of 1018% could result in significant decrease in reservoir storage along major rivers in the West. The impact of climate change on river flows and storage will also affect hydropower production.

Compounding this is the prediction that in the coming years, electricity demand in the West will increase at a rate of 4-6% more under climate change conditions than they would otherwise. This increase in demand will likely encourage new energy development, which can place significant additional stress on already limited water supplies. Extraction and consumption of fossil fuels currently uses significant amounts of water. In 2000, coal and gas steam-generating electric plants in the eight state Interior West withdrew over 650 million gallons of water per day, totaling over 728,000 acre-feet each year.[19]

Some proposed new sources of energy would also have dramatic additional water demands. Water consumption estimates for oil shale range from 2.1 to 5.2 barrels of water per barrel of oi1.[20] At 3 bbl water/bbl oil, producing one million barrels of oil per day would consume about 150,000 acre-feet per year—the total amount that some water resource managers say may remain in the entire upper Colorado River Basin for development.[21] Power production to support in-situ retort also uses additional water. Shell's in-situ process uses approximately 250 to 300 kWh/bbl oil , and each kWh of electricity generated consumes about 0.5 gallons of water .[22],[23],[24],[25] A production rate of one million bbl/day oil would require about 150,000 ac-ft water/yr just for power production.

Feeling the need to adapt and diversify water resources, many communities throughout the west are also considering large scale pipelines to transport water from one region to another. Some of these proposals are for pipelines exceeding 200

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[16] Tim Barnett et al., "The Effects of Climate Change on Water Resources in the West: Introduction and Overview," Climatic Change, 62, 2004, 7

[17] U.S. Census Bureau, http://quickfacts,census.gov/qfcliindex.html

[18] Melillo. Climate Change Impacts on the United States. 97

[19] Clean Air Task Force and Western Resource Advocates, The Last Straw: Water Use by Power Plants in the Arid West, 2003, 2

[20] Bartis, J.T., et al., Oil Shale Development in the United States: Prospects and Policy Issues. RAND Corporation. Santa Monica, CA. 2005.

[21] Magill, B. Water manager: Climate change to ebb state's flows. The Daily Sentinel, January 27. 2007.

[22] Bartis, J.T., et al., Oil Shale Development in the United States: Prospects and Policy Issues, 2005.

[23] Clark, J. R., Nuclear energy proposed for production of shale oil. Oil and Gas Journal, vol 104(26), 2006. 18-20.

[24] Department of Energy (DOE), Report to Congress: The Interdependency of Energy and Water. 2006. Available at: http://www.sandia.gov/energy-water/does/121-RptToCongress-EWwETAcomments-FINAL.pdf Accessed 2/28/07.

[25] Forbes, S. Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements. DOE/NETL/2006-1235. 2006. Accessed 2/17/07. Available at: http://www.netl.doe.govitechnologies/coalpoweriewr/pubs/WaterNeedsAnalysisPhasel 1 006.pdf

miles in length.[26] Pumping water this distance requires immense amounts of energy if met through coal or gas-fired power plants.[27] The construction of these power plants, which emit great deals of carbon dioxide will only further perpetuate the cycle of climate change and all its associated impacts.

AGRICULTURE IN THE WESTERN UNITED STATES

Eighty percent of all water in the United States is used for agricultural irrigation;[28] if temperatures rise, causing elevated evaporation rates and decreasing the amount of surface water available for humans, then farmers may be forced to look elsewhere for water. One place for farmers to draw upon is groundwater. Overpumping these underground aquifers (pumping more quickly than the aquifer is replenished) can cause land subsidence, salt-water intrusion and a myriad of other problems, further exacerbating difficulties that many states are already experiencing.[29]

LOOKING FORWARD

Decreasing river flows and lake and reservoir levels that are the expected by-product of climate change provide great incentives to step-up water conservation.

Role of Governments.—While the bulk of conservation work needs to be carried-out by municipal governments, state and federal agencies can play an important role by providing funding and technical assistance and helping shape regional and state-specific education and message development.

Planning.—The uncertainties generated by climate change require more frequent conservation planning and conservation goal-setting by water suppliers. Substantial state funding should be made available in the form of planning and implementation grants.

Implementation.—Many cities in the West have demand management programs but, in many areas, improvements can still be made as cities refine their conservation programs and savings goals. Conservation program elements often include:

- Rate structures that reward conservation and provide incentive to avoid water waste;
- Rebate programs the assist customers (both residential and business) with installing high efficiency water fixtures, appliances, and devices;
- City ordinances and utility programs that encourage efficient irrigation;
- Business and residential audits that identify property-specific water issues;
- Education programs that deliver a consistent conservation message to all;

Outdoor Water Use.—As municipal landscapes irrigation accounts for roughly half of total annual municipal water use, it deserves special attention. Successful outdoor programs include:

- Incentives and requirements to amend the soil before planting new landscapes;
- Encouraging Xeriscape—to boost the prevalence of water-saving landscapes and, in some cases, limiting the amount of turf as a percentage of total landscaped area;
- Increasing efficiency by changing watering habits (decreasing the numbers of watering days per week and lowering the amount of time per sprinkler zone);
- Irrigation improvements, including rains sensors (that turn off sprinkler systems during rain) and more efficient sprinkler head placement and water pressure.

Because the West's new residents have not yet arrived, we should focus on new development to decrease the future water-use footprint, by encouraging residential and commercial developers and builders to use state-of-the-art conservation practices.

In addition to the water conservation elements noted above, we need to build a future where energy is used more efficiently and more electricity is generated from renewable resources like, wind and solar power—since these sources require water little and do not emit green house gases that further contribute to climate change. Our recent analysis concludes that 7.3 million acre-feet (2.4 trillion of gallons) can

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[26] Christina Roessler, Las Vegas and the Groundwater Development Project: Where does it start? Where will it end?, Progressive Leadership Alliance of Nevada, Las Vegas, NV, 2006.

[27] ibid

[28] Glenn Schaible, "Irrigation, Water Conservation, and Farm Size in the Western United States," Amber Waves, June 2004. http://www.ers.usda.gov/AmberWaves/June04/findings/IrrigationWestern.htm

[29] McKinney. Environmental Science: Systems and Solutions, 3rd Ed, 231 6

be saved each year across the West, more specifically; 613 Acre-feet (200 billion gallons) of water can be saved in Nevada alone. In addition to the water savings from greater efficiency and renewable sources, there are other substantial pollution and economic benefits of changing the "business as usual" approach to energy development.[30]

CONCLUSION

The water resources of the West are magnificent resources and ones that are plagued by conflicting objectives. We desire electricity, food and development, yet we treasure our natural heritage and rich biological diversity. In the coming decades the challenge for the West will be to find an equitable balance between these goals; to use technological advances to aid human ingenuity, but not rely upon them as our sole crutch; to value human development, while preserving natural ecosystems for future generations.

The vast majority of credible scientists believe that temperatures are rising in the western United States and that this will alter the natural environment that humans and other organisms rely so heavily upon. For this reason it is critical that governments and individuals take proactive measures to safeguard our natural resources. Managing the allocation of water in the west is a complex undertaking and will only be further complicated as supplies fluctuate. Prioritizing use, requiring conservation and addressing the root causes that have brought us to this place are all necessary steps to deal with the impacts that a changing climate may bring.

Perhaps most importantly, measures must be put in place to encourage the efficient use of water. Such measures focus on demand side issues instead of supply side concerns. Rather than rely on the antiquated approach of finding more water, this approach asks the question, how can water demand be decreased or made more efficient? In the face of a changing climate and exploding populations, efficiency measures must be part of a long term solution. What is equally as important is that efficiency measures can easily be embraced by all sectors of water users; helping urban, industrial and agricultural communities take steps to reduce use and improve the efficiency of their water.

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[30] Western Resource Advocates, A Balanced Energy Plan for the Interior West, 2004