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Sustainability and climate models for the Intermountain West: An annotated bibliography

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INTRODUCTION

This resource on climate models and sustainability in the Intermountain West, a region that includes the states of Arizona, Colorado, Idaho, Nevada, New Mexico, and Utah, is a collaborative effort between UNLV Libraries (http://library.unlv.edu/) and Brookings Mountain West (http://brookingsmtnwest.unlv.edu/). The selected citations include academic, government, and non-profit information that highlight ongoing research on climate models and sustainability efforts in the region. The websites, government studies, independent reports, scholarly articles, and media reports reflect the diversity and complexity of climate change and sustainability issues in a region that contains widely varying ecosystems. Brookings Mountain West staff proposed the creation of this resource in Spring 2011 and Marianne Buehler, Urban Sustainability Librarian for the UNLV University Libraries, led the research effort to identify and evaluate available resources on these topics. Buehler, in partnership with Bill Brown, UNLV Director, ~~of Planning and Communication at~~ Brookings Mountain West, refined the list and annotations, with the invaluable assistance of Chris Galvan, a sociology doctoral candidate at UNLV.

This bibliography is an updated version of the original 2011 collaboration between UNLV University Libraries and Brookings Mountain West. This document is meant to correct faulty links while still maintaining the integrity of the original document; as such, links are organized and numbered in the style of the original. Some of the sources - particularly those reliant on probability models - are now outdated and should be looked at from a historical perspective. The Intermountain West spans mountains, marshes, basins, and ~~populated cities~~ large metropolitan rregions, so the speed with which systems within react to climate change can be indicative of the nation's response. This 2015 revision was authored primarily by Daniel Diaz-Vita and Agnes Dulguun Enkhtamir, with the supervision and guidance of Rosan Mitola, John Watts, and William E. Brown, Jr.

Daniel Diaz-Vita graduated Ed W. Clark High School in 2015 with an advanced honors diploma. He will attend Yale University in the coming fall as a member of the Class of 2019.

Agnes Dulguun Enkhtamir graduated Centennial High School in 2015 with an advanced honors diploma. She will attend Yale University in the coming fall as a member of the Class of 2019.

WEBSITES AND BLOGS

Arizona

1. Arizona Water Institute: Arizona's three universities focused on sustainability.
   http://www.azwaterinstitute.org/

   The Arizona Water Institute is now closed due to state and university budget shortfalls. A few projects begun by AWI remain active, including the AHIS and EWSR efforts as listed above. If needed, contact information is still available

2. Arizona State University Julie Ann Wrigley Global Institute of Sustainability. *Collaborative research: Assessing decadal climate change impacts on urban populations in the southwestern USA*. Retrieved from website https://sustainability.asu.edu/research/project.php?id=517

   "This study will demonstrate the technical feasibility, empirical validity, and computational tractability of this approach using neighborhoods in Phoenix, AZ as case studies. The microclimate predictions of the model will be useful to predict neighborhood-level human health and social impacts, water and energy use, urban heat island effects, and urban flooding, in neighborhoods in cities around the world. The potential social benefits of this research include a research tool that can empirically validate, quantitative design of urban neighborhoods that are more resilient to climate change and other future challenges (i.e. water or energy shortages), allows the optimization of neighborhoods that minimize water and energy use, mitigate heat island impacts, and improve social and health outcomes. This modeling tool can change cities by making them adaptive by design."

3. Arizona State University. *Decision center for a desert city.* Retrieved from website https://dcdc.asu.edu/

   "Conducting climate, water, and decision research and developing innovative tools to bridge the boundary between scientists and decision makers and put our work into the hands of those whose concern is for the sustainable future of Greater Phoenix."

4. Sustainable Tucson. *Water articles and other resources.* Retrieved from website http://www.sustainabletucson.org/affinity/water/

   Sustainable Tucson is a non-profit, grass-roots organization that builds regional resilience and sustainability through awareness raising, community engagement and public/private partnerships. Their members focus their action, advocacy and research through working groups addressing the unprecedented challenges of our time, economic meltdown, population pressures, climate change, and resource depletion. The water articles and other resources include information dealing with sustainability and various water issues that are faced in the Tucson area.

5. The Water Plight of Phoenix (http://www.columbia.edu/~kk2534/Phoenix%20Water/index.html)

   This website serves as a source of information regarding the past, present, ~~-~~and future of this vanishing ~~water~~ resource in the desert. It ~~will~~ also explor~~es~~ the ~~vast~~ population's dependence on

water and considers the impact of ~~potential outlooks from~~ current statistics on the future growth of the region.

~~6. The Earth Institute at Columbia University. *Columbia water center.* Retrieved from website http://water.columbia.edu/.~~

~~The mission of the Columbia Water Center is to creatively tackle water challenges of a rapidly changing world where water and climate interact with food, energy, ecosystems and urbanization. The Columbia Water Center, in collaboration with other Earth Institute units and external partners, is leading intellectual inquiry into the assessment, understanding, and resolution of the global crisis of freshwater scarcity.~~

Why is the above item in the list, it is from the geography of the region?

7. College of Agriculture and Life Sciences, University of Arizona. (2015). *Water resources research center.* Retrieved from website http://wrrc.arizona.edu/

The University of Arizona Water Resources Research Center (WRRC) promotes understanding of critical state and regional water management and policy issues through research, community outreach and engagement, and public education. The WRRC assisting communities in water management and policy; educating teachers, students and the public about water; and encouraging scientific research on state and regional water issues.

8. Arizona Department of Water Resources (http://www.azwater.gov/AzDWR/)

The Arizona Department of Water Resources (ADWR) "administers and enforces Arizona's groundwater code, and surface water right laws; negotiates with external political entities to protect Arizona's Colorado River water supply; oversees the use of surface and groundwater resources under state jurisdiction, and represents Arizona in discussion of water rights with the federal government."

Colorado

1. Western Water Assessment for the State of Colorado. *Colorado climate preparedness project.* Retrieved from website http://www.coloadaptationprofile.org/

~~The Colorado Climate Preparedness Project was undertaken by the Western Water Assessment for the State of Colorado. The primary purpose of this project is to assist Colorado in continuing to prepare itself for climate variability and change by providing a catalog of climate vulnerabilities and current activities, including personnel, products and projects from Colorado and other appropriate entities. The project focuses on five sectors: agriculture, electricity, forests/wildlife/ecosystems, tourism/recreation, and water. Provides a wealth of information for numerous projects under the various tabs.~~ "The Colorado Climate Preparedness Project created the Western Water Assessment for the State of Colorado. The primary purpose of this project is to assist Colorado in continuing to prepare for climate variability and change by providing a catalog of climate vulnerabilities and current activities, including personnel, products and projects from Colorado and other appropriate entities."

2. Colorado State University. *Colorado climate center.* Retrieved from website http://ccc.atmos.colostate.edu/

"The Colorado Climate Center was established by the state in 1974, through the Colorado State University Agricultural Experiment Station, to provide information and expertise on Colorado's complex climate. Through its threefold program of Climate Monitoring (data acquisition, analysis, and archiving), Climate Research and Climate Services, the Center is responding to many climate related questions and problems affecting the state today."

3. Colorado Department of Natural Resources. *Colorado division of water resources.* Retrieved from website http://water.state.co.us/Home/Pages/default.aspx

"The Colorado Division of Water Resources (DWR)**,** also known as the *Office of the State Engineer,* administers water rights, issues water well permits, represents Colorado in interstate water compact proceedings, monitors streamflow and water use, approves construction and repair of dams and performs dam safety inspections, issues licenses for well drillers and assures the safe and proper construction of water wells, and maintains numerous databases of Colorado water information."

4. Colorado River Water Conservation District (http://www.coloradoriverdistrict.org/).

The mission of the Colorado River Water Conservation is "to lead in the protection, conservation, use and development of the water resources of the Colorado River basin for the welfare of the District, and to safeguard for Colorado all waters of the Colorado River to which the state is entitled."

5. United States Geological Survey. *Colorado droughtwatch.* Retrieved from website http://co.water.usgs.gov/drought/

"Includes graphic comparisons of streamflow and volume to historic values for 23 sites" and the "comparison of recent daily-average streamflows to historical streamflows for long-term streamgages."

6. United States Department of the Interior. *Drought in the upper Colorado River Basin.* Retrieved from website http://www.usbr.gov/uc/feature/drought.html

The Upper Colorado Region is responsible for managing and protecting water and associated resources including project facilities, endangered species, and many other environmental considerations. As drought continues to persist in the Upper Colorado Region and throughout the West, the challenge of fulfilling this responsibility increases, making wise management of our finite water resources imperative. Part of the Upper Colorado Region's role in addressing these challenges is to bring competing interests together to find consensus-based approaches to the contemporary water challenges in the West.

7. Western Water Assessment: Intermountain West Climate Summary 2005-2012. (http://wwa.colorado.edu/climate/iwcs/).

"Provides the latest climate information in a simple, compact document aimed at water managers, planners, and policy makers with water-related interests." "A cool, wet April delayed melt and added to the snowpack across most of the region's mountains. As a result, May 1st snow packs in the three-state region increased from the April 1st levels, and are much above average in all but southeastern Utah and southern Colorado. The most dramatic increases have been in Wyoming, northern Utah, and northern Colorado." Also includes drought and precipitation predictions, visual aids, and a wealth of information on climate conditions in the Intermountain West.

Idaho

1. Community Water Resource Center (http://www.uidaho.edu/cda/cwrc).

   "The mission of the Community Water Resource Center is to serve the education, outreach and research needs of the northern Idaho relating to local water quality and resource issues."

2. Idaho Water Resource Board. *State water plan.* Retrieved from website http://www.idwr.idaho.gov/waterboard/WaterPlanning/StateWaterPlanning/State_Planning.htm

   "The Idaho Water Resource Board is charged with the development of the Idaho Comprehensive State Water Plan. The plan includes the statewide water policy plan and associated component basin and water body plans which cover specific geographic areas of the state."

3. United States Department of the Interior Bureau of Reclamation Pacific Northwest Region. (2006, July). Reclamation managing water in the west: Final Boise/Payette Water Storage Assessment Report. Retrieved from website http://www.usbr.gov/pn/programs/srao_misc/bp_storagestudy/report/finalboisepayrpt.pdf

   Managing Water in the West: Final Boise/Payette Water Storage Assessment Report 2006, U.S. Department of the Interior Bureau of Reclamation Pacific Northwest Region. This assessment is just one activity and one aspect of the many activities that multiple agencies are conducting to address water supply and water management issues in the Boise and Payette River Basins.

4. Water Resources in a Changing Climate (Idaho climate change): EPScOR research. (http://www.idahoclimatechange.org/)

   The project seeks ~~Goal is~~ to improve the statewide research infrastructure for understanding the effects of climate change on water resources in our region and the impact of these effects of ecological, human and economic systems.

5. Idaho Climate Think Tank. (http://idahoclimate.org/)

   "The Idaho Climate Think Tank is a non-partisan, non-profit endeavor to educate Idahoans about climate change and to formulate real world solutions to mitigating carbon emissions."

Nevada

1. Mejia, J. (2011. April). Climate modeling research interest. [Web blog post] Climate modeling and impacts. Retrieved from website http://climatemodeling.blogspot.com/2011/04/integrated-system-model-framework-and.html

   The Climate Modeling Group (DRI/DAS, Reno, NV) "is focused on the development and implementation of statistical and Regional Climate Model downscaling techniques using Global Clime Modeling output from the CMIP3 and CMIP5 into space scales relevant for regional and local impact studies. The synthesis and interpretation of these results increases scientific understanding to provide information of value to the applications community. The downscaling techniques consist in creating consistent and quantitative fine scale datasets suitable for climate variability and climate change impact studies. Our working framework is focused to explore and explain future climate change signals in Nevada and the Intermountain West region."

2. Sundaram, V., &, Enloe, J.P. It's all water: Demonstration of an innovative treatment technology for water banking in Nevada. *Nevada Water Environment Association.* Retrieved from website http://nvwea.org/sswe-newsletters-detail/3034-its-all-water

   "Water shortages forecast for the west and the possibility of extended drought pose serious challenges for Nevada. Potential water shortages can be addressed in the immediate future by insightful management of available freshwater resources, and recycling or banking 'once used' water resources (e.g., reuse of municipal effluent)."

3. Nevada Climate Change Portal (http://www.sensor.nevada.edu/NCCP/Default.aspx).

   The focus of this website "is to advance the quality and quantity of infrastructure and data collection for climate, hydrological and ecological information pertaining to the state of Nevada. This website provides information on the Nevada Climate Change Project and access to both the NevCAN (Nevada Climate-ecohydrology Assessment Network) and climate modeling output."

4. The State of Nevada Division of Water Resources (http://water.nv.gov/index.cfm)

   "The mission of the Nevada Division of Water Resources (NDWR) is to conserve, protect, manage and enhance the State's water resources for Nevada's citizens through the appropriation and reallocation of the public waters. In addition, the Division is responsible for quantifying existing water rights; monitoring water use; distributing water in accordance with court decrees; reviewing water availability for new subdivisions and condominiums; reviewing the construction and operation of dams; appropriating geothermal water; licensing and regulating well drillers and water rights surveyors; reviewing flood control projects; monitoring water resource data and records; and providing technical assistance to the public and governmental agencies."

New Mexico

1. Ashmore, D.I., Ashmore, S.R., Behles, J.E., Loftin, D.M., Merrick, R.J., &, Witherspoon, J. (2001, April). *Evaluating the sustainability of the Albuquerque water supply.* Retrieved from website http://www.challenge.nm.org/archive/00-01/FinalReports/013/

"Large amounts of data from the City and USGS were gathered and meticulously examined. It first had to be decided what data would be used where. Calculating future rainfall and gallons per capita per day were the first steps towards the completion of the project. The final product is a program that can predict how much water will be taken from the aquifer one hundred years following any given year, based on user input."

2. O'Hare, C. (2000, December). Water, growth and sustainability: Planning for the 21st century. *New Mexico Water Resource Research Institute.* Retrieved from website http://www.wrri.nmsu.edu/publish/watcon/proc45/ohare.pdf

"I think we probably have the most sever water shortage emergency of any large city within the state and have implemented water use restrictions." Keynote address from Water Programs Administrator for the City of Santa Fe's Sangre De Cristo Water Division.

3. New Mexico EPSCoR (http://www.nmepscor.org/).

"New Mexico EPSCoR, is working to improve the research, cyberinfrastructure, and human resources required for New Mexico to achieve its energy, education, and workforce development potential. The infrastructure and activities of Energize New Mexico are designed to support shared-use equipment, engage new research and community college faculty, and support the STEM pipeline by training teachers, undergraduate and graduate students, and post-doctoral fellows. Research findings will be communicated broadly through new partnerships with NM's museum network, a citizen-centric web portal, and vibrant, experiential programs targeting K-12 students."

4. University of New Mexico University Libraries. *Hydrology and other resources. Retrieved from website http://libguides.unm.edu/content.php?pid=15497&sid=199424*

"University of New Mexico LibGuide: USGS and EPA Mexico water resource data, snow survey, climate information, and more."

5. United States Geological Survey. *New Mexico water science resource center.* Retrieved from website http://nm.water.usgs.gov/

The U.S. Geological Survey (USGS) ~~Web~~ webpage for water resources of the state of New Mexico provides direct links to all kinds of water-resource information. The web page provides information regarding the streams and rivers of New Mexico. Information about groundwater, water quality, and many other topics is also available. The USGS operates "the most extensive satellite network of stream-gaging stations in the state, many of which form the backbone of flood-warning systems."

Utah

1. Eldred, C., Kim, J., Pennell, C., Reichler, T., Rutz, J., &, Staten, P. (2010, August). Climate research group. *University of Utah.* Retrieved from website http://www.inscc.utah.edu/~reichler/research/research.shtml

"The Climate Research Group at the University of Utah studies climate and climate change with a focus on atmospheric dynamics. We are primarily interested in processes that have global impacts, large spatial scales, and longtime scales (weeks and longer)."

2. Carroll, L., O'Connell, A., O'Dell, M., & Wechsler, A. (2009, Sept). League of Women Voters of Utah water study. *League of Women Voters*. Retrieved from http://lwvutah.org/AirWaterIssues/lwvutWaterStudy_10-10-19.pdf

"In 2008 the League of Women Voters of Utah decided to do a study of Utah water so that we could better advocate for our members' deep concerns about water for people and water for the environment. This paper is concerned with accounting for our water and how we manage it, not with water quality either for human uses or for wildlife… Utah is the second driest state in the nation; Utah has the second highest per capita water use. However, we are told to expect more people, and the climate section will show that Utah can most likely expect longer, hotter droughts at the least and more likely a hotter, drier climate overall. The outcomes from the models vary from severe drought with dire consequences to more moderate declines in precipitation that, although serious, may be manageable. Scientists and most water managers agree that global warming will bring higher temperatures to all of Utah. Most of Utah's usable water comes from snowpack. The state's system of reservoirs fills in late spring and early summer from the slow snowmelt. The water level in the reservoirs starts to be drawn down beginning in late summer, through the rest of the year and into the next spring. The system depends upon a substantial snowfall and the timing of the spring snow melt. Little snow or more precipitation falling as rain does not allow for timely storage in Utah's high mountain reservoirs or for efficient seasonal allocation. If Utah has a hotter and drier climate, there will be less water in any form, a smaller snowpack, and probably higher human usage to counter the hotter, drier weather. Even if Utah 13 were to be warmer but wetter, there are problems. More precipitation will fall as rain rather than snow, filtering through the ground to our aquifers not to our reservoirs, where it is more accessible to the water delivery system now in place. The smaller snowpack will melt early, and since Utah receives little summer moisture, it is likely that summer water use will still be high and long…. The Governor's Office of Planning and Budget projects that the population will grow from 2,833,337 in 2010 to 5,368,567 in 2050, mostly on the Wasatch Front (GOPB, 2009)." "Water usage is highest in dry states due to precipitation, which has increased due to global warming. Tucson has low per capita water use, and Utah's dropped from 293 gpcd in 2000 to 260 gpcd in 2005 (UDWR (2009) Weber R. Basin, p. 47). Both are largely attributable to efficiencies achieved by both suppliers and consumers of water."

3. Utah State University. *Utah climate center.* Retrieved from website https://climate.usurf.usu.edu/

"The mission of the Utah Climate Center (UCC) is to facilitate access to climate data and information, and to use expertise in atmospheric science to interpret climate information in an accurate and innovative fashion for the public. The mission includes the design of new products to meet present and future needs of agriculture, natural resources, government, industry, tourism, and educational organizations in Utah and the intermountain region."

4. University of Utah. *Scientific computing and imaging institute.* Retrieved from website http://www.sci.utah.edu/

"The Scientific Computing and Imaging (SCI) Institute is a permanent research institute at the University of Utah. Directed by Professor Chris Johnson, the Institute is now home to over 190 faculty, students, and staff. The faculty, drawn primarily from the School of Computing, Department of Bioengineering, and Department of Electrical and Computer Engineering, is noted for its breadth of collaborations both nationally and internationally. The SCI Institute has established itself as an internationally recognized leader in visualization, scientific computing, and image analysis. The overarching research objective is to create new scientific computing techniques, tools, and systems that enable solutions to problems affecting various aspects of human life. A core focus of the Institute has been biomedicine, but SCI Institute researchers also solve challenging computational and imaging problems in such disciplines as geophysics, combustion, molecular dynamics, fluid dynamics, and atmospheric dispersion."

Western States

1. University of Arizona. *Southwest climate change network.* Retrieved from website http://www.southwestclimatechange.org/

"Southwest Climate Change NETWORK: Climate, impacts, solutions, articles featured and library tabs with more information. Recognizing the growing need for information about our changing climate, the Institute of the Environment and the Climate Assessment for the Southwest (CLIMAS) at The University of Arizona developed and jointly administer the Southwest Climate Change Network. The Institute of the Environment is a cross-campus and community resource and a catalyst in the area of environment and society; it promotes both disciplinary and interdisciplinary research relating to the Earth's environment, from local to global scales, and how this environment is likely to change in coming seasons, years, and decades. CLIMAS is a project housed within the Institute and funded by the U.S. National Oceanic and Atmospheric Administration to carry out stakeholder-driven interdisciplinary climate research. Since 1998, CLIMAS has contributed to the Southwest's ability to respond sufficiently and appropriately to climatic events and climate changes."

2. United States Global Change Research Program. Retrieved from website http://www.globalchange.gov/

"United States Global Change Research Program integrates federal research and solutions for climate and global change: The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the global environment and their implications for society. Contains reports and publication."

3. U.S. Department of the Interior. Bureau of Reclamation. Water Smart Program. West-Wide Climate Risk Assessments. http://www.usbr.gov/WaterSMART/wwcra.html

4. Office of the Secretary of Interior. (2010). *Order number 3289, amendment number 1.* Retrieved from website http://www.usbr.gov/WaterSMART/docs/so3289A1.pdf

5. Western States Water Laws http://www.blm.gov/nstc/WaterLaws/
Insert line space

"This website reviews the water laws of eleven western states (Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming). Special

attention is paid to the states' water rights systems, the application processes, groundwater regulations, the general adjudication processes, and the states' in-stream flow programs."

6. The University of Arizona. *Department of hydrology and water resources.* Retrieved from website http://www.hwr.arizona.edu/

   "Links to a variety of Western Water Resources Issues: Water resource centers, water plans, dams, drought, groundwater, water quality, state water resources, environmental organizations, federal agencies, and conservation."

7. University of California Davis. *California drought watch.* Retrieved from website http://drought.ucdavis.edu/about.html

   California Drought Watch is "generated by UC Davis water, agricultural and environmental sciences researchers, students, and affiliated water organizations throughout the state." The web page also provides "access to the latest California drought news, renowned experts and tips for practicing and embracing sustainable living."

8. United States Drought Monitor-West (http://droughtmonitor.unl.edu/Home/RegionalDroughtMonitor.aspx?west)

   The United States Drought Monitor provides records of the current and past drought conditions throughout different regions of the United States. The web page provides information regarding the number of individuals impacted by the drought and more statistics.

SCHOLARLY ARTICLE AND BOOKS

1. Dickinson, R., Errico, M., Goirgi, F., & Bates, G. (1989, Dec). A regional climate model for the Western United States in Climate Change, 15(3), 383 - 422. Retrieved from http://link.springer.com/article/10.1007%2FBF00240465

   "A numerical approach to modeling climate on a regional scale is developed whereby large-scale weather systems are simulated with a global climate model (GCM) and the GCM output is used to provide the boundary conditions needed for high resolution mesoscale model simulations over the region of interest. In our example, we use the National Center for Atmospheric Research (NCAR) community climate model (CCM1) and the Pennsylvania State University (PSU)/NCAR Mesoscale Model version 4 (MM4) to apply this approach over the western United States (U.S.). The topography, as resolved by the 500-km mesh of the CCM1, is necessarily highly distorted, but with the 60-km mesh of the MM4 the major mountain ranges are distinguished. To obtain adequate and consistent representations of surface climate, we use the same radiation and land surface treatments in both models, the latter being the recently developed Biosphere-Atmosphere Transfer Scheme (BATS). Our analysis emphasizes the simulation at four CCM1 points surrounding Yucca Mountain, NV, because of the need to determine its climatology prior to certification as a high-level nuclear waste repository. We simulate global climate for three years with CCM1/BATS and describe the resulting January surface climatology over the Western U.S. The details of the precipitation patterns are unrealistic because of the smooth topography. Selecting five January CCM1 storms that occur over the western U.S. with a total duration of 20 days for simulation with the MM4, we demonstrate that the mesoscale model

provides much improved wintertime precipitation patterns. The storms in MM4 are individually much more realistic than those in CCM1. A simple averaging procedure that infers a mean January rainfall climatology calculated from the 20 days of MM4 simulation is much closer to the observed than is the CCM1 climatology. The soil moisture and subsurface drainage simulated over 3–5 day integration periods of MM4, however, remain strongly dependent on the initial CCM1 soil moisture and thus are less realistic than the rainfall. Adequate simulation of surface soil water may require integrations of the mesoscale model over time periods."

2. Thornthwaite, C. (1948, Jan). An approach toward a rational classification of climate in the American Geographical Society, 38(1), 55 - 94.

"The direction that the modern study of climate has taken has been dictated largely by the development of meteorological instruments, the establishment of meteorological observatories, and the collection of weather data. The catalogue of climatic elements consists of those that are customarily measured and usually includes temperature, precipitation, atmospheric humidity and pressure, and wind velocity. Increasingly, climatic studies have tended to become statistical analyses of the observations of individual elements. Because of this, climatology has been regarded in some quarters as nothing more than statistical meteorology."

3. Spencer, T. & Altman, P. (2010, June). Climate change, water, and risks: Current water demands are not sustainable. *National Resources Defense Council*. Retrieved from http://www.nrdc.org/globalwarming/watersustainability/files/WaterRisk.pdf

4. Overpeck, J. & Udall, B. (2010, July). Climate change, water, and risk: Current water demands are not sustainable in Science, 328(5986), 1642 - 1643.

"In the past decade, it has become impossible to overlook the signs of climate change in western North America. They include soaring temperatures, declining late-season snowpack, northward-shifted winter storm tracks, increasing precipitation intensity, the worst drought since measurements began, steep declines in Colorado River reservoir storage, widespread vegetation mortality, and sharp increases in the frequency of large wildfires. These shifts have taken place across a region that also saw the nation's highest population growth during the same period."

5. Kerr, G. (2007, Dec). Global warming coming home to roost in the American West in Science, 318(5858), 1859. Retrieved from http://www.sciencemag.org/content/318/5858/1859.full

"At the fall meeting of the American Geophysical Union, a group of 11 climate scientists from 5 institutions announced they have securely tied the shrinking snowpack of the American West to a human-induced warming there."

6. Barnett, T., Pierce, D., Hidalgo, H., Bonfils, C., Santer, B., Das, T., Bala, G., Wood, A., Nozawa, T., Mirin, A., Cayan, D., & Dettinger, M. (2008, Jan). Human-induced changes in the hydrology of the western United States in Science, 319(5866), 1080 - 1083. Retrieved from http://www.sciencemag.org/content/319/5866/1080.full

"Observations have shown that the hydrological cycle of the western United States changed significantly over the last half of the 20th century. We present a regional, multivariable climate

change detection and attribution study, using a high-resolution hydrologic model forced by global climate models, focusing on the changes that have already affected this primarily arid region with a large and growing population. The results show that up to 60% of the climate-related trends of river flow, winter air temperature, and snowpack between 1950 and 1999 are human-induced. These results are robust to perturbation of study variates and methods. They portend, in conjunction with previous work, a coming crisis in water supply for the western United States."

7. Leung, R., Quian, Y., & Bian, X. (2003). Hydroclimate of the western United States based on observations and regional climate simulations of 1981 - 2000 in American Meteorological Society, 16(12), 1892 - 1911. Retrieved from http://journals.ametsoc.org/doi/pdf/10.1175/1520-0442%282003%29016%3C1892%3AHOTWUS%3E2.0.CO%3B2

"The regional climate of the western United States shows clear footprints of interaction between atmospheric circulation and orography. The unique features of this diverse climate regime challenges climate modeling. This paper provides detailed analyses of observations and regional climate simulations to improve our understanding and modeling of the climate of this region. The primary data used in this study are the 1/8° gridded temperature and precipitation based on station observations and the NCEP–NCAR global reanalyses. These data were used to evaluate a 20-yr regional climate simulation performed using the fifth-generation Pennsylvania State University–National Center for Atmospheric Research (Penn State–NCAR) Mesoscale Model (MM5) driven by large-scale conditions of the NCEP–NCAR reanalyses. Regional climate features examined include seasonal mean and extreme precipitation; distribution of precipitation rates; and precipitation intensity, frequency, and seasonality. The relationships between precipitation and surface temperature are also analyzed as a means to evaluate how well regional climate simulations can be used to simulate surface hydrology, and relationships between precipitation and elevation are analyzed as diagnostics of the impacts of surface topography and spatial resolution. The latter was performed at five east–west transects that cut across various topographic features in the western United States."

8. Lempert, R. & Groves, D. (2010, July). Identifying and evaluating robust adaptive policy responses to climate change for water management agencies in the American West in Science Direct, 77(6), 960 - 974. Retrieved from http://ac.els-cdn.com/S0040162510000740/1-s2.0-S0040162510000740-main.pdf?_tid=2f428308-1f5c-11e5-99a7-00000aab0f02&acdnat=1435691829_81d84034cc040f061edfe043dbbf26b4

"Climate change presents a significant planning challenge for water management agencies in the western United States. Changing precipitation and temperature patterns will disrupt their supply and extensive distribution systems over the coming decades, but the precise timing and extent of these impacts remain deeply uncertain, complicating decisions on needed investments in infrastructure and other system improvements. Adaptive strategies represent an obvious solution in principle, but are often difficult to develop and implement in practice. This paper describes work helping the Inland Empire Utilities Agency (IEUA) explicitly develop adaptive policies to respond to climate change and integrating these policies into the organization's' long-range planning processes. The analysis employs Robust Decision Making (RDM), a quantitative decision- analytic approach for supporting decisions under conditions of deep uncertainty. RDM studies use simulation models to assess the performance of agency plans over thousands of

plausible futures, use statistical “scenario discovery” algorithms to concisely summarize those futures where the plans fail to perform adequately, and use these resulting scenarios to help decision makers understand the vulnerabilities of their plans and assess the options for ameliorating these vulnerabilities. This paper demonstrates the particular value of RDM in helping decision makers to design and evaluate adaptive strategies. For IEUA, the RDM analysis suggests the agency's current plan could perform poorly and lead to high shortage and water provisioning costs under conditions of: (1) large declines in precipitation, (2) larger-than-expected impacts of climate change on the availability of imported supplies, and (3) reductions in percolation of precipitation into the region's groundwater basin. Including adaptivity in the current plan eliminates 72% of the high-cost outcomes. Accelerating efforts in expanding the size of one of the agency's groundwater banking programs and implementing its recycling program, while monitoring the region's supply and demand balance and making additional investments in efficiency and storm-water capture if shortages are projected provides one promising robust adaptive strategy — it eliminates more than 80% of the initially-identified high-cost outcomes.”

10. Leung, R., Quian, Y., Bain, X., Washington, W., Han, J., & Roads, J. (2004). Mid-century ensemble regional climate change scenarios for the western United States in Climatic Change, 62, 75 - 113. Retrieved from http://www.climateknowledge.org/NA_precipitation/Leung_Regional_Water_ClimaticChange_2004.pdf

    “To study the impacts of climate change on water resources in the western U.S., global climate simulations were produced using the National Center for Atmospheric Research/Department of Energy (NCAR/DOE) Parallel Climate Model (PCM). The Penn State/NCAR Mesoscale Model (MM5) was used to downscale the PCM control (20 years) and three future (2040–2060) climate simulations to yield ensemble regional climate simulations at 40 km spatial resolution for the western U.S. This paper describes the regional simulations and focuses on the hydroclimate conditions in the Columbia River Basin (CRB) and Sacramento-San Joaquin River (SSJ) Basin. Results based on global and regional simulations show that by mid-century, the average regional warming of 1 to 2.5 ◦C strongly affects snowpack in the western U.S. Along coastal mountains, reduction in annual snowpack was about 70% as indicated by the regional simulations. Besides changes in mean temperature, precipitation, and snowpack, cold season extreme daily precipitation increased by 5 to 15 mm/day (15–20%) along the Cascades and the Sierra. The warming resulted in increased rainfall at the expense of reduced snowfall, and reduced snow accumulation (or earlier snowmelt) during the cold season. In the CRB, these changes were accompanied by more frequent rain-on snow events. Overall, they induced higher likelihood of wintertime flooding and reduced runoff and soil moisture in the summer. Changes in surface water and energy budgets in the CRB and SSJ basin were affected mainly by changes in surface temperature, which were statistically significant at the 0.95 confidence level. Changes in precipitation, while spatially incoherent, were not statistically significant except for the drying trend during summer. Because snow and runoff are highly sensitive to spatial distributions of temperature and precipitation, this study shows that (1) downscaling provides more realistic estimates of hydrologic impacts in mountainous regions such as the western U.S., and (2) despite relatively small changes in temperature and precipitation, changes in snowpack and runoff can be much larger on monthly to seasonal time scales because the effects of temperature and precipitation are integrated over time and space through various surface hydrological and land atmosphere feedback processes. Although the results reported in this

study were derived from an ensemble of regional climate simulations driven by a global climate model that displays low climate sensitivity compared with most other models, climate change was found to significantly affect water resources in the western U.S. by the mid twenty-first century."

11. Steven A. Mauget, 2003: Multidecadal Regime Shifts in U.S. Streamflow, Precipitation, and Temperature at the End of the Twentieth Century. *Journal of Climate,* 16, 3905–3916. doi:http://dx.doi.org/10.1175/1520-0442(2003)016<3905:MRSIUS>2.0.CO;2

    "Multi-decadal Regime Shifts in U.S. Streamflow, Precipitation, and Temperature at the End of the Twentieth Century." Mauget, Steven A., 2003: J. Climate, 16, 3905–391. Covers years: 1896–2001. During the late 1980s and early 1990s, a significant incidence of low-ranked annual flow conditions throughout the West was roughly coincident with the onset of Western warmth during the mid-1980s. Evidence of highly significant transitions to wetter and warmer conditions nationally, and consistent variation in stream flow analyses, suggests that increased hydrological surplus in the Central and Eastern United States and increased hydrological deficit in the West may be representative of the initial stages of climate change over the continental United States.

12. Martinez, E.L. (2000, December). Water, growth and sustainability: Planning for the 21st century. *New Mexico Water Resource Research Institute.* Retrieved from website http://www.wrri.nmsu.edu/publish/watcon/proc45/martinez.pdf

    "Eluid L. Martinez was appointed Commissioner of the Bureau of Reclamation by President Clinton in 1995. He oversees the operation and maintenance of Reclamation's water storage, water distribution, and electric power generation facilities in the 17 western states. As Commissioner, Eluid has furthered Reclamation's goal of a continued emphasis on water resource management for the West's divergent interests, which consists of cities, irrigators, Native American Tribes, recreational interests, and fish and wildlife needs. Eluid retired from New Mexico state government in 1994 as a distinguished engineer with extensive experience in water resource administration, management, and flood protection programs. His positions included State Engineer and Secretary of the NM Interstate Stream Commission. A native of Rio Arriba County, he received an undergraduate degree in civil engineering at NMSU. He is an accomplished artist who hails from a rich heritage of nine generations of Santeros. His sculptures, lithographs, and prints reside in the permanent collection of such museums as the Smithsonian Institute and the Denver Art Museum."

13. Acton, R. (2001). The Water Challenge: Contemporary Issues in Northern Nevada. In E. Herzik & D. Soden. (Eds.), *Nevada in the new millennium.* Dubuque, IA: Kendall/Hunt Pub.

14. Levi, B.G. (2008, April). Trends in the hydrology of the western US bears the imprint of manmade climate change. *Physics Today*, 16. http://dx.doi.org/10.1063/1.2911164

15. Digital Scholarship@UNLV. *Faculty articles and other resources.* Retrieved from website http://digitalscholarship.unlv.edu/fac_articles/

16. Benson, R. D. (2012). Federal water law and the "double whammy": How the bureau of reclamation can help the west adapt to drought and climate change. *Ecology Law Quarterly*, *39*(4), 1049-1083. Retrieved from website

http://ezproxy.library.unlv.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=85394824&site=ehost-live

This article examines the techniques of the U.S. Bureau of Reclamation (USBR), which operates and oversees hundreds of federal water projects scattered through the American West.

17. Quillace, M. (2013). Water Transfers for a Changing Climate. *Natural Resources Journal*, *53*(1), 55-116. Retrieved from website http://ezproxy.library.unlv.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=87416380&site=ehost-live

"The prior appropriation doctrine that dominates the water laws of the Western United States was perhaps the inevitable consequence of the need to manage water resources in a region where the demand for water often exceeds the supply. This doctrine has proved surprisingly clumsy at accommodating changing water needs during times of shortage. Economists have long viewed water markets as an attractive solution for reallocating water to meet the demands of an evolving community of water users. But most western states have been skeptical-sometimes even hostile-to proposed changes in historic water use patterns. This reluctance to encourage the transfer of existing water rights to serve critical new water needs too often leads to the development of new and expensive water projects with serious adverse environmental consequences. Still, many water transfers have gone forward and many involve moving water from agricultural to urban use. This is not surprising since most of the water used in the West goes to irrigated agriculture and most of the new demand is coming from the West's burgeoning urban centers. But for a variety of reasons, transfer activity has proved inadequate to accommodate these growing needs. Climate change now threatens to exacerbate this problem, by diminishing water supplies in some of the most arid regions of the West. New ways of thinking about reallocating water could go a long way to solving this problem. This article offers concrete recommendations for promoting robust water markets that can address water shortages that are otherwise likely to confront the West. The article concludes with a series of practical and creative ways for reforming western water law to help ensure that water gets to where it is needed most efficiently."

18. Christian-Smith, J., Levy, M. C., & Gleick, P. H. (2015). Maladaptation to drought: A case report from California, USA. *Sustainability Science*, 10(3), 491-501. doi:http://dx.doi.org/10.1007/s11625-014-0269-1

This report explores the connections between the availability of natural water and societal water demand and management, mainly in the western state of California. The authors utilize the Barnett and O'Neill's criteria for "maladaptation to examine responses in the agricultural and energy sectors to a multi-year California drought. The case study evaluates California's strategies for dealing with severe droughts and provides insight into new strategies for future situations, such as "a shift from crisis-driven responses to the development and enactment of long-term mitigation measures that are anticipatory and focus on comprehensive risk reduction."

19. Sun, Y., Tong, S. T. Y., Fang, M., & Yang, Y. J. (2013). Exploring the effects of population growth on future land use change in the Las Vegas wash watershed: An integrated approach of geospatial

modeling and analytics. *Environment, Development and Sustainability*, 15(6), 1495-1515. doi:http://dx.doi.org/10.1007/s10668-013-9447-z

"The metropolitan area of the Las Vegas Valley is one of the most rapidly growing areas in the southwestern United States. The population and city are expanding at a faster rate compared to the natural resources, such as land and clean water. Lake Mead, the main supply of fresh water to the region, has seen exponential drops in water levels throughout the past the decades. To create "effective sustainable management plans, the very first step is to predict the plausible future urbanization and land use patterns." The article introduces an approach "to predict the future land use pattern at the Las Vegas Wash watershed using a Markov cellular automata model" and many other techniques. The conclusion of the article creates insight for "local planners and policy makers, assisting their efforts in construction alternative sustainable urban development schemes and environmental management strategies."

20. Wise, E. K. (2012). Hydroclimatology of the US intermountain west. *Progress in Physical Geography,* 36(4), 458-479. doi:http://dx.doi.org/10.1177/0309133312446538

"The semi-arid US Intermountain West is characterized by complex hydroclimatic variability, influenced both by topography and by atmosphere and ocean processes operating over a large range of time and space scales. Understanding climate–hydrology interactions has become increasingly important as demands on water resources grow from both within and beyond the region, particularly in light of projected climate changes. This paper reviews key atmospheric and oceanic controls that impact the Intermountain West's water supply, how those controls vary over multiple timescales, the tree-ring record of hydroclimatic variability in the region, projected climate change impacts, and research needs for the future. Water availability in the Intermountain West is largely influenced by interrelated atmospheric features that include the strength and position of the Pacific subtropical high, the intensity and geographic location of the Aleutian low, the latitude of the westerly storm track, and teleconnections such as the Pacific North American pattern and the El Niño−Southern Oscillation system. The tree-ring record of pre-instrumental conditions in the Intermountain West indicates that there have been droughts in the past that were more severe than those experienced in the historical record. Climate model projections of future moisture-related changes, including decreased snowpack and changing seasonality of precipitation, may exacerbate strain on the region's water supply. Advances in climate modeling and in our understanding of climate variability over multiple time and space scales would improve capacity for water resource management in the Intermountain West."

21. Gastelum, J. R. (2012). Analysis of Arizona's water resources system. *International Journal of Water Resources Development, 28*(4), 615-628. doi:http://dx.doi.org/10.1080/07900627.2011.625524

This peer reviewed study uses qualitative systems analysis to evaluate the efficiency of current water laws and regulations in meeting water demands of Arizona. This investigation also centers on water conservation in active management areas, rural Arizona, and water rights transfers.

22. Salvaggio, M., Futrell, R., Batson, C. D., & Brents, B. G. (2014). Water scarcity in the desert metropolis: How environmental values, knowledge and concern affect Las Vegas residents' support for water conservation policy. *Journal of Environmental Planning and Management, 57*(4), 588-611. doi:http://dx.doi.org/10.1080/09640568.2012.756806

This study, though conducted in 2014, is based on data from the 2009 Las Vegas Metropolitan Area Social Survey. It strives to examine associations between environmental values, especially water conservation policies, specifically in Las Vegas but the data can be applied to any heavily populated desert city. The researchers also offer suggestions for water management, conservation, and outreach.

"Specifically, we consider: (a) the combined influence of environmental value orientation, knowledge of drought conditions and concern about water use on support for water conservation policies; (b) the relative association of each individual variable on policy support; (c) factors explaining support to increase water prices and restrict water use; and (d) associations between socio-demographic factors and water policy support."

23. Groves, D. G., Fischbach, J. R., Bloom, E., Knopman, D., & Keefe, R. (2013). *Adapting to a changing Colorado River: Making future water deliveries more reliable through robust management strategies* RAND. Retrieved from http://www.rand.org/pubs/research_reports/RR242.html

    This study evaluates the efficiency of the Colorado River system over the next 50 years, factoring in current climate change models.

24. Berggren, J., Christian-Smith, J., & Cohen, M. (2013). *Water to supply the land: Irrigated agriculture in the Colorado River Basin.* Pacific Institute for Studies in Development, Environment, and Security. Retrieved from http://pacinst.org/publication/water-to-supply-the-land-irrigated-agriculture-in-the-colorado-river-basin/

    The Colorado River supports many populated metros in the American Southwest and northwest Mexico and contributes to the irrigation of millions of acres of land. Demands on the river exceed the river's supply, a situation that will only grow worse in the face of increasing demand and climate change. This study examines current Colorado River law and changes needed to keep the river from running dry.

25. Greenberg, L. (2013). Trusting the public: reshaping Colorado water law in the face of changing public values. *Boston College Environmental Affairs Law Review, 40*(1), 259-295. Retrieved from http://lawdigitalcommons.bc.edu/ealr/vol40/iss1/7/

    Colorado employs the rule of prior appropriation in regards to water allocation, but the inflexible application of the policy has resulted in "economically inefficient and environmentally detrimental consequences." This study calls for changes in Colorado water law to correct for the overuse and misuse of its water.

26. Oglesby, A. (2012). Implementation of the Arizona water settlement act in New Mexico: An overview of legal considerations. *Natural Resources Journal, 52*(1), 215-235. Retrieved from http://gilaconservation.org/PDF/AWSA%20Legal%20Overview%20Final.pdf.

    "The Arizona Water Settlements Act of 2004 (AWSA) promotes water development in southwestern New Mexico by providing money and an opportunity to divert up to an additional 14,000 acre feet per year from the Gila River system as part of an exchange with the Central Arizona Project. The AWSA provides a federal subsidy of $66 million to New Mexico to fund

projects that meet water supply demands in the region. If New Mexico decides to take additional water from the Gila River system in exchange for Central Arizona Project water, the AWSA will authorize an additional federal subsidy of between $34 and $62 million to fund the capital costs of using that water. This analysis of the costs and liabilities associated with diverting additional Gila River water concludes that it is possible to assure a more sustainable and certain long-term water supply through alternative water utilization projects. New Mexico should not accept the second subsidy, thereby not committing itself to the federal water project. Rather, New Mexico should forgo the diversion of the additional water and utilize only the first federal subsidy of $66 million to support local water projects."

27. Larson, K. L., Wiek, A., & Withycombe Keeler, L. (2013). A comprehensive sustainability appraisal of water governance in Phoenix, AZ. *Journal of Environmental Management, 116*, 58-71. doi: http://dx.doi.org/10.1016/j.jenvman.2012.11.016

    This study appraises water governance for Phoenix, Arizona and surrounding rural regions but is applicable to similar areas. It also offers solutions to perceived problems, the most salient being addressing interconnections across hydrological units and sub-systems, increasing decentralized initiatives for multiple purposes, incorporating justice goals into decisions, and building capacity through collaborations, and social learning with diverse interests.

GRADUATE AND INSTITUTIONAL RESEARCH

Graduate Research:

1. Safi, A. (May, 2011). Climate change in rural Nevada: The influence of vulnerability on risk perception and environmental behavior. Retrieved from website http://digitalscholarship.unlv.edu/cgi/viewcontent.cgi?article=1907&context=thesesdissertations

    This dissertation examines "the impact of vulnerability on risk perception, stated willingness to adopt individual mitigation behavior, and support for climate change mitigation policies." This paper explores three areas: physical vulnerability, sensitivity, and adaptive capacity in climate change mitigation policies.

2. Perez, R. & Ruiz, C. (2011). Groundwater: Solution to the Las Vegas water problem?. Retrieved from http://digitalcommons.library.unlv.edu/focs_ug_research/2011/april16/41/

    This paper discusses the SNWA's Groundwater Development Project and provides a discussion of the issues for and against it. It explores consequences of over pumping groundwater and potential solutions to Las Vegas' water problems.

Institutional Research:

1. (n.d.). Climate change seminar series. Retrieved from: http://digitalcommons.library.unlv.edu/climate_change/

This is a collection of submissions from 2010-2012 from authors exploring climate change and potential impacts to Nevada.

2. Nevada Infrastructure for Climate Change Science, Education, and Outreach. (2010). *Annual Nevada NSF EPSCoR Climate Change Conference Presentations*. [Electronic files]. Retrieved from: http://digitalcommons.library.unlv.edu/epscor/

Online collection of research posters and PowerPoint slides presented at the 2010 conference.

GOVERNMENT RESEARCH

1. Arizona State Legislature. (n.d.) Executive order 2010 - 06. Retrieved from http://azmemory.azlibrary.gov/cdm/singleitem/collection/execorders/id/690/rec/9

"The executive order recognizes the importance of reducing greenhouse gas emissions while maintaining Arizona's economic growth and competitiveness. Increased greenhouse gas emissions, a key driver influencing climate change may result as Arizona's population and economy expands, but Arizona has significant strengths on which to build, including stringent renewable energy standards and one of the nation's most aggressive energy efficiency standards. The Governor's policy supports Arizona's continued collaboration in regional and national endeavors to advance clean energy and implement cost-effective solutions to climate change while safeguarding its unique state interests. The Arizona Department of Environmental Quality has an important role in ensuring clean air, safe water, and better protected land for all Arizonans. Together with Arizona businesses and communities, we strive for pragmatic, pro-active approaches to climate change by advancing clean renewable energy, smart growth, fuel efficient transportation and energy efficiency policies and practices that make sense for Arizona."

2. Spencer, T. & Altman, P. (2010, June). Climate change, water, and risks: Current water demands are not sustainable. *National Resources Defense Council*. Retrieved from http://www.nrdc.org/globalwarming/watersustainability/files/WaterRisk.pdf

"Climate change will have a significant impact on the sustainability of water supplies in the coming decades. A new analysis, performed by consulting firm Tetra Tech for the Natural Resources Defense Council (NRDC), examined the effects of global warming on water supply and demand in the contiguous United States. The study found that more than 1,100 counties— one-third of all counties in the lower 48—will face higher risks of water shortages by mid-century as the result of global warming. More than 400 of these counties will face extremely high risks of water shortages."

3. Morello, L. (2011). Climate: Waiting to battle warming 'imprudent,' NAS warns Congress. *E&E News PM*. Retrieved from http://www.eenews.net/eenewspm/stories/1059948981/feed

"Climate change is real and poses "significant risks" to society, the National Academy of Sciences said today, warning that delaying cuts in greenhouse gas emissions will make dealing with the problem harder in the future." Each additional ton of greenhouse gases emitted commits us to further change and greater risks," the report says. The plain-spoken document, prepared in response to Congress' request for "action oriented" advice, says waiting to combat warming is

"imprudent." It calls for the federal government to take a lead role in combating climate change in the United States—which it said cannot be addressed effectively with piecemeal efforts by state and local governments—and abroad." The risks associated with doing business as usual are a much greater concern than the risks associated with engaging in strong response efforts," the report adds. "This is because many aspects of an 'overly ambitious' policy response could be reversed if needed, through subsequent policy change; whereas adverse changes in the climate system are much more difficult (indeed, on the timescale of our lifetimes, may be impossible) to 'undo.'" 21 The analysis, prepared by a team of scientists, economists and engineers, also weighs in on the state of climate science, which it deems sound—though it says some degree of uncertainty about the rate and severity of future climate change is inevitable." Given the inherent complexities of the climate system, and the many social, economic, technological, and other factors that affect the climate system, we can expect always to be learning more and to be facing uncertainties regarding future risks," the report says. "This is not, however, a reason for inaction.""

4. Chambers, J., Devoe, N., & Evendon, A. (2006). Collaborative Management in the Great Basin: Examining the issues and developing a framework for action. University of Nevada, Reno. Retrieved from http://www.cabnr.unr.edu/GreatBasinWatershed/Issues_Papers.pdf

   "This GTR is the product of the workshop on "Collaborative Watershed Research and Management in the Great Basin" that was held in Reno, Nevada on November 28-30, 2006. Cosponsors included University of Nevada, Reno, Desert Research Institute, Great Basin Cooperative Ecosystems Studies Unit, Utah State University, Agricultural Research Service, Bureau of Land Management, State of Nevada, Department of Wildlife and Game, USDA Forest Service, Region 4, USDA Forest Service, Rocky Mountain Research Station, US Geological Survey."

   "This file contains a number of reports regarding climate change and sustainability in the Southwestern U.S. In summation: "Because the Great Basin is a semi-arid region, the changing climate is likely to have a greater influence than in more mesic regions. The Great Basin warmed by 0.6 to 1.1F in the last 100 years and is projected to warm by an additional 3 to 6F by the end of this century (Environmental Protection Agency 1998, Wagner 2003). Precipitation increased 6-16% in the last 50 years; it is projected to continue to increase in the future (Baldwin and others 2003). However, snowpack has declined and the decreases in the Great Basin have been among the largest in the nation (Mote and others 2005). Both the onset of spring and the timing of spring snowmelt-driven stream flow are now about 10-15 days earlier than 50 years ago (Cayan and others 2001, Baldwin and others 2003, Stewart and others 2004). In the future it is likely that spring peak flows will be reduced and even earlier as more winter precipitation falls as rain. The frequency of droughts and floods is predicted to increase. These changes in flow regimes will result in management challenges related to water storage, channel maintenance, floods and droughts, pollutants, and biodiversity (Baldwin and others 2003). Water resources now used for hydropower, irrigation, riparian and aquatic habitat and fisheries all may be negatively affected." This report provides a plethora of sources and links to related organizations."

5. Anderson, D., Boesch, D., Burkett, V., Carter, L., Cohen, S., Grimm, N., Hatfield, J., Hayhoe, K.m Janetos, A.m Kaye, J., Lawrimore, J., McCarthy, J., McGuire, D., Miles, E., Mills, E., Overpeck, J., Patz, J., Pulwarty, R., Santer, B., Savonis, M., Schwartz, G., Shea, E., Stone, J., Udall, B., Walsh, J.,

Wehner, M., Wilbanks, T., & Weubbles, D. (2009). Global climate change impacts in the United States. *U.S. Global Change Research Program*. Retrieved from http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf

This report summarizes the science of climate change and the impacts of climate change on the United States, now and in the future. It is largely based on results of the U.S. Global Change Research Program (USGCRP) and integrates those results with related research from around the world.

6. Parr, C., Jordan, J., Erickson, D., Graham, R., Rainey, E., Rigby, J., Storer, L., & Uhling, T. (1999). Idaho comprehensive state water plan: Payette River Basin. Idaho Water Resource Board. Retrieved from http://www.idwr.idaho.gov/waterboard/WaterPlanning/CompBasinPlanning/Payette/PDF/payettesum.pdf

The Payette River Basin Plan describes and evaluates water resources and related economic, cultural, and natural resources in the basin. "The plan takes actions and recommends water policy and water resource management options to improve, develop, and conserve the water resources of the Payette River Basin."

7. Alexander, P., Brekke, L., Davis, G., Gangopadhyay, S., Grantz, K., Hennig, C., Jerla, C., Llewellyn, D., Miller, P., Pruitt, T., Raff, D., Scott, T., Tansey, M., & Turner, T. (2011). Secure Water Act Section 9503(c): Reclamation climate change and water. *U.S. Department of Interior Policy and Administration Bureau of Reclamation of Denver, Colorado*. Retrieved from http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf

"A recent paper by the Congressional Budget Office summarizes the current understanding of the impacts of climate change in the United States, including that warming will tend to be greater in the interior of the contiguous United States. Temperature and precipitation conditions over Western United States regional drainages are projected to change as the effects of global climate change are realized. Projections of future temperature and precipitation are based on multiple Global Circulation (or Climate) Models (GCMs) and various projections of future greenhouse gas emissions (GHG), technological advancements, and global population estimates. A survey of these models over any of the regional drainages shows that there is model consensus agreement reported between climate model projection." The report discusses in detail the major Western Basins and relevant predictions. It also provides a number of great visuals. In my limited research, this is the best resource available.

8. Digital Scholarship@UNLV. *Water Publications.* Retrieved from website http://digitalscholarship.unlv.edu/water_pubs/

Insert description of website ?

9. Utah Department of Environmental Quality: Climate Change Work Group. The Division of Air Quality received a grant from the Hewlett Foundation to help develop specific policy and program options to document and reduce greenhouse gas emissions in Utah. The grant will help support a stakeholder work group that has been established and provides analytical support to the Governor's Blue Ribbon Council on Climate Change. The work group also assists the Council in

identifying policy and program options.
http://www.deq.utah.gov/Issues/Climate_Change/index.htm

Note: It appears that the climate change workgroup is now dissolved, but the Utah Department of Environmental Quality still has active groups, such as the Division of Air Quality, Water Quality Task Force, and Water Monitoring Council. Learn more at: http://www.deq.utah.gov/

10. Anderson, M. & Woosley L. (2013). Water availability for the western United States: Key Scientific challenges. *U.S. Geological Survey Circular 1261*. Retrieved from http://pubs.usgs.gov/circ/2005/circ1261/

"In the Western United States, the availability of water has become a serious concern for many communities and rural areas. Near population centers, surface-water supplies are fully appropriated, and many communities are dependent upon groundwater drawn from storage, which is an unsustainable strategy."

~~11. Martinez, E.L. (2000, December). Water, growth and sustainability: Planning for the 21st century. *New Mexico Water Resource Research Institute*. Retrieved from website http://www.wrri.nmsu.edu/publish/watcon/proc45/martinez.pdf~~

~~"Eluid L. Martinez was appointed Commissioner of the Bureau of Reclamation by President Clinton in 1995. He oversees the operation and maintenance of Reclamation's water storage, water distribution, and electric power generation facilities in the 17 western states." This is a keynote speech from a conference on water issues in the west.~~

Also found on page 16……..

12. Gangopadhyay, S. & Pruitt, T. (2011, March). West-wide climate risk assessments: Bias-corrected and spatially downscaled surface water projections. U.S. Department of the Interior Bureau of Reclamation. Retrieved from http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf

"The major Reclamation river basins listed within the SECURE Water Act are the Colorado and Columbia River Basins and the Klamath, Missouri, Rio Grande, Sacramento, San Joaquin, and Truckee River basins. Reclamation is accomplishing the SECURE Water Act authorities through activities within its WaterSMART Basin Study Program. Surface water projections discusses the technical aspects of modeling predictions. This discussion is very informative if the reader is interested in learning such methodologies. The report also provides the evidence used in 23 the SECURE water report listed above and a range of visual aids."

13. Reclamation: Managing water in the West. U.S. Department of Interior (http://www.usbr.gov/)

"Reclamation is a contemporary water management agency with a Strategic Plan outlining numerous programs, initiatives and activities that will help the Western States, Native American Tribes and others meet new water needs and balance the multitude of competing uses of water in the West. [The] mission [of Reclamation] is to assist in meeting the increasing water demands of the West while protecting the environment and the public's investment in these structures."

14. U.S. Environmental Protection Agency. *Climate change*. Retrieved from http://www.epa.gov/climatechange/

The mission of the U.S Environmental Protection Agency is "to protect human health and the environment."

REPORTS AND STUDIES

1. Hurd, B. H. & Coonrod, J. (n.d.) Climate change and its implications for New Mexico's water resources and economic opportunities, 45. Retrieved from http://aces.nmsu.edu/pubs/research/economics/TR45.pdf

"Social, economic and environmental systems in water-scarce New Mexico and throughout the arid southwest are vulnerable to disruptions in water supplies that are likely to accompany future climate changes. With a particular focus on potential economic consequences for New Mexico, this study uses a hydro-economic model of the Rio Grande watershed to integrate plausible changes in climate with hydrologic responses and water demands within a framework that optimizes water-use allocations for the greatest economic benefit. The study uses three climate change scenarios across two future time periods selected to represent the range of effects indicated by the outputs across eighteen global climate models (GCMs) using the SRES A1B emissions scenario. These six climate change scenarios were then used to model runoff changes using the WATBAL hydrologic model (Yates, 1996), which integrates climate and hydrologic variables, and to change water demand parameters in the hydro-economic model. Primary findings confirm that ecosystems are at greatest risk in New Mexico, followed by agricultural water users, as water is increasingly transferred to maintain urban and industrial users, whose economic productivity is greater. While total annual economic losses are estimated in the vicinity of $300 million, under severe climate changes, where runoff is reduced by nearly 30%, both economic and non-economic losses are likely to be significantly higher. This is due primarily to the effects of some strongly optimistic model assumptions, e.g., assuming no conflicts over water rights or water transfers and to several significant and valuable omissions in the analysis, e.g., the environmental and social services that agriculture and the environment provide."

2. Steenburgh, J., Bowling, D., Garrett, T., Gillies, R., Horel, J., Julander, R., Long, D., & Reichler, T. (2007, Sept). Climate change and Utah: The scientific consensus. *Blue Ribbon Advisory Council on Climate Change*. Retrieved from http://www.highroadforhumanrights.org/wp-content/uploads/2011/02/utah_climate_report_2007.pdf

"As directed by Governor Jon Huntsman's Blue Ribbon Advisory Council on Climate Change (BRAC), this report summarizes present scientific understanding of climate change and its potential impacts on Utah and the western United States. Prepared by scientists from the University of Utah, Utah State University, Brigham Young University, and the United States Department of Agriculture, the report emphasizes the consensus view of the national and international scientific community, with discussion of confidence and uncertainty as defined by the BRAC."

3. Williamson, S., Ruth, M., Ross, K., & Irani, D. (2008, July). Economic impacts of climate change on Colorado. *Center for Integrative Environmental Research University of Maryland.* Retrieved from

http://cier.umd.edu/climateadaptation/Colorado%20Economic%20Impacts%20of%20Climate%20Change.pdf

"Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Colorado and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues."

4. Parra, N., Williamson, S., Ruth, M., Ross, K., & Irani, D. (2008, July). Center for Integrative Environmental Research University of Maryland. *Economic impacts of climate change on Nevada.* Retrieved from http://cier.umd.edu/climateadaptation/Nevada%20Economic%20Impacts%20of%20Climate%20Change.pdf

"Policymakers across the country are now seeking solutions to curb greenhouse gas emissions and to help us adapt to the impending impacts triggered by past emissions. The debate to date has primarily focused on the perceived costs of alternative solutions, yet there can also be significant costs of inaction. Climate change will affect our water, energy, transportation, and public health systems, as well as state economies as climate change impact a wide range of important economic sectors from agriculture to manufacturing to tourism. This report, part of a series of state studies, highlights the economic impacts of climate change in Nevada and provides examples of additional ripple effects such as reduced spending in other sectors and resulting losses of jobs, wages, and even tax revenues."

5. Propst, L. (2010, Jan). Growth and sustainability in the Las Vegas valley. *Sonoran Institute.* Retrieved from http://climatechange.education.unlv.edu/sites/default/files/FinalLasVegasReport12-17-09lores.pdf

"The Las Vegas Valley has made initial steps toward achieving sustainability. Many of the issues facing the Valley have been identified. For most of these, specific strategies and recommendations have been developed. What is needed now is action, with collaborative implementation of the proposed solutions. The current pause in development, occasioned by the national economic downturn and its effects on Las Vegas, provides an excellent opportunity for the city and surrounding area to wholeheartedly embrace sustainability on multiple fronts. This opportunity must be seized if the region is to achieve sustainability and thereby continue to thrive."

6. Carroll, L., O'Connell, A., O'Dell, M., & Wechsler, A. (2009, Sept). League of women voters of Utah water study. *League of Women Voters*. Retrieved from http://lwvutah.org/AirWaterIssues/lwvutWaterStudy_10-10-19.pdf

"Voters of Utah decided to do a study of Utah water so that we could better advocate for our members' deep concerns about water for people and water for the environment. This paper is

concerned with accounting for our water and how we manage it, not with water quality either for human uses or for wildlife."

7. Ackerman, F., & Stanton, E. (2011, Feb). The last drop: Climate change and the southwest water crisis. *Stockholm Environmental Institute*. Retrieved from http://sei-us.org/Publications_PDF/SEI-WesternWater-0211.pdf

   "At present, without climate change, the Southwest is relying on the unsustainable withdrawal of groundwater reserves to meet today's demand; those reserves will be drained over the next century as population and incomes grow. With climate change, the Southwest water crisis will grow far worse. Continuing the current trend in global greenhouse-gas emissions will make the cost of the next century's projected water shortage at least 25 percent higher. Adaptation (conservation and efficiency) measures, however, have the potential to greatly lower water use throughout the region. As climate change exacerbates water woes, some adaptation will be essential to stave off unplanned water shortages and restrictions. Bringing the Southwest's water use down to sustainable levels will necessitate either very strong residential adaptation measures, or a combination of strong agricultural adaptation measures (including the elimination of some low-value crops) and moderate residential measures."

   This study was funded by the Kresge Foundation, a nonprofit private foundation that "works to expand opportunities in America's cities through grant making and investing in arts and culture, education, environment, health, human services, and community development efforts in Detroit."

8. Weldon, A., Scholley, S., & Stewart, M., Ruedy, J. (2010, April). Water resources. *Research Division Legislative Counsel Bureau Nevada State Legislature.* Retrieved from http://www.leg.state.nv.us/Session/76th2011/Exhibits/Assembly/NRAM/ANRAM111H.pdf

   "... Nevada's population explosion, coupled with the ongoing drought... make determining the sustainability of groundwater sources a critical concern. Conservation measures, water banking, water transfers, and conversions of water to new uses are possible sources of relief, as is the promise of desalination in the future. Nevada at the present has adopted the prior appropriation doctrine, which states that water must be put to 'beneficial use' and maintains the priority clause…. Water belongs to public NRS 533.025 'The water of all sources of water supply within the boundaries of the State whether above or beneath the surface of the ground, belongs to the public.'"

9. Nevada EPSCOR. (2009, Feb). *ERTAB meeting: Nevada infrastructure for climate change science, education, and outreach* [Powerpoint slides]. Retrieved from http://epscorspo.nevada.edu/nsf/climate1/ertab/Feb52009ERTABmeetingNevadaEPSCoRDana.pdf

   "The vision of this project is to create a statewide interdisciplinary program that stimulates transformative research, education, and outreach on the effects of regional climate change on ecosystem services (especially water resources) and support use of this knowledge by policy makers and stakeholders."

10. Bardino, M. (2009, Dec). Governor Bill Richardson signs climate change executive order. Retrieved from https://www.env.nm.gov/OOTS/documents/PR-GovExecCCOrder-12-7-09.pdf

"Recognizing the profound implications that global warming and climate variation could have on the economy, environment and quality of life in the Southwest, New Mexico Governor Bill Richardson signed executive order."

11. Alexander, P., Brekke, L., Davis, G., Gangopadhyay, S., Grantz K., Hennig, C., Jerla, C., Llewellyn, D., Miller, P., Pruitt, T., Raff, D., Scott, T., Tansey, M., & Turner, T. (2011). SECURE water act section 9503(c): Reclamation climate change and water 2011. *U.S. Department of Interior Policy and Administration Bureau of Reclamation*. Retrieved from http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf

"Acknowledging the uncertainties associated with future climate and associated potential impacts, the Omnibus Public Land Management of 2009 (Public Law 111-11) Subtitle F – SECURE Water authorized Reclamation to continually evaluate and report on the risks and impacts from a changing climate and to identify appropriate adaptation and mitigation strategies utilizing the best available science in conjunction with stakeholders."

12. Reed, K. (2005, Feb). Renegotiating urban water management in Flagstaff, Arizona. *University of Arizona*. Retrieved from http://www.usbr.gov/lc/phoenix/reports/ncawss/allfiles/09_CL1-04ThesisFlagstaffH20Mngmnt.pdf

"The rise of water conservation measures in municipalities in the western United States is often attributed to drought stress and increasing urban populations, and I suggest it signals the emergence of a management model based on resource sustainability that intends to incorporate 'nature' into management decisions. Drawing from archival data, I trace socioeconomic and biophysical factors that led to the implementation of conservation measures in Flagstaff, Arizona. A content analysis of contemporary water problems, their causes, and potential management responses informed by semi-structured interviews with key water policymakers in the area, representatives from community interest groups, and scientists indicates that more than three times as many informants, including those with historically opposing viewpoints, prefer conservation measures over supply augmentation policies. Contributing to the broad political ecology literature, I incorporate concepts introduced by ecological Marxism and the social production of nature literature to interpret the popularity of conservation measures and suggest some subsequent implications."

13. Cohen, M. (2011, June). Municipal deliveries of Colorado Basin water. *Pacific Institute*. Retrieved from http://pacinst.org/wp-content/uploads/sites/21/2013/02/crb_water_8_21_2011.pdf

"The iconic Colorado River supplies water to millions of people in fast-growing cities in the Colorado River's watershed, such as Las Vegas, Mexicali, Phoenix, and St. George, Utah (see Figure ES-1 at the end of the Executive Summary). Tens of millions of people outside the watershed, from Denver to Albuquerque and from Salt Lake City to Los Angeles, San Diego, and Tijuana, also receive water exported from the basin to meet at least some of their residential and commercial water needs. More than half of the people receiving water from the basin live in southern California. In fact, about 70 percent of the people that receive water from the basin do not actually live in the basin. This study reports population and water delivery data and

trends for 100 cities and water agencies that use Colorado River basin water, compiling such information for the first time in one location."

SECONDARY SOURCES: NEWSPAPER ARTICLES

1. Zabarenko, D. (2011, April 25). Climate change to hit American water supply. Retrieved from http://www.trust.org/item/?map=climate-change-to-hit-american-west-water-supply

   Climate change is predicted to cut water flow in some of the American West's biggest river basins - including the Rio Grande and the Colorado - by up to 20% this century, according to the Interior Department. "Irrigation, drinking water to be affected by 2100… Driest areas are also some of the most heavily populated… Interior Department calls for conservation and efficiency."

   This article is a summary a 2011 report prepared by the Interior department, this information, particularly the predicted values, may be outdated. The Thomson Reuters Foundation is the charitable arm of Thomson Reuters. The Foundation aims to advance independent journalism, human rights, women's rights, and the rule of law. The Thomson Reuters Foundation does not have a financial interest in water supplies of the American west.

2. Klein, E. (2010, Feb 10). No, the snow does not disprove global warming. *The Washington Post*. Retrieved from http://voices.washingtonpost.com/ezra-klein/2010/02/no_the_snow_does_not_disprove.html

   Earth's atmosphere is getting warmer, but it affects different regions in different ways, so the snow in Washington, DC does not indicate global warming is a hoax. "What's difficult about getting it to snow isn't temperature, but precipitation. And global warming is expected to increase precipitation."

3. Sweet, P. (2008, June 1). Quenching Las Vegas' Thirst. When will Las Vegas run out of water? With expected changes in climate and no change in future water usage, Lake Mead could run dry by 2021. *The Las Vegas Sun*. Retrieved from http://lasvegassun.com/news/topics/water/

   A Colorado River reservoir in Lake Mead accounts for 90% of the valley's water supply, but the reservoir levels have been falling steadily for a decade. Southern Nevada water managers are calling for a halt in development in the region and to construct a pipeline to draw groundwater stored in rural Nevada to Las Vegas. This news piece has interactive elements and displays a countdown to when Las Vegas will run out of water if a pipeline isn't built. "They say no amount of conservation can replace the need for this backup source of drinking water." Opponents to the pipeline say it would sacrifice the ranching way of life in Eastern Nevada.

4. Loomis, B. (2011, April 26). Report: Climate change to sap Utah water supply. T*he Salt Lake Tribune*. Retrieved from http://www.sltrib.com/sltrib/politics/51690000-90/report-colorado-river-climate.html.csp

   "The Colorado River Basin likely will lose about 9 percent of its annual runoff by mid-century because of a warming climate, further squeezing Utah and its neighbors in a region that already

expects to struggle getting water to its growing population, according to a U.S. Interior Department report released in 2011."

This article cites the same Interior Department report the Thomson Reuters Foundation did. The 2011 predictions will be off as rate of climate change alters.

5. Gertner, J. (2007, Oct 21). The future is drying up. *The New York Times*. Retrieved from http://www.nytimes.com/2007/10/21/magazine/21water-t.html?pagewanted=print

The snowpack in the Sierra Nevada that provides most of the water for Northern California is at its lowest level in 20 years. The most optimistic climate models for the second half of this century suggests that 30 to 70% of the snowpack will disappear. This, will reduce the flow of the Colorado River, which is a major supply in the intermountain west. "One study in particular, by Martin Hoerling and Jon Eischeid, suggests the region is already 'past peak water,' a milestone that means the river's water supply will now forever trend downward."

This article was corrected in November of 2007. The climate models referenced in this article are now outdated, but they still provide a rough trajectory climate change was thought to follow in 2007.

6. Kotler, S. (2010, July 2). Steady state: A sustainable economy for the Southwest. EcoHearth. Retrieved from http://ecohearth.com/eco-op-ed/482-steady-state-a-sustainable-economy-for-the-southwest.html

"Western states rely on the Colorado River, but the river is no longer viable. Last year, a study done at the Scripps Institution of Oceanography (published in Water Resources Research) compared water usage 28 to population, then factored in a variety of global-warming possibilities. It concluded there is now a 50- 50 chance both Lake Mead and Lake Powell—the Colorado's major feeders—will be bone dry by 2021. And since the entire area runs on hydroelectric power, the study also found that this energy tap could be turned off by 2017."

This article was lasted edited on May 22, 2014.

7. McCool, Dan. (2010, April 20). Colorado River policy faces an age of limits. The Salt Lake Tribune. Retrieved from http://www.sltrib.com/opinion/ci_14921852

Climate scientists are predicting a 10-to-30 percent reduction in flow for the Colorado—a stark contrast to the rosy assumptions that underlay the Colorado River Compact when it was signed 88 years ago. Researchers from the Scripps Institution of Oceanography recently predicted that Lake Mead and Lake Powell have a 50 percent chance of going dry by 2021. These days, Lake Mead is at 45 percent capacity and Lake Powell is at 57 percent.

8. Mulkern, A. (2015). Reclamation provides $50M in grants to parched West. E&E. Retrieved from: http://www.eenews.net/greenwire/stories/1060018963/search?keyword=water+sustainability+arizona

The Obama administration will be spending nearly $50M on water conservation in 12 western states. Reclamation will spend around $24M in grants for 50 water/energy efficiency projects in

the Intermountain West as well as Montana, Nebraska, Oregon, Texas, and Washington. California will be receiving $23M.