SWRR

Sustainable Water Resources Roundtable

DOE, National Renewal Energy Laboratory
Golden, Colorado July 19, 2016

Water & Energy Issues in the West

Proceedings:

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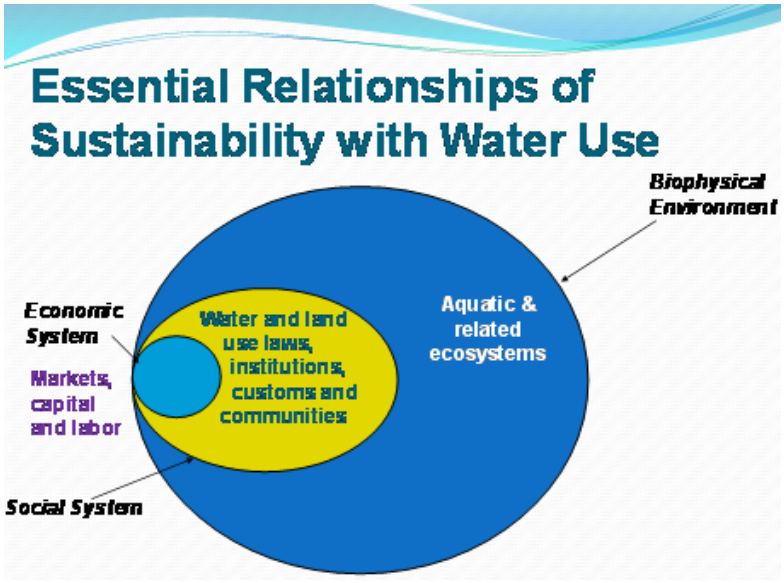
SWRR Activities & History: David Berry, SWRR Facilitator davidberry@aol.com

David Berry began by summarizing the origins of the Sustainable Roundtable in 2002 at a meeting of the Interagency Working Group on Sustainable Development Indicators. After presentations on the Roundtable on Sustainable Forests, the meeting participants agreed that a Water Roundtable would be useful. The group has had over 1,000 participants from federal, state, and local governments; corporations; nonprofits and academia. Meetings have alternated between Washington, D.C. and locations around the country including California, Colorado, Florida, Maryland, Michigan, Minnesota, New Hampshire, and Virginia.

SWRR includes many aspects of water when considering sustainability:

- **Water availability**
- **Water quality**
- **Human uses and health**
- **Environmental health**
- **Infrastructure and institutions**



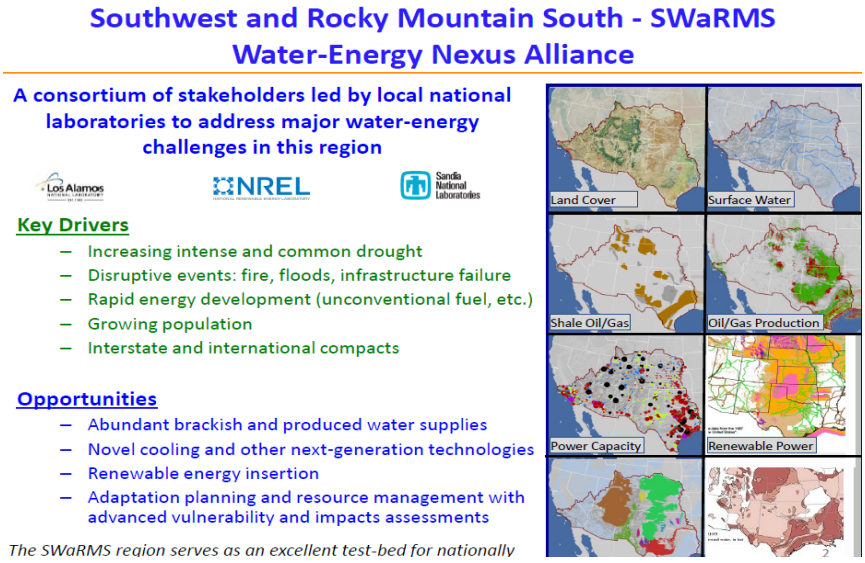
Berry said that Sustainability requires:

- Systems Thinking & a Holistic Approach
- Awareness of Time Horizons, Scales, Trajectories
- Managing Risk & Uncertainty
- New Tools
- Common Ground for Solutions
- Continuous Education

He concluded by telling the participants that once they step into a SWRR meeting, they are not observers but part of the Sustainable Water Resources Roundtable

Southwest & Rocky Mountain South (SWaRMS) Water-Energy Nexus Alliance:
Jordan Macknick, NREL jordan.macknick@nrel.gov

Jordan Macknick began his presentation with an overview of the genesis of The Southwest & Rocky Mountain South (SWaRMS) Water-Energy Nexus Alliance. SWaRMS is a consortium of stakeholders led by local national laboratories to address major water-energy challenges in this region. SWaRMS developed out of a number of meetings and reports addressing these challenges.



The SWaRMS Mission (Draft): Total Water-Energy Management. *With sparse and near-fully subscribed water availability in the SWaRMS region, the alliance will focus on integrating modeling and data analysis capabilities, advancing deployment of new technologies, and actively engaging stakeholders to enable optimal planning and management of regional water and*

A SWaRMS strategy kickoff meeting was held June 24, 2014. Twenty-one representatives from federal and state agency, NGO, legislative, academic, and industry communities attended. The major outcomes of the meeting were unilateral support of participants for an integrated, multi agency, regional, research and development program to address unique energy and water issues in the Southwest and Southern Rocky Mountains; and the emergence of regional water energy themes. Two topic specific meetings followed in 2015.

Colorado Energy Water Food Meeting – August 4, 2015. The outcomes of this meeting included the following:

- Support of the need for an integrated, multi agency, regional, research and development program to address region specific energy and water issues
- Unique CO focus on challenges
- Increasing variability in all dimensions
- Downstream surface water user impacts on both agriculture and municipalities
- Need for on-site, real-time measurement and monitoring (biocides, inhibitors, frack flowback, etc.)
- Life Cycle Assessment relative to energy-water-food
- Water treatment, waste water reuse and energy generation, alternative water storage and distribution, use of renewables for water treatment
- Climate change impacts on watersheds and water resources

SWaRMS Water-Energy Alliance Research
Strategic Case Studies

Multi-disciplinary approach to addressing complex interconnected issues:

- Data, Modeling, and Analysis
- Advanced Technology Development and Deployment
- Policy and Stakeholder Engagement

SWaRMS Regional Meeting – September 23, 2015. The SWaRMS region serves as an excellent test-bed for nationally important water-energy challenges and opportunities. Four key strategic areas were identified to pursue research opportunities and case studies.

1. Alternative Water Utilization The use of alternative water resources, including brackish groundwater and O&G produced water, to meet shortfalls in freshwater supplies
2. Energy planning under climate uncertainty Climate change impacts and decision support for energy development planning under changing water supply conditions
3. Low-Water Energy Reducing the dependency and vulnerability of the energy system on freshwater resources, as it relates to the development of the transportation sector, thermoelectric generation, and hydropower
4. Co-management of energy and water Co-management of energy and water resources through distributed and centralized infrastructure and operational decision-making frameworks

Macknick concluded by describing the ongoing steps and future directions of the Alliance.

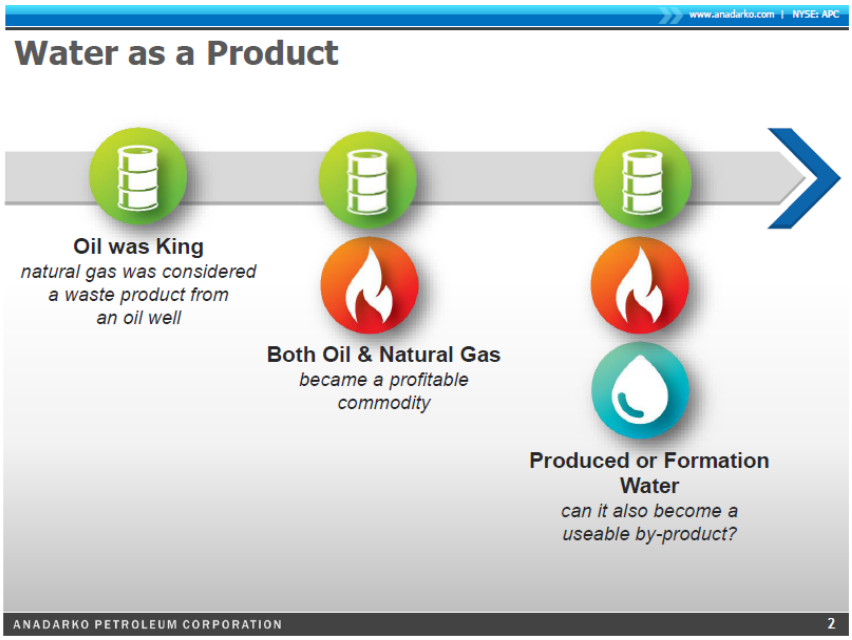
- Continued engagement with regional and federal stakeholders
- Further development of case study research plans and partnerships
- Identification of specific test bed research facilities
- Regional meetings and forums
- Leveraging strategic case studies to undertake long-term projects

SWaRMS Organizing Committee: Mike Hightower, Stephanie Kuzio, Tom Lowry, Jordan Macknick, Richard Middleton, Robin Newmark, Jeri Sullivan Graham, Vince Tidwell, Cathy Wilson, Andrew Wolfsberg,

Panel on Produced and Brackish Water: Moderator, Mike Hightower, Sandia National Laboratories mmhight@sandia.gov

Produced Water: **Jill Cooper, Anadarko Petroleum Corporation, HSE Manager Data, Advocacy and Reporting** www.anadarko.com

Although oil and gas production is not a significant user of water compared to other sectors, according to Jill Cooper they can play a significant role in water production. Colorado OGCC projected that water usage for oil and natural gas is about 0.08% of total water use in Colorado for example and EPA projected nationwide upstream water use is >1% of total water use.



Produced water is generated from most actively producing oil and natural gas wells in the United States. The cost of managing the water is the key consideration in this. Wells will typically produce energy for 30 years but each has a different “water profile” and needs to be managed accordingly.

Cooper described ways in which oil and natural gas can be an important part of the water solution.

- *Opportunities*
  - Water sourcing, management and disposal
  - Can bring “trapped water” to the surface –net gain to the system
  - Collaboration is important to achieve progress
- *Actions necessary to maximize opportunities*
  - Invest in improvements in water treatment technologies
  - Reduce the cost of water treatment
  - Support laws and regulations that allow the beneficial reuse of water
  - Identify entities interested in accepting the treated water
  - Educate the general public around water in general

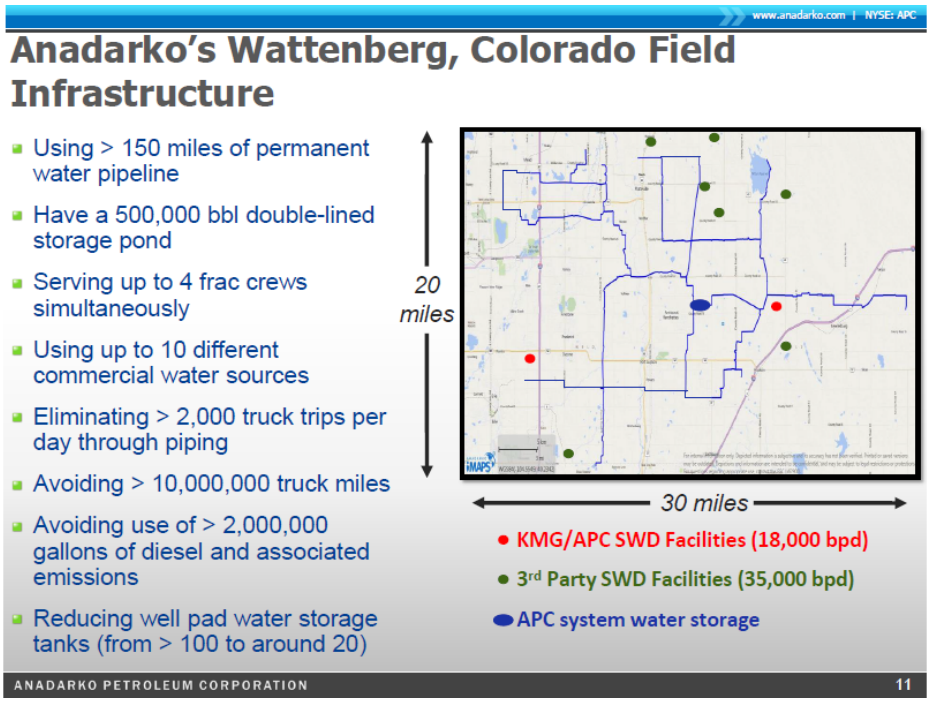
The Energy Water Initiative (EWI) was established in response to public and stakeholder interest in the link between energy and water. EWI is a collaborative effort to study, communicate, and improve lifecycle water use and management in onshore oil and natural gas exploration and production. Technology and knowledge-sharing; recommended management practices and technologies; and fact-based information to stakeholders are elements of their mandate. EWI follows API's anti-trust provisions during all meetings and discussions. EWI Partners include major energy corporations such as Anadarko, ConocoPhillips, Cheseapeake Energy, and XTOEnergy, Inc.

Cooper gave examples from a 2015 EWI case study that found several industry trends leading to marked benefits.

1. Improving Fracturing Chemistry - - Increasing use of non-fresh water
2. Innovation in Treatment Technology - - Increasing feasibility of produced water reuse
3. Increasing Water Conveyance Systems - - Reducing truck traffic
4. New Water Storage Designs - - Provides flexibility and reliability when using non-fresh water
5. Trend: Increasing Transparency - - Improves relationships with stakeholders
6. Dedicated Water Staff - - Improves water management, planning technical support and performance

She listed several of Anadarko's Water Management Objectives of their operation at Wattenberg, CO

1. Make responsible use of flowback and produced water
2. Ensure water management issues do not impact oil production
3. Decrease dependence on saltwater disposal (UIC) wells
4. Reduce demand for fresh water supplies
5. Reduce trucking traffic
6. Reduce COGCC reportable spills
7. Maximize use of existing field infrastructure
8. Improve stakeholder relationships within the Region



Cooper concluded with a few examples of what Andarko's water programs can include:

- Outreach to build stakeholder confidence
- Collaboration with other operators, universities, and agencies
- Building infrastructure improvements to meet partner needs
- Innovating for regional water benefits
- Recycling and using produced water to conserve and maximize fresh water
- Building efficient redundancy and reliability into the system

Advanced Water Treatment: Yuliana Porras-Mendoza, U.S. Bureau of Reclamation Research & Development Office yporrasmendoza@usbr.gov www.usbr.gov

The Bureau of Reclamation was established in 1902. It constructs dams, power plants, and canals in 17 western states. The Bureau manages, develops, and protects water and related resources in an environmentally and economically sound manner in the interest of the American public.

In her presentation, Yuliana Porras-Mendoza discussed three of the Bureau's Research and Development Office Programs.

- Science & Technology Program (S&T)
  - Reclamation researchers
  - Various research topic areas
- Desalination and Water Purification Research Program (DWPR)
  - External funding
  - Brackish Groundwater National Desalination Research
  - Facility (BGNDRF); Alamogordo, NM
- Other Reclamation Facilities
  - Water Quality Improvement Center (WQIC); Yuma, AZ
  - Denver Water Lab; Denver, CO

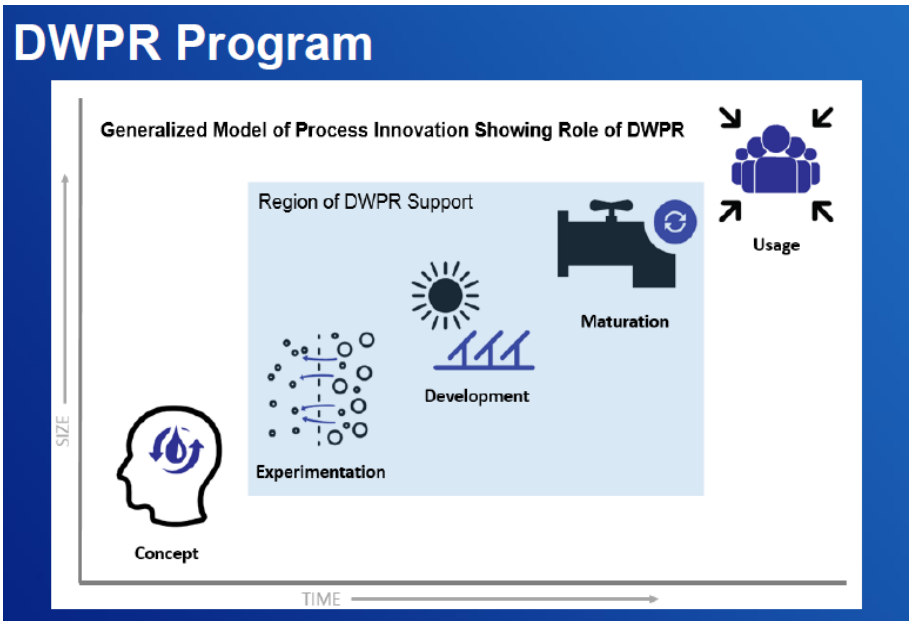
S&T is a Reclamation-wide competitive, merit-based applied research and development program. Reclamation employees are the principal investigators with partners from stakeholder, university, non-profit organizations, private sector, and other local/state/federal entities

Advanced water treatment research

- Produced Water
  - Summary of Current Research on Produced Water Treatment;
  - Dr. Katie Guerra, kguerra@usbr.gov
- Concentrate Management
  - Toolbox; Saied Delagah, sdelagah@usbr.gov
  - Partners: North Texas Metropolitan Water District and Eastern Municipal Water District
- Pitch to Pilot Funding Opportunity
  - New cooperative agreement competition
  - Seeking innovative pilot scale water treatment technologies and processes for inland desalination
  - Feature a unique competition approach designed to accelerate proposal review and selection
  - Deadline to apply July 27, 2016
  - Award up to $100,000 per project for up to 3 projects
- Prize Competitions – Water Prize Competitions
  - Aquatic Ecosystem Restoration
    - Sediment management
    - Recovering/Protecting threatened and endangered aquatic species
  - Infrastructure Sustainability

- Water storage and delivery infrastructure
- Hydropower infrastructure

- Water Availability
  - Creating useable water supplies through water treatment
  - Water supply forecasting and management



DWPR Program

- Brackish Groundwater National Desalination Research Facility – Alamogordo, NM
  - Focal point for developing and testing of technologies for the desalination of brackish and impaired water found in the inland states
  - Opened on August 16, 2007
  - Clients: federal/state/local agencies, academia, private sector, research organizations

- Program focuses on funding research to augment water supplies
  - Focus on reducing cost, energy, and environmental impacts

- Three funding opportunity announcements
  - Laboratory studies (up to $150k per project; 13 months)
  - Pilot scale (up to $400k per project; 24 months)
  - Demonstration scale (up to $1.5m per project; 36 months)

- DWPR Program FY 16
  - Selected 12 projects for a total of $1.8 million: 9 projects laboratory studies; 3 pilot projects

Utilities' Work with Brackish Water: Robert Renner, Water Research Foundation
RRenner@WaterRF.org

Robert Renner announced to the group that 2016 is the 50th anniversary of The Water Research Foundation (WRF). WRF is a research cooperative governed by utilities with over 1,000 subscribers and partners and over $500M of research.

He began by laying out some of the potential benefits of traditional water supply planning.

- Predict Demand
- Obtain surface or groundwater supply with sufficient estimated yield
- Develop infrastructure and policies to maintain quality of service

He then noted that changes in how we use land and water challenge these traditional approaches:

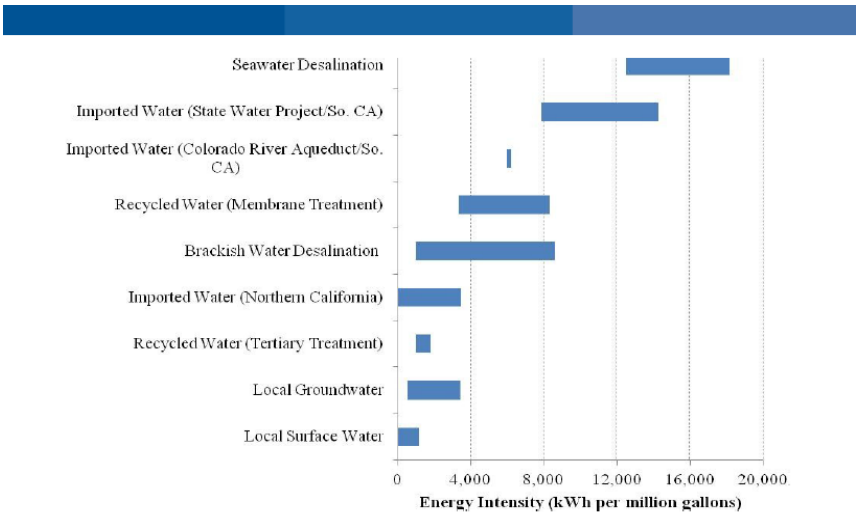
- Maturation of land use development and subsequent water use development
- Shifts in social value - from exploitation to stewardship of resource
- Emerging understanding of uncertainty factors and impact on: water supply availability; water demands; water quality

Meeting new challenges requires new planning approaches. Some of these are already being utilized. [WEF Project 4615, Evaluating Alternative Water Supplies to Balance Cost with Reliability, Resilience, and Sustainability]

- Incorporate risks and uncertainties
- Evaluate reliability, resilience, vulnerability, sustainability
- Look at Alternative Supplies like reuse and desalination

Renner noted some considerations for utilities in decision-making. [WRF project 4615: Framework for Evaluating Alternative Water Supplies: Balancing Cost with Reliability, Resilience, and Sustainability]

- Cost
- Environmental benefits: IPR/DPR/brackish desalination
- Regulatory considerations: brine disposal
- Local hydrology/geology/climate
- Resilience, reliability, sustainability



Comparison of the Energy Intensity of California Water Supplies
Sources: Veerapaneni et al. 2011; GWI 2010; Cooley et al. 2012; GEI Consultants/Navigant Consulting, Inc. 2010; pulled from http://pacinst.org/desal-and-energy-use-should-we-pass-the-salt/

Renner than turned to the issue of how to work with brackish water.

Brackish Desalination or Reuse?

- Energy Use: Brackish desal and reuse can have similar energy requirements: Improved energy efficiency in both reuse and desalination technologies in recent years
- Environmental Impact: Both have environmental benefits and costs

Brackish Desalination: Most brackish plans are in CA, FL, TX: Texas 34 with total of 73 MGD;
FL >100 Site-Specific Considerations:

- Regulatory considerations (state, local); FL allows concentrate to land because low salinity
- Local hydrology, geology, and climate: FL and TX use UIC due to unique geology

Advantages of Brackish Desal:

- Preservation of fresh water aquifers
- More suitable to small utilities: well and treatment; typically have lagoons
- Cost: $1.50 per 1000 gallons

Brackish Desal Considerations:

- Concentrate disposal
- Energy costs: largest single variable cost; electricity prices are projected to rise

DPR ENERGY USAGE

Technology/water source	Energy required			Carbon footprint kg CO_{2e}/10^3 gal
	Range, kWh/10^3 gal	Typical		
		kWh/10^3 gal	kWh/m^3	
Secondary treatment without nutrient removal	1.35 – 1.05	1.25	0.33	0.63
Tertiary treatment with nutrient removal effluent filtration	1.95 – 1.60	1.85	0.49	0.93
Advanced water treatment	3.25 – 3.50	3.30	0.87	1.65
Ocean desalination	9.50 – 14.75	12.00	3.17	6.00
Brackish water desalination	3.10 – 6.20	5.85	1.55	2.93
Interbasin transfer of water, California State Water Project	7.92 – 9.92	9.20	2.43	4.60
Interbasin transfer of water, Colorado River water	6.15 – 7.40	6.15	1.62	3.07
Conventional water treatment	0.30 – 0.40	0.37	0.10	0.19
Membrane-based water treatment	1.00 -1.50	1.25	0.33	0.63

OCWD actual energy usage

Source: Tchobanoglous, 2015:
http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/recharge/rw_swa_dprexpertpanel/item05-tchobanoglous.pdf

Chemical Considerations for an Updated National Assessment of Brackish Groundwater Resources: Pete McMahon, USGS

pmcmahon@usgs.gov Co-authors: J.K. Böhlke, J. Stanton, K. Dahm, D. Parkhurst, D. Anning.

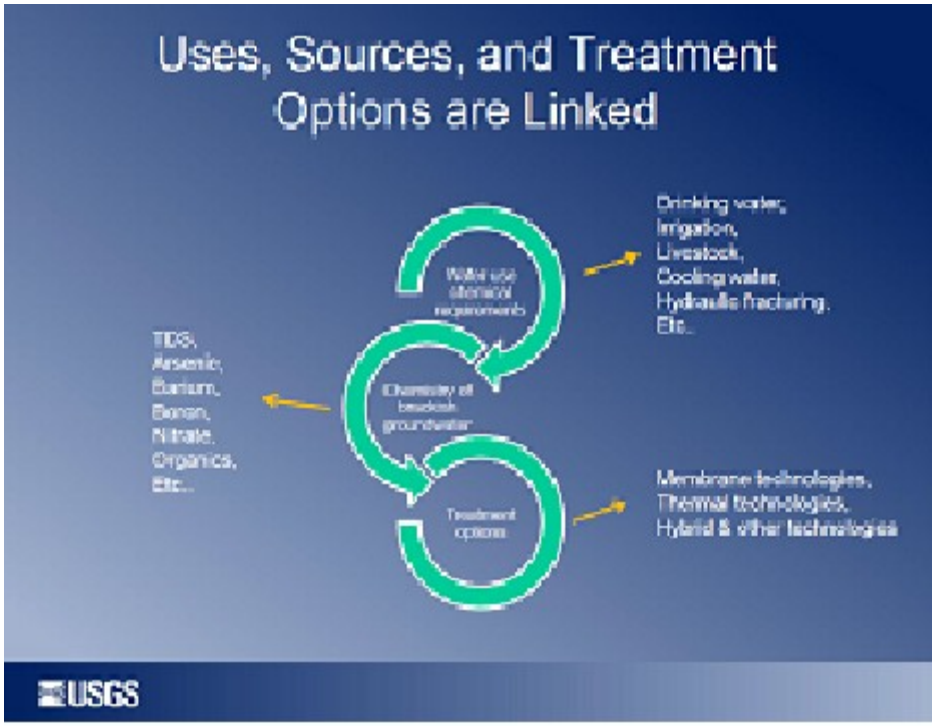
A starting point for Pete McMahon and his co-authors was Section 9507(c) Brackish Groundwater Assessment of the 2009 SECURE Water Act, which stipulates, "Increase the acquisition and analysis of water resources for irrigation, hydroelectric power, municipal, and environmental uses, and for other purposes."

McMahon began by defining brackish water as 1,000 to 10,000 mg/L total dissolved solids (TDS), and followed with a description of the major components of his study.

1. Compile readily available information
2. Generate national maps of total dissolved solids (TDS) concentrations and other chemical characteristics
3. Describe chemical and physical characteristics of brackish aquifers
4. Describe current brackish groundwater use
5. Identify data gaps

Existing data on water quality were compiled:

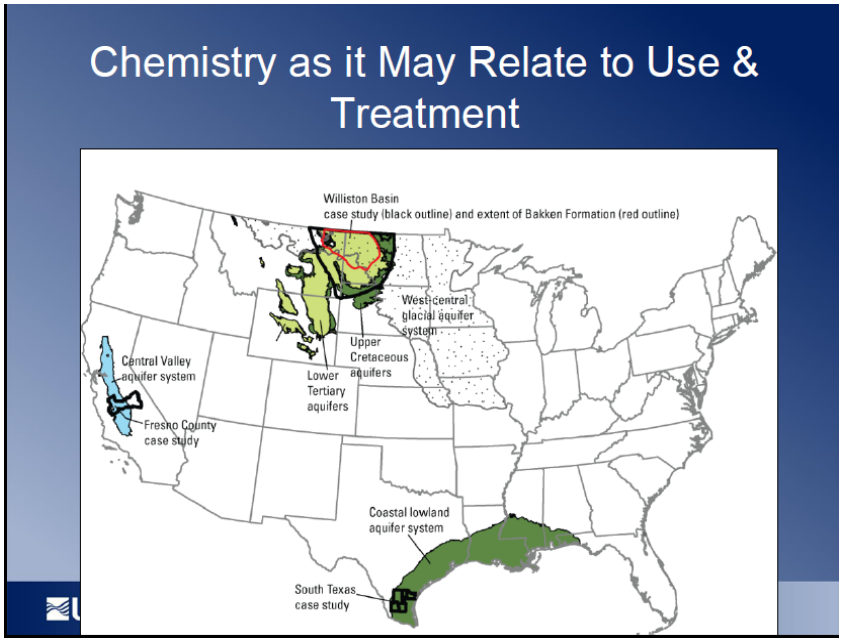
- Site/well information, TDS, field parameters, major ions, most trace elements, nutrients, tritium, radium
- Sources (35 data sets)
  - Federal agencies
  - National Geothermal Data System (Geo-Heat Center)
  - State agencies
  - Selected reports
- Over 1.4 million water-quality samples compiled

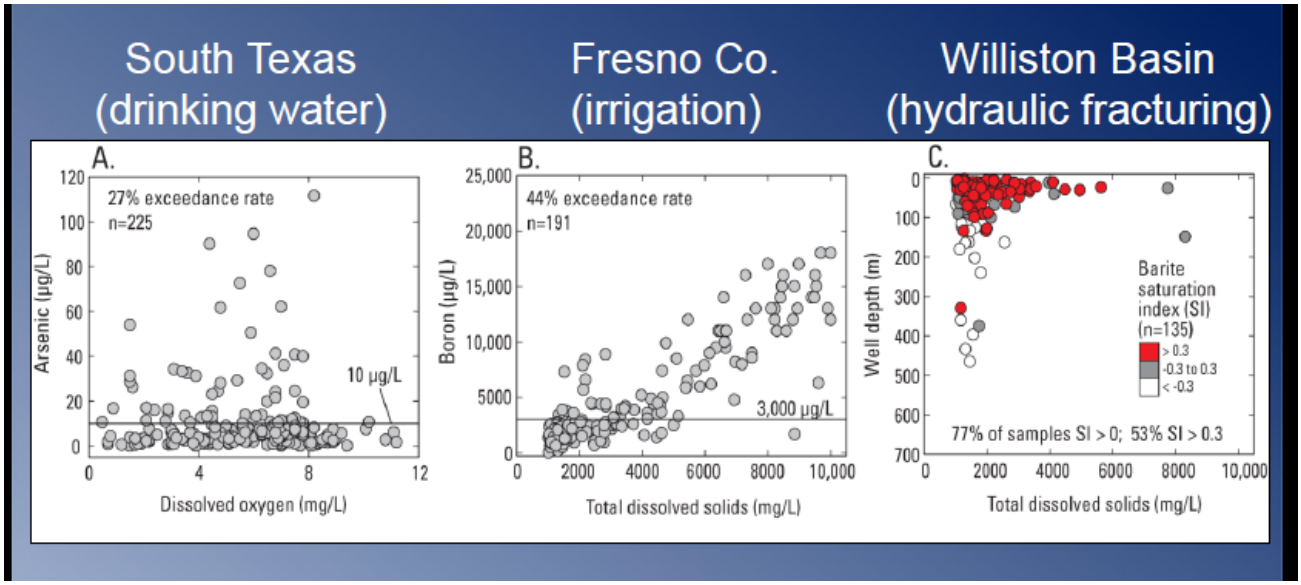


- About 380,000 sites met data needs of the study

The availability of Brackish Groundwater was assessed

- Physical factors
  - Volume & depth
  - Porosity & permeability
  - Connectivity with other water-bearing units
- Chemical factors
  - Chemical requirements of proposed use
  - Chemical characteristics of the resource
  - Treatment options to make resource compatible with use





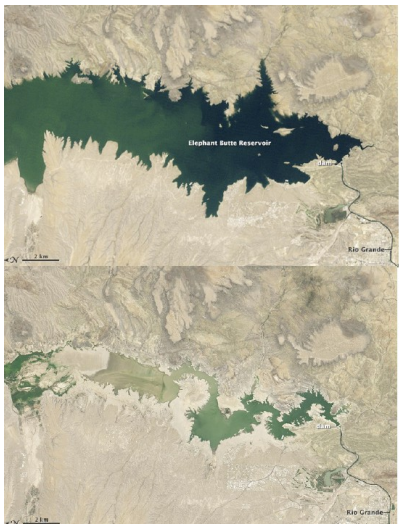
McMahon ended with a set of conclusions from the study.

1. National assessment that includes chemical characterization could provide a useful framework for understanding the overall availability and limitations of the resource.
2. Assessment of the most prevalent water-quality problems associated with BGW could help guide research and development efforts related to treatment technologies.
3. Thorough compilation of existing data could improve understanding of the spatial variability in key geochemical characteristics that are important with respect to use and treatment requirements.

Water and Energy Data, Science, and Policy in New Mexico-a Balancing Act on the Edge of Drought: Dr. Jeri Sullivan Graham, Los Alamos National Laboratory & NM Energy, Minerals, and Natural Resources Department (EMNRD)

ejs@lanl.gov; 505-695-4875 Jeri.sullivangraham@state.nm.us

Jeri Sullivan Graham gave the group some background on the acute issues of water availability in New Mexico. NASA Landsat images of Elephant Butte Reservoir give an alarming example of the problem.

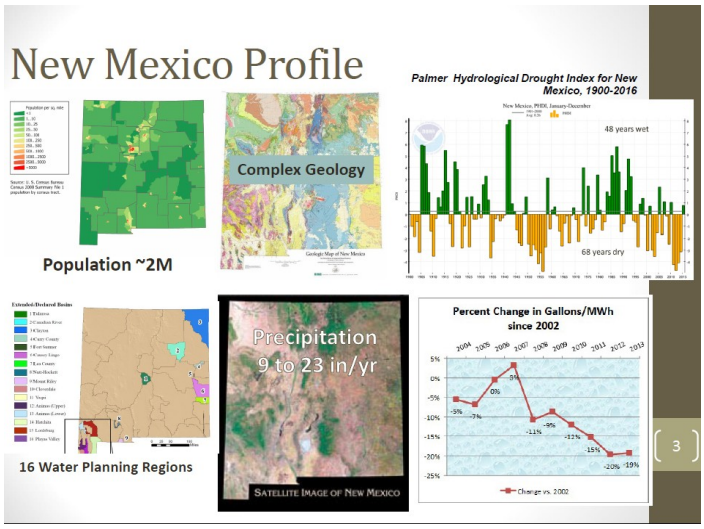


Elephant Butte Reservoir
NASA Earth Observatory
Landsat 8 images

Acquired June 2, 1994
89% of maximum
(2.2 Maf)

Acquired July 8, 2013
3% of maximum

http://earthobservatory.nasa.gov/IOTD/view.php?id=81714



Sullivan Graham then described some of the critical issues regarding water and energy in New Mexico:

- Our water is fully allocated and so future generation and production must adapt
- Options to explore: alternative water resources for oil and gas and improved use/reuse of fresh water for power generation.
- Balance multiple outside issues and regulatory pressures to keep the sales price of electricity low and still use less water; keep the cost of oil and gas production low and better manage water
- Incorporating the cost of infrastructure adaptation into the price of electricity and into oil and gas production is an ongoing process.
- The effects of extreme events and watershed damage are a current challenge and expected to increase in significance

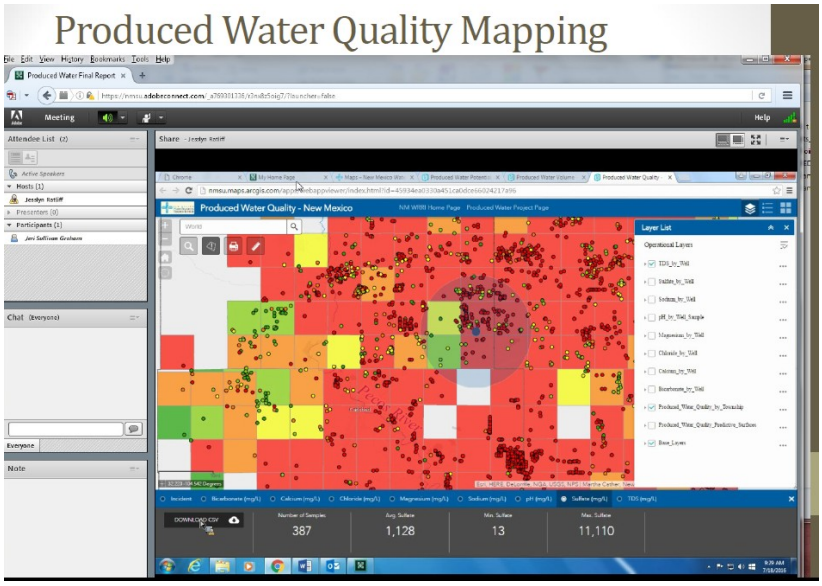
A partnership between the State and Los Alamos National Lab was formed to assist in EWN Policy. Its role includes:

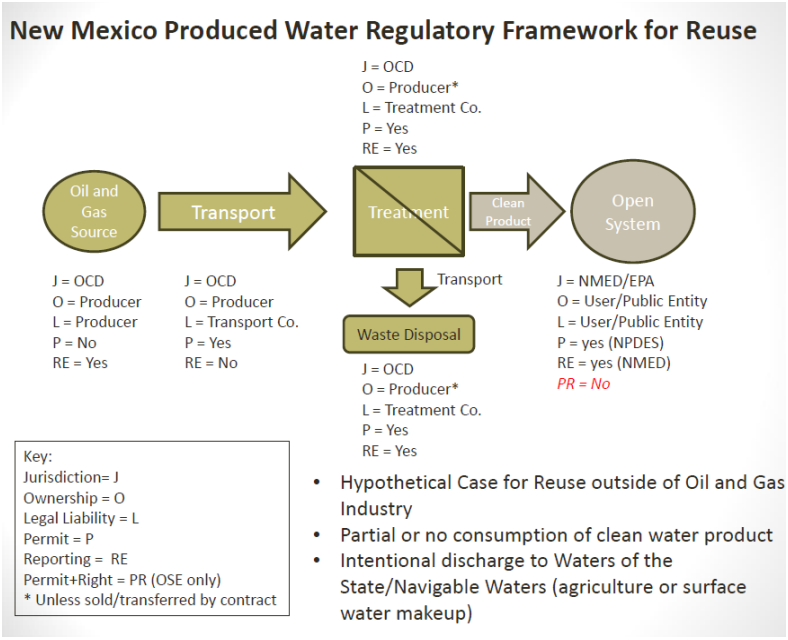
- New water resources-Brackish, Produced, Wastewaters
  - Regulatory “square peg” problem
  - Inform with a “neutral science” perspective
  - Result: new produced water regulations for reuse/recycling

- Coordinate research and inform research dollars to be spent
  - Point out why funding resource is appropriate for unusual case
  - Result: NMED awards EPA funds to NMWRRI team for produced water reuse research (research completed June 30, 2016)

- Coalesce groups around science-informed concepts
  - Build a Brackish water working group

- Informing multiple agencies-NMOSE, EMNRD, NMED
- Result: budget request for research dollars in NM FY16 budget and agency refocusing to include brackish water as a resource





Sullivan Graham's current study addresses the feasibility of utilizing produced water to improve drinking water supply in Southeastern New Mexico.

- Collaboration between Water Resources Research Institute (NMSU), Petroleum Recovery Research Center (NMT), EMNRD, & Los Alamos National Laboratory
- Funded by USEPA/New Mexico Environment Department-Source Water Protection grant funding
- Inventory of produced water locations, quantities, and quality
- Mapping products for analysis
- Regulatory analysis for uses within and outside of oil and gas industry

- Update and reissue of the PRRC Produced Water database
- Treatment methods and cost analyses

Discussion

Q: Regarding produced Water. What is yield variance on location? What are records/reporting on yield/time variability?

A: (JSG) Records and reporting follow state-specific processes. For New Mexico, reporting on produced and re-injected water is good. However, state sources are scarce on fracking.
A: (JC) For Anadarko, produced water is cost-tracked (amount & transportation costs). Use of 30-60 wells.

Q: What reuse options are employed for produced water?

A: (JC) We try when possible. There are many well-bore considerations (contamination re-injection etc). Completions have more flexibility over past years (currently 95%). For company purposes, we cannot use recycled, retreated produced water unless it is of extremely high quality.
A: (JSG) Reuse based on location & lease, and infrastructure development. Trucking transport is very ineffective; some third party infrastructure and treatment solutions exist.

Q: What are current solutions for disposal of brackish water?

A: (YP) it's dependent upon quality, location & cost. Deep well injection, evaporation, halophytes, zero liquid discharge.
A: (RR) Usually use deep well injection in natural caverns provide the best cumulative results.

Q: Regarding statistics were given on recoverability of 25%-50% of brackish water and 25% produced water. Based on current conditions, what is the availability/practicality of these resources?

A: (PM) Those projections may be higher than actual yield.
A: (YP) Dependent upon cost on conversion. [*this appeared to be panel consensus*]
A: (RR) Waste water is still more practical for use than groundwater/brackish water. There are some issues with California desalinization plants (ozone effects, lawsuits).
A: (JC) Discharge permit allows recycled & reused applications. Private industry would benefit from accurate education to inform policy and public perception. The public is very unaware of private industry cooperation with state, federal, and other private partnerships that optimize resource use.

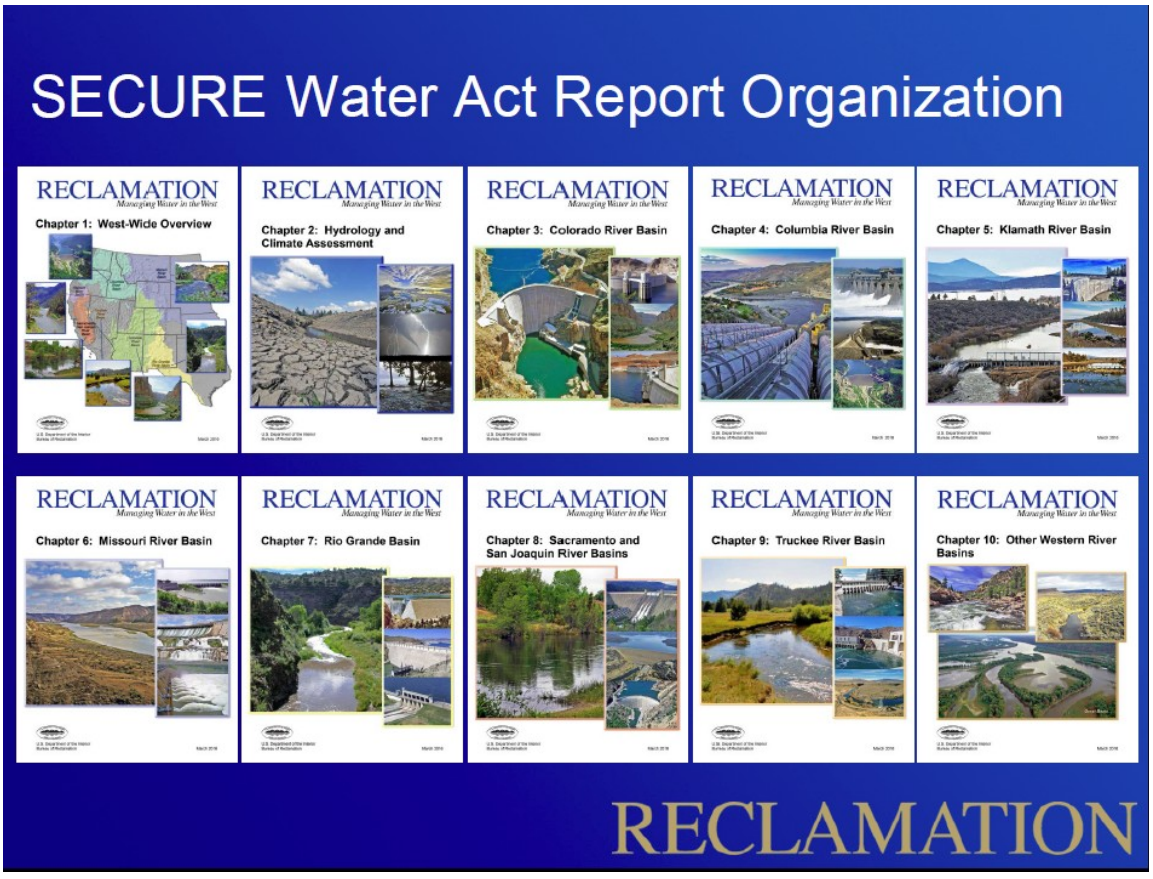
LUNCH SPEAKER:
SECURE Water Act Report to Congress and Data Visualization Tool:
Katharine Dahm, Water Resources & Planning Division, Bureau of Reclamation
kdahm@usbr.gov, 303-445-2495

Katharine Dahm began with an overview of the role of the Bureau of Reclamation. The Bureau manages, develops, and protects water and related resources in an environmentally and economically sound manner in the interest of the American public. It plays an important role in the country's water and energy production.

- The nation's largest wholesale water supplier, operating 337 reservoirs
- The second largest producer of hydropower in the United States
- Delivers 10 trillion gallons of water to more than 31 million people each year.
- Manages, with partners, 289 recreation sites that have 90 million visits annually.

The SECURE Water Act was enacted in Subtitle F section 9503 of the 2009 Public Law 111-11. The law requires submission of a report to congress every five years: the first was published in 2011, the second came out this year, and the third is due in 2021. The SECURE (Science and Engineering to Comprehensively Understand and Responsibly Enhance) report describes:

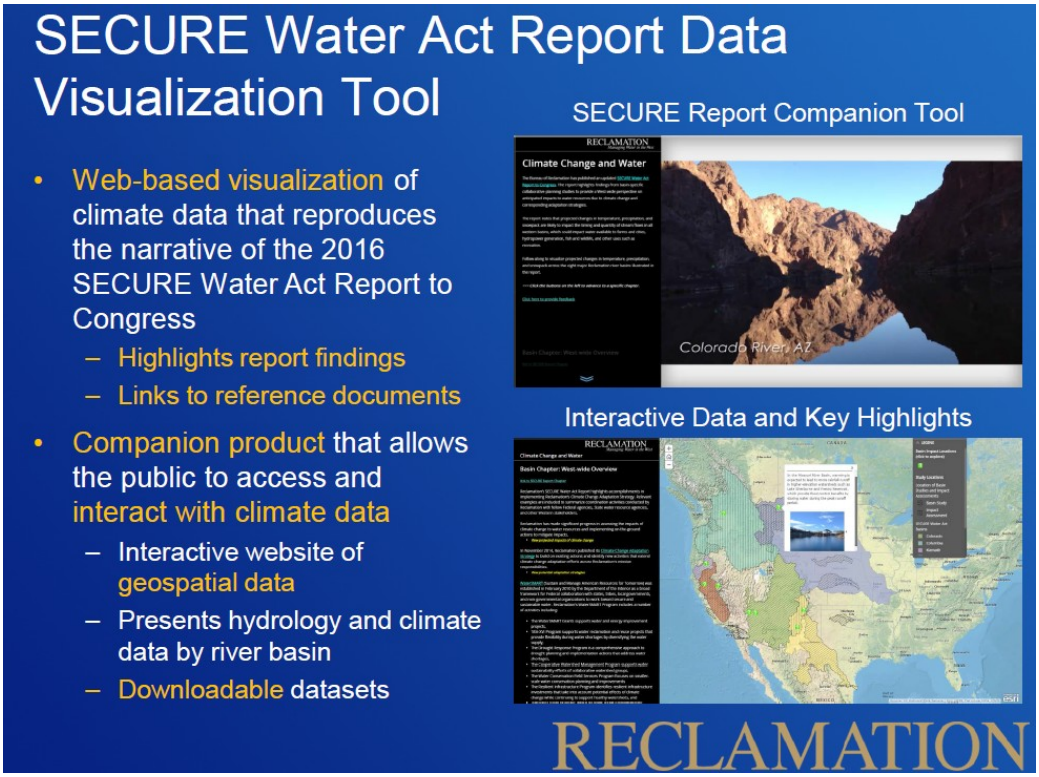
1. Effects and risks resulting from global climate change with respect to the quantity of water resources
2. Impacts of global climate change with respect to operations
3. Mitigation and adaptation strategies considered and implemented
4. Coordination activities conducted by the Secretary
5. the implementation of a west-wide risk assessment monitoring plan



Dahm presented highlights from the report:

1. Projected increases in temperature will increased rainfall-runoff during the cool season rather than snowpack accumulation
2. Changes in the magnitude and timing of water will impact the ability of existing water infrastructure and water management practices to satisfy competing water demands
3. Portfolios of adaptation actions will be necessary to mitigate the impacts of climate change
4. Collaborative planning activities in each watershed and west-wide are needed to build climate resiliency

The *SECURE Water Act Report and Tool* is available for the public at:
www.usbr.gov/climate/SECURE



Discussion

Q: Western states are reliant upon 60-80y reservoirs. What is the status of sediment concentration?

A: (KD) Submitted report discusses the projected impacts of climate change on reservoir sedimentation. Most reservoirs have a 100y critical point of design quickly being approached. Reclamation is coordinating with the U.S. Army Corps of Engineers to update a national database for reservoir sedimentation conditions.

Q: Is the US BuRec researching aquifer storage?

A: (KD) Large federal projects are not likely to installing large-scale aquifer storage systems, but Reclamation's WaterSMART basin studies do identify small-scale subsurface storage as a potential adaptation strategy for climate change. Other programs in WaterSMART also support non-Federal partners and stakeholders to implement and construct small-scale aquifer recharge

projects to improve water efficiency and drought resiliency.

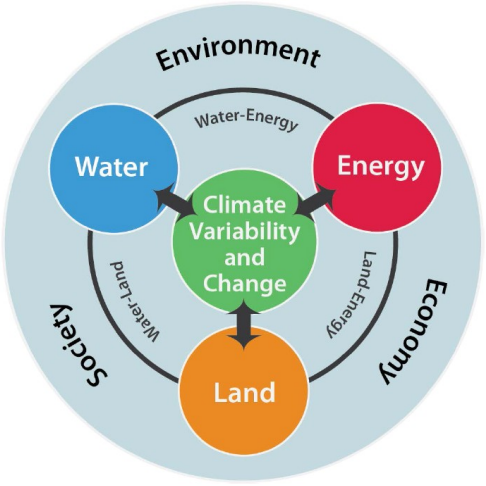
Panel on Competing Demands for Water: Actions Emerging from the Food/Water/Energy Nexus Discussions: Moderator, Bob Wilkinson, University of California Santa Barbara wilkinson@es.ucsb.edu

Climate Impacts at the Nexus of Energy, Water, & Land Resources: Kristen Averyt, University of Colorado Boulder, Associate Director for Science, Cooperative Institute for Research in Environmental Sciences kristen.averyt@colorado.edu

Kristen Averyt framed her presentation with a look at the complexity of addressing water, energy, and land together. There are individual impacts within the environment, economy, and land sectors, and interesting synergies when you look at them together.

The Energy-Water Nexus in the US Electricity Sector:

- 48% total water withdrawals
- 161 millions gallons per day
- 38% of total freshwater withdrawals
- ~5% of total consumptive use



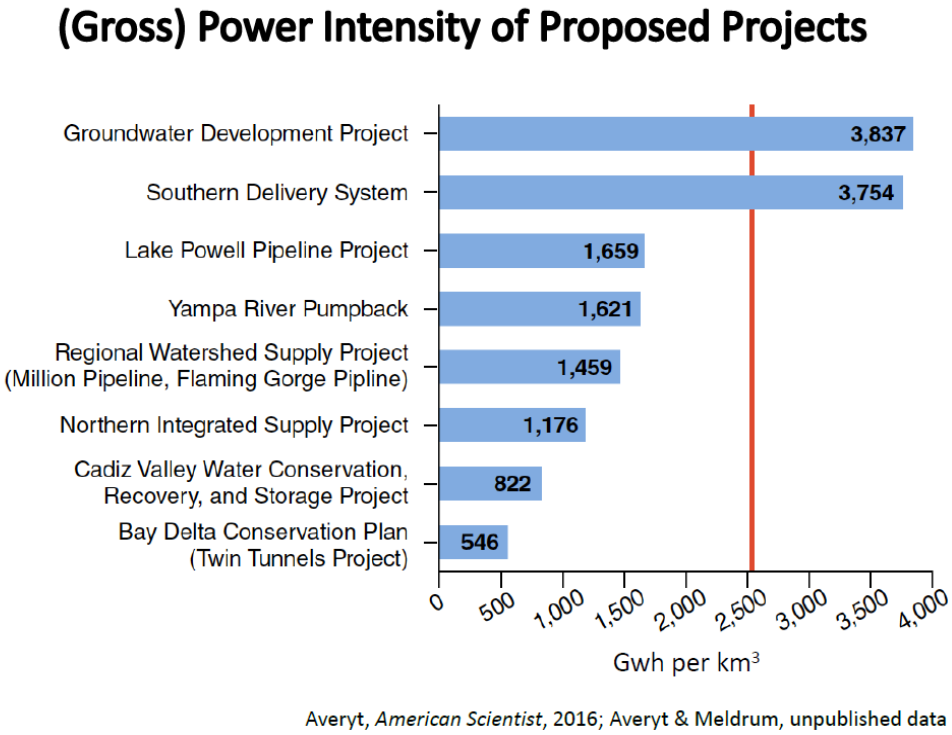
NCA, 2014

Energy-Water-Heat Collisions are serious concerns. A 2003 heat wave in France led to 50,000 heat-related deaths. Another in 2006 led to the shutdown of nuclear power plants in Spain, Germany, France, and the UK. We grapple with whether these things can happen here.

Averyt turned to a discussion about the Regional Energy Deployment Model (ReEDS). The model is spatially resolved into 356 wind/solar regions, and 134 balancing areas (BAs) for demand and other renewables. It serves load, meets planning and operating reserves requirements, and obeys physical constraints. It incorporates policy & regulatory considerations and water availability constraint.

- Generation technologies
  - Coal (pulverized, IGCC, & IGCC-CCS)
  - Nuclear
  - Natural Gas (combustion turbine(NGCT), combined cycle(NGCC), & CC-CCS)
  - Biomass (dedicated, cofired with coal, landfill-gas/MSW)
  - Geothermal (hydrothermal & EGS)
  - Hydropower, Marine Hydrokinetic
  - Solar (concentrating solar power & PV)
  - Wind (onshore & offshore)
- Storage: pumped hydropower storage, CAES, batteries
- Demand-side technologies: plug-in hybrid/electric vehicles (PHEVs), thermal energy storage in buildings, interruptible load

In some places, more water will be required for power generation in order to meet the electricity demands of a growing population in a hot climate. Water requires power: the US water sector uses around 13% of the US electricity supply; the southwest water sector around 20% of the SW electricity supply.



Averyt, *American Scientist*, 2016; Averyt & Meldrum, unpublished data

Note in this graph that NET power production of CAP is in red. The difference between gross and net is an opportunity to reduce the energy used by these projects.

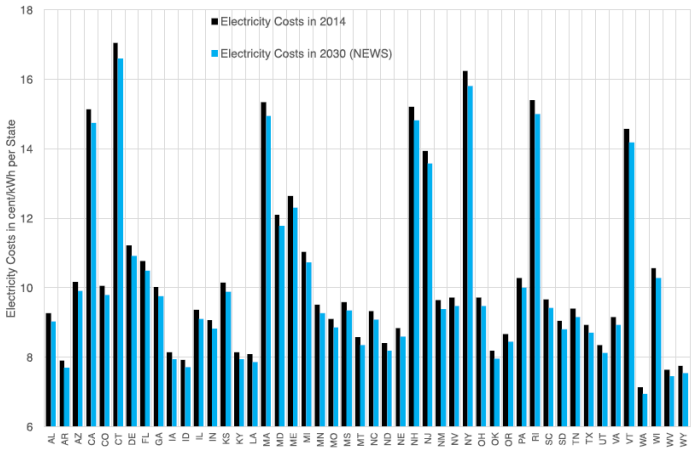
Between 2011 to 2015 California Hydropower declined from 20% to 12% of total generation: solar and wind increase to 30% of total generation; natural gas increase by 16% & C emissions by 8%; and agriculture (est. 2015) incurred a $2.7B revenue loss and $0.6B in pumping costs.

Energy Sector Decarbonization Impacts: Dr Christopher T M Clack, Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado
http://cires.colorado.edu/

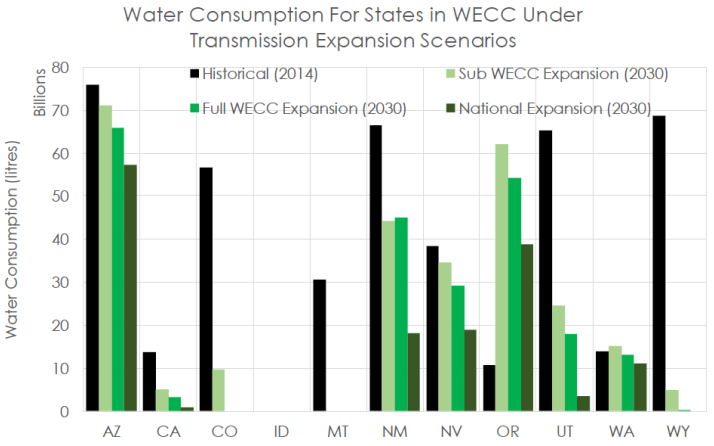
Christopher T M Clack started by articulating the premise upon which his CIRES study is based: 1) humans are releasing gigantic amounts of carbon dioxide, and other green house gases, into the atmosphere, 2) green house gases are causing the planet to heat up beyond normal climate variations.

He explained that power generation from solar and wind is subject to variability of weather and has led to the assumption that renewable technologies need backup fossil fuel generation or storage. He and his colleagues' study targets the continuous U.S. electricity sector to find the cost-optimal networks of wind and solar generators that fulfill the requirements of an electric power system. Carbon emissions are reduced through moving from our regionally divided electricity system to a national system enabled by high voltage direct current transmission. (from http://rdcu.be/f2Dg)

How the national system impacts my state?



Transmission Expansion Impacts On My State?



Clack discussed the following critical key findings of his study.

- It is not always best practice to place variable generators where the most power potential is.
- A large area system is beneficial for numerous reasons, but particularly to find more sites that are valuable for variable generation.
- Co-optimizing allows benefits from multiple different features; such as water, jobs, effluents, and carbon dioxide.
- Each component can be tracked and optimized upon for each time step within the model.

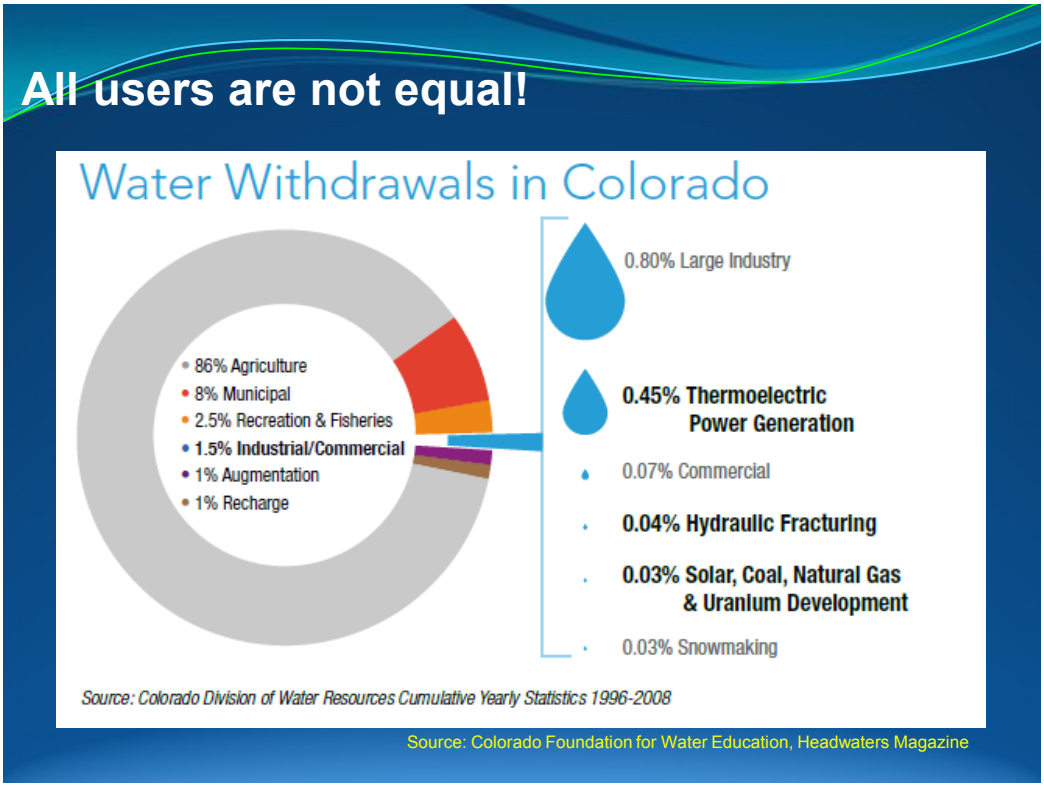
A free copy of the Nature Climate Change Papercan be downloade at: http://rdcu.be/f2Dg C. T. M. Clack, Y. Xie, and A. MacDonald: Linear Programming Techniques for Developing an Optimal Electrical System including High-Voltage Direct Current Transmission and Storage, International Journal of Electric Power and Energy Systems, 68, 103-114, (2015).

Water Management in the Energy Sector: Rich Belt, Xcel Energy
richard.l.belt@xcelenergy.com

Rich Belt told the participants that the Public Service Company of Colorado is a subsidiary of Xcel Energy. It has 1.4 million electric customers, 1.3 million natural gas customers, and 3,800 employees in Colorado. Annual Revenues are $4.2 billion in revenues with $477 million paid annually in taxes and franchises, and $727 million in local spending

Public Service Company of Colorado is the nation's largest provider of wind power with 2,365 MW of on line and an additional 250 MW planned. The company currently has 87 MW capacity in large solar installations with additional 170 MW planned.

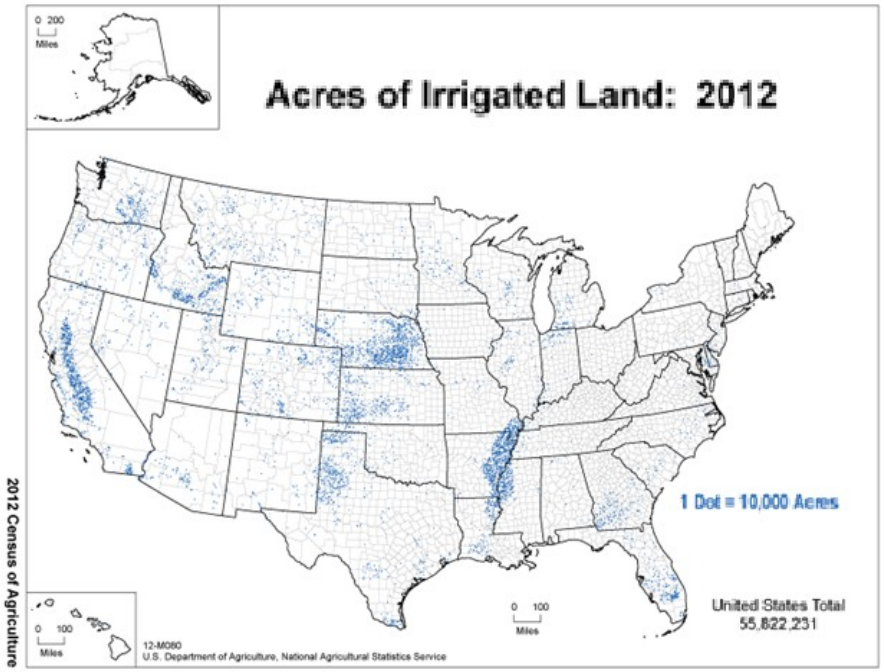
Belt says the Dow Jones Sustainability Index for the company is 100% in water-related risk management. However, there is a lot of competition for water resources in the west, Agriculture, Municipalities, and Recreation and Fisheries withdraw much more water than the entire energy sector.



Panel on Water Sustainability: Moderator, Stan Bronson, Florida Earth Foundation

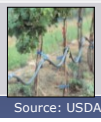
Innovative water and energy conservation in agriculture: Reagan Waskom, Colorado State U. Reagan.Waskom@colostate.edu

Reagan Waskom began his presentation by showing the extent of irrigated land in the United States. In the map below, each blue dot represents 10,000 irrigated acres. There is a high proportion of irrigated land in the Ogallala aquifer states in the middle of the country, in the lower Mississippi valley – especially Arkansas; and in the Central Valley in California.



In the eleven western states, direct water use for livestock watering is less than 1% of total. Crop production is very water intensive, consuming 80-90% of all water used in the western states. The USGS typically reports water withdrawals, while it is consumptively used water that matters most in water management. Additionally, it is important to note that the monetary value of water in agriculture is much lower than the value for industry or municipal supplies, explaining why water is moving out of agriculture in the West.

Irrigation Methods in US

Irrigation Method	US Totals
 Surface	39%
 Sprinkler	54%
 Drip/micro	7%

Source: USDA 2013 Census of Agriculture data

Waskom explained that Ag water conservation is

- Improved irrigation application efficiency
- Increased capture and utilization of precipitation
- Increased water delivery efficiencies
- Conservation practices to reduce evaporation
- Decreased non-beneficial consumptive use
- Decreased crop consumptive use

The opportunities inherent in water conservation include improved crop production, conserved water for additional beneficial uses and financial incentives. The challenges to accomplish this are legal, financial, environmental, political, and social.

Waskom explained that water use efficiency is the ratio of water applied compared to water consumed by evapotranspiration whereas water conservation relates to consumptive use.

Water efficiency can be improved by:

- Ditch lining
- Pressurized pipe
- Conversion of flood irrigation to gated pipe/surge/sprinkler/drip
- Land leveling to increase irrigation uniformity
- Furrow dikes and contour farming
- Crop residue management
- Water metering
- Irrigation scheduling
- Tail water recovery
- Polyacrylamide (PAM) use in ditches and furrows

Water conservation or reductions in crop consumptive use is attained when:

- 1) irrigated acres are decreased
- 2) you switch to cool season crops or
- 3) crops with a shorter growing season
- 4) deficit irrigation is practiced
- 5) Evaporative losses from the field surface are reduced as a result of conservation tillage, mulching, and or drip irrigation.

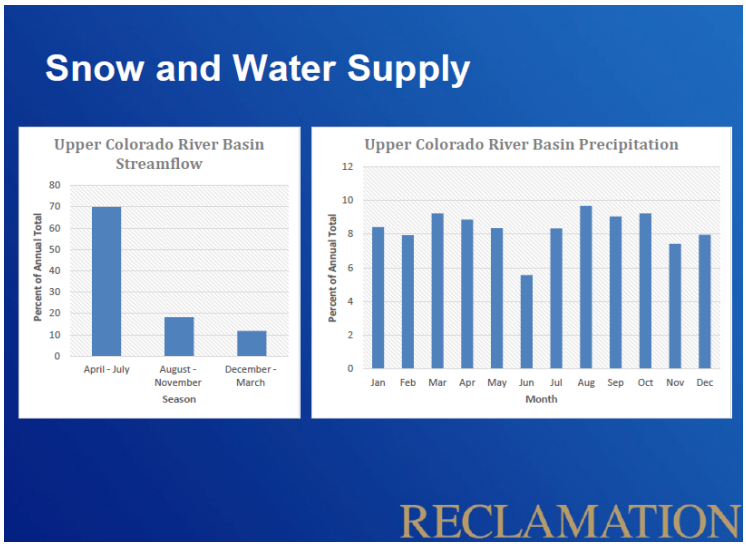
Waskom said that energy costs are the largest operating expense in irrigation and these costs can be reduced by repair and maintenance of pumping plants, updating pumping plants to newer greater efficiency models, irrigation scheduling, and modified sprinkler packages. Sprinkler systems can be more efficient with reduced operating pressure. This leads to reduced water pumped, reduced wind drift loss, and reduced canopy evaporation loss

Snowpack and Water Supply: Kenneth Nowak, U.S. Bureau of Reclamation
knowak@usbr.gov

Ken Nowak focused on three topics in his presentation: snow and water supply; factors impacting water availability; and climate modeling considerations.

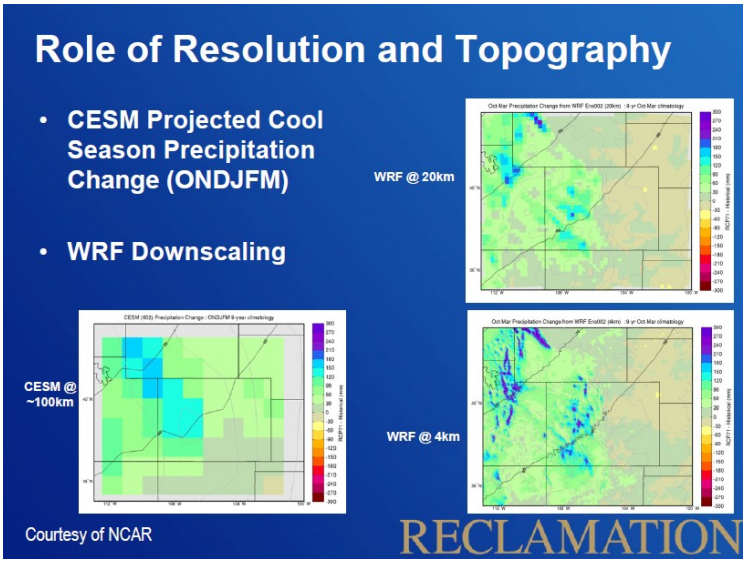
Factors Impacting Water Availability

- Warming
  - Runoff Timing
  - Runoff Efficiency
  - Evapotranspiration
- Changes in Precipitation
  - Amount
  - Phase
- Dust on Snow
  - Runoff Timing
  - Runoff Amount



Snow and snowmelt runoff are fundamental components of western water management. Snowmelt runoff efficiency is an important part of water availability. Snow at high elevations contributes a significant portion of annual runoff.

He emphasized that from a climate modeling perspective, topography is critical for projecting future conditions.

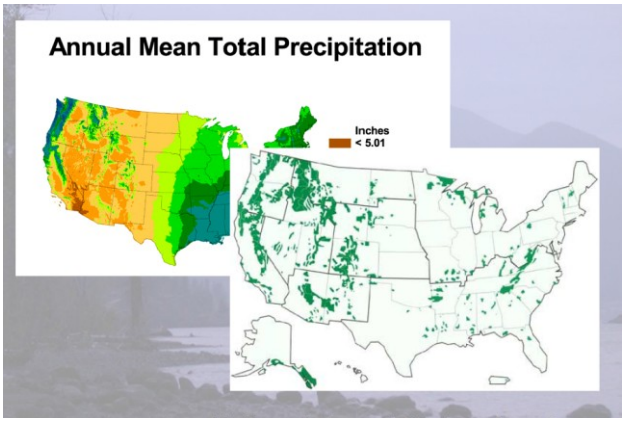


Role of Western National Forests in Sustainable Water Management: Polly Hays, Water Program Manger, Rocky Mountain Region, USFS

pehays@fs.fed.us

"No national forest shall be established, except to improve and protect the forest… or for the purpose of securing favorable conditions of water flows…" – Organic Administration Act 1897

"The connections between forests and rivers is like that between father and son. No forest, no rivers. Gifford Pinchot



Polly Hays presented an overview of the role, status, and processes of the natural and built infrastructure in National Forest System Lands. The system encompasses national forests; research; and state and private forestry. Research areas include, fire & aquatic population response; post-fire management activities and aquatic ecosystems; and fire and watershed processes.

She gave examples of some of the research addressing sustainable water management.

- Cold water used as a climate shield to protect native aquatic species
- Geomorphic Road Analysis and Inventory Package (GRAIP)
- Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

Identifying and Managing Vulnerability

- Snowpack and Natural Infrastructure
  - Watershed Restoration
  - Best Management Practices
  - Managing Uses
- Storage and Built Infrastructure
  - Operations/Maintenance
  - Disturbance/Risk

BMPs for all resource BMPs for all resource activities: 75 practices in 11 resource areas

- General Planning
- Aquatic Ecosystem Management
- Chemical Use
- Facilities & Non--recreation Special Uses
- Wildland Fire Management
- Minerals
- Grazing
- Recreation
- Roads
- Mechanical Vegetation Management
- Water Uses

180 million people in over 68,000 communities rely on national forests and grassland to capture and filter drinking water. Healthy forests provide not only clean water for drinking, but also habitat for fish and wildlife. The Forest Service works with communities and partners to conserve, maintain, and improve watersheds to meet the needs of the population and maintain healthy ecosystems on our National Forest System lands.

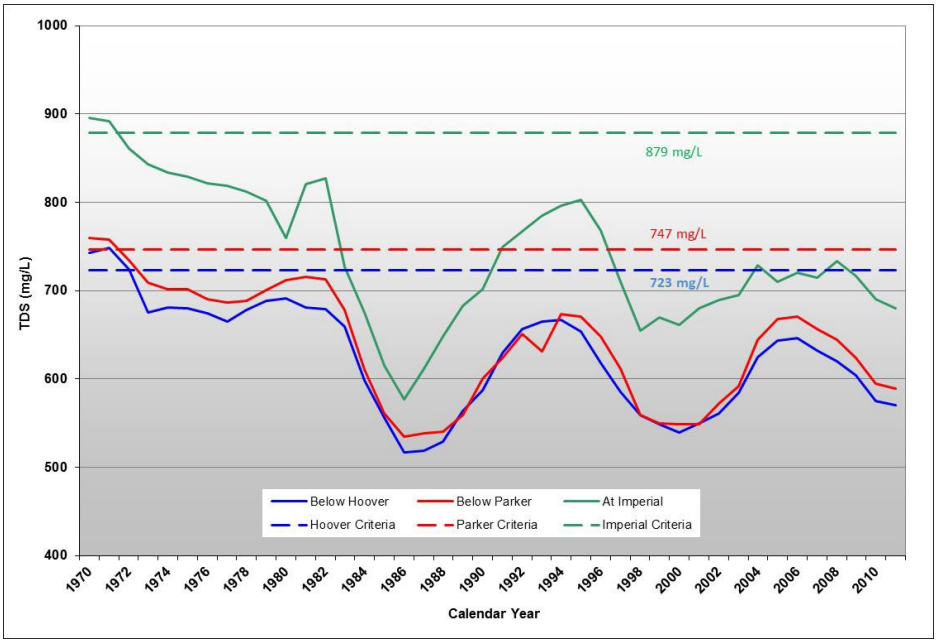
A Sustainability Success Story: Colorado River Basin Salinity Control Program, Robert Boyd, Bureau of Land Management rboyd@blm.gov

Robert Boyd began with a quick summary of facts on the Colorado River Basin:

- Primary Water Supply for 40+ Million People
- Irrigates 5.5 Million Acres of Cropland
- Sustains aquatic/riparian habitat for numerous sensitive species
- Used by millions for water-based recreation
- Flows 1,400 miles from Rocky Mountain Headwaters to Gulf of California
- Water Allocated to States and Mexico via complex series of political agreements, court decrees, and treaties

Salinity in the river Increases from 50 mg/L at the headwaters, to 850 mg/L at the Gulf of California. Ten million tons of dissolved salts are transported annually below Hoover Dam. This high salinity causes about $382 million in economic damages to water users and adds to the long standing source of conflict over water delivered under treaty with Mexico.

Boyd then spoke about the regulatory history of the Basin up to the Agriculture Improvement and Reform Act of 1996 and 2008 Revisions to the Act, which provided for Basin States Program-Cost-Share Requirements. The program partners include seven federal agencies, seven states and hundreds of water districts, canal and ditch companies, and thousands of private water users and producers.



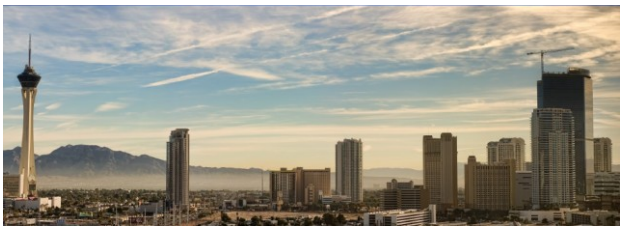
The cooperative program has resulted in notable reductions in salinity in the Colorado River Basin.

Water Resources Management - The Future of the West: Tony Willardson, Executive Director, Western States Water Council twillardson@wswc.utah.gov

The Western States Water is an advisory body to eighteen Western Governors on water policy issues. It works with the Western Governors' Association (WGA) to provide the states with a collective voice and foster collaboration. In his presentation, Tony Willardson described some of the programs they are working on to achieve their mission. He began with the fact that future growth and prosperity of the Western states depend upon the availability of adequate quantities of water of suitable quality.

Water needs and strategies for a sustainable future

- Growth and Water Policy Nexus
- Meeting Future Water Demands
- Water Infrastructure Needs and Strategies
- Resolution of Indian Water Rights Claims
- Climate Change – Drought/Floods
- ESA & Protecting Aquatic Species



Willardson acknowledged that decisions about where and how to grow are rarely influenced by water policy or by the availability of water. He discussed some of the factors influencing water policy and growth in the West.

- Population growth is continuing at an unprecedented rate in the West with ramifications for not only cities but also rural communities and agricultural areas.
- In the future, we may not be able to sustain unlimited growth and still maintain our current quality of life. Difficult political choices will be necessary….
- It is obvious that changing demographics and values placed on various water uses is transforming the future of water management.
- New uses to accommodate growth must largely rely on water obtained from changes to existing uses of surface and ground water, with limited opportunities to develop new supplies.
- In many instances, this will result in the reallocation of water to "higher valued uses."

The 2015 Western Governors Drought Forum led to WGA's Policy Resolution 2015-8 with the objective to:

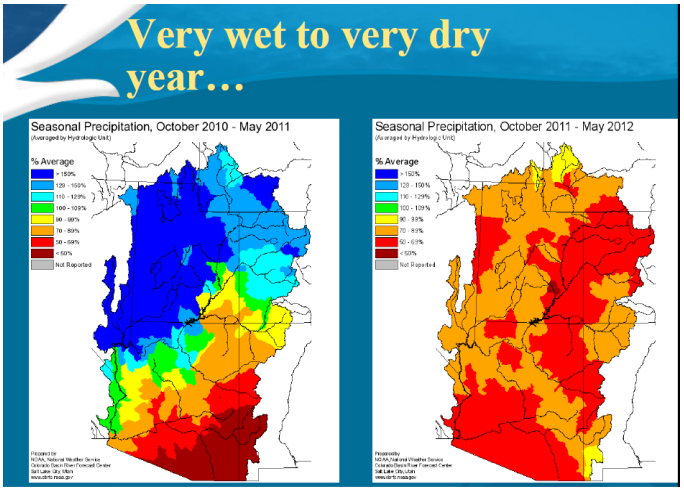
- Collect, maintain & enhance use of basic data
- Support critical federal programs that provide important basic water supply information – snow, precipitation, streamflow, groundwater, ET, etc.
- Recognize the essential role of federal partnerships and need for coordination on water data.
- Potential water impacts of extreme weather events
- Communicate & share best management practices

What do we need to know to balance our short/long term water budget?

- What's our income: Precipitation; Streamflow; Ground water recharge
- How much is in savings: Snowpack; Groundwater; Soil moisture; SW/GW storage & capacity
- How much is my net worth
- What are your fixed costs: Water rights; Priority uses; Tribal/Federal water rights
- Who's writing checks: Agriculture; Municipal & Industrial; Energy; Environment; Recreation

What are the risks and uncertainty we face?

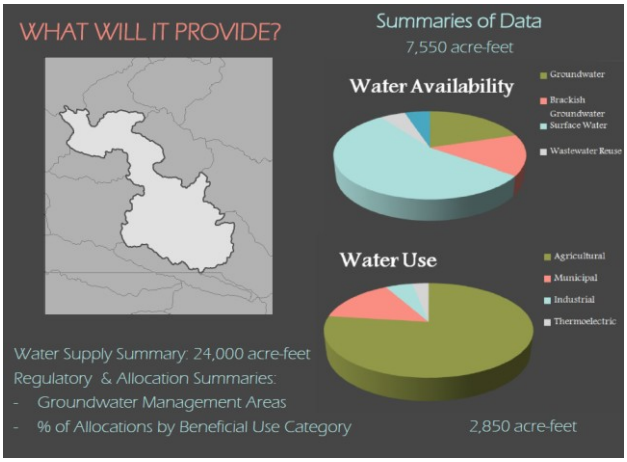
- General lack of data on water needs and past, present and future uses
- Increasing population & energy needs
- Climate change and variability
- Endangered species' and other instream uses and outflows to bays and estuaries
- Unquantified Native American water rights



Priority State & Federal Actions

- Increase support/funding for data
- Identify and close data gaps
- Gather/disseminate real-time data
- Foster remote sensing capabilities
- Reduce costs through innovation

Willardson turned to the Water Data Exchange (WaDE). It was formed to better enable the states to share important water data with each other, the public and federal agencies, and to improve the sharing of federal data with the states, to assist their planning efforts. Future steps include accessing federal data as well.



Discussion

Q: What is the threshold of impact chemical loading can have on water systems? What are long-term effects of chemical treatment increasing as water sources are depleted?

A: USGS has a report; states want self-control.

Q: Agriculture has reduced water use by 25% over 25 years. Should this be "reinvested" in more agriculture?

A: (RW) Agriculture can use as much as possible/available.