ARIZONA WATER RESOURCE

The Water Resources Research Center Quarterly Newsletter

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IRRIGATED AGRICULTURE IN ARIZONA:
A FRESH PERSPECTIVE

WRRC CONFERENCE 2017 MARCH 28

The Evolution of the AWR's Look Over the Years.

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The Water Resources Research Center produces research reports, outreach materials, and regular publications, including the Weekly Wave e-news digest, the quarterly Arizona Water Resource newsletter and the Arroyo, an annual publication focusing on a single water topic of timely concern in Arizona. **Sign up online to receive WRRC newsletters, event updates and more at: wrrc.arizona.edu/subscribe**.

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AWR Changing with the Times

by Susanna Eden and Andres Sanchez, Water Resources Research Center

Twenty-four years ago, the WRRC created the Arizona Water Resources newsletter (AWR) to provide timely, engaging, and useful information on initiatives, projects, resources, legislation, research, and related topics regarding the water resources of Arizona and the region. Throughout these years the AWR has reflected the concerns of the community it serves.

AWR's headlines have highlighted a wide variety of topics over the years. The first issue, February 1992, brought attention to the ample snowfall in Arizona during the Winter. The AWR raised issues associated with vulnerability to floods and infrastructure damage due to frequent high intensity precipitation events. The "Floods of '93: Déjà Vu All Over Again" article reported Arizona's experiences with flooding that occurred that year, comparing it with the flood that occurred in 1983. When the 1997 – 1998 El Niño event caught global

AWR Changing continues on page 2

All Digital AWR Coming in January

Beginning with the winter 2017 issue, the AWR will be going to an all-digital format. The change will provide increased flexibility, better efficiency, and reduced waste. This issue will be the last AWR printed and mailed to subscribers.

To receive the AWR in digital form, please be sure that we have your email address. The easiest way to do that is to subscribe on line at **wrrc.arizona.edu/subscribe.** You may also call or email the WRRC at 520-621-9591, wrrc@email.arizona.edu.

We hope you have enjoyed receiving our Arizona Water Resource newsletter over the years. Since publishing its first issue in February 1992, we have worked to make the AWR a publication that responds to a recognized need for water resource news, announcements, and in depth features. We plan to continue to fulfill the AWR's founding mission in its new format.

AWR Changing continued from page 1

attention, the AWR published four special El Niño News issues, informing Arizona water professionals and others interested in water affairs of plans, projects, and activities relating to weather affected by El Niño. The early years of the Central Arizona Project (CAP) appeared in several AWR issues when Arizona's low usage of its Colorado River water allocation preoccupied water administrators. In the 21st Century, the drought affecting the Southwest United Stated shifted AWR's attention to securing water supplies, conservation, and reuse.

The AWR began as a monthly and for many years appeared on a bimonthly basis. Joe Gelt edited the AWR from its inception and wrote most of its stories, keeping a format that drew on Southwestern Indian themes. This Southwestern look and its two-color format—turquoise and black—came to be identified with the Gelt years. His unique style was appreciated by AWR readers throughout his 19-years as editor.

Examples of Joe Gelt's imprint on the AWR abound. For the March-April 2008 issue, he commemorated the contribution of Dr. Sol Resnick to the WRRC, 50 years after its founding as the University of Arizona Institute for Water Utilization. The feature article reproduced Dr. Resnick's recollections of the Institute's beginnings and contained a photograph of Resnick's grandson, born in 2007, two years after his death.

A poem by Alison Hawthorne Deming, who was the Director of the University of Arizona Poetry Center from 1990 to 2002, led the June-July 1995 issue. It celebrated the perfect synchronization of water and nature. Other feature articles included news about archeological findings of prehistoric irrigation canals constructed by Arizona's earliest inhabitants approximately three thousand years ago. In a futuristic vein, the AWR described the concept of high-rise greenhouse-like structures for crop production that conserve land and water. Featuring a photograph titled "The Face of Drought", the face of a young woman caked in cracking mud, he presented a special edition covering the Arizona-Israeli-Palestnian Water Management and Policy Workshop held in Tucson August 31-September 2, 2009.

After Gelt's retirement, the current quarterly schedule was adopted and Susanna Eden became the new AWR Editor, bringing changes, including a full-color look, which came in 2013 with a updated redesign. Eden also increased the contributions of graduate student writers and others to the content.

Graduate student Stephan Elizander Przybylowicz contributed a feature on Hydrophilanthropy, a practice that embodies humanitarian actions oriented to increase and sustain clean water in areas of need. Other student-written articles included a personal account of the water use of a ranching family by Alanna Riggs; and an analysis of how science, technology, engineering and math (STEM) fields are redefining and strengthening water education in Arizona written by Jacob Prietto.

The structure of the AWR has evolved throughout the years. The Water Vapors column linked all the members of the water community for many years, with items about conferences and workshops, community views and concerns, and the activities of people working in the water field. In the early 2000s the AWR incorporated Special Supplements by the U.S. Geological Survey and others to display and publicize water-related research and projects. The AWR has offered the opportunity to professionals from outside the WRRC to express their opinions and share their knowledge on a wide range of topics in the Guest View column. In recent years the AWR has shown a spotlight on the contributions of WRRC's students, publishing brief biographies containing their remarkable accomplishments and aspirations.

After her firs appearance in a Guest View, WRRC Director Sharon B. Megdal has written a Public Policy Review column, providing her personal and professional insight on policy issues, in each AWR from 2002 to the present.

Keeping an eye toward the future, the AWR will continue to evolve. Look for the Winter 2017 issue in its all-digital format in January.

Projects Featuring Water Resources Receive Environmental Honors

Awards for Environmental Excellence, presented at the annual awards banquet on September 10, rewarded efforts by communities, fi ms, organizations, and individuals for promoting sustainability, conservation, and preservation of Arizona's natural assets. Water-related projects received a fair share of awards, which were presented by Arizona Forward, an organization created to mobilize support for the benefit of communities, the economy, and the environment. Of the 16 first place Crescordia Awards, Tucson Water took two: one for its Advanced Oxidation Process Project, which uses first-in the-nation technology to improve contaminant removal at the Tucson International Airport Area Groundwater Remediation Project, and a second for its Conservation and Education Program. The El Rio Design Guidelines and Planning Standards, developed through a partnership among the cities of Avondale, Goodyear, and Buckeye, Maricopa County, and the Flood Control District of Maricopa County, also received a top honor. Finally, Beyond the Mirage, a project involving, social media, the internet, television, and person-to-person communication to raise public knowledge and awareness about the complex world of water, won a Crescordia in the category of Environmental Education/Communication. Tucson Water also won an Award of Merit, for its Clearwater Recharge and Recovery Project, as did Pima County Regional Flood Control District, for Paseo De Las Iglesias, and the City of Phoenix, for the PHX Water Smart program. Phoenix also won for Phoenix Invests to Protect Water Supplies, an investment in protection of watershed forests.

Susanna Eden, Cody and Jatta Sheehy, and John and Lynn Marie Booth with the Crescordia Award for Beyond the Mirage.

Study Estimates the Costs of Sea Level Rise on Housing

The upside of lacking a coastline is that Arizona home owners are not personally affected by sea level rise, but Zillow, the real estate web site that allows you to look up comparative home values, has identified rising sea levels and associated flooding as a threat nearly as costly as the 2008 housing bust. Zillow mapped projected sea levels for the year 2100 and the currently existing houses that would be inundated. The numbers run into millions of homes and billions of dollars. They used National Oceanographic and Atmospheric Administration (NOAA) maps along with their own real estate data to arrive at their conclusions. The almost 1.9 million U.S. homes at risk—that's about 2 percent of the total—are worth $882 billion. Some states like Florida and Hawaii will lose a significant percentage of their housing to the sea: 12.5 percent and 9 percent, respectively. The Zillow report points out that 2100 is a long way off and policy and homebuyer choices are likely to either mitigate or exacerbate the problem, or both.

Tucson Water Makes a Splash in Water Reuse

Tucson has embraced water reuse as part of its water portfolio and is gaining recognition for its efforts. Water reuse organizations honored Tucson Water for its leadership in resource recovery, watershed protection, culture change, and community partnering. The Water Environment Federation, the National Association of Clean Water Agencies, the Water Environment & Reuse Foundation, and WateReuse jointly recognized Tucson water as winner of their "Utility of the Future Today" program.

A forward-looking water reuse project, in which Tucson Water participated, also took a prize from the WaterReuse organization for "Project of the Year". The six-month pilot test evaluated alternative non-RO-based potable reuse treatment, including short-term soil aquifer treatment, nanofil ration, ozone, biological activated carbon filtration, and granular activated carbon adsorption. The innovative and sustainable potable reuse treatment scheme was successful in producing highly purified water.

New Program Will Help Tucson's Low-Income Families Harvest Rainwater

The City of Tucson has approved a first-of-its-kind program that will make it possible for low-income families to participate in its rainwater harvesting program. A water conservation tool, rainwater harvesting also is used to support new trees. Increasing shade from trees can reduce electric bills as well as reduce the impacts of the urban heat island. The program will provide grants and loans for low-income families to install rainwater collection systems. A system with a medium-size tank can cost $2,000 or more. People are already lining up for the program. The Sonoran Environmental Research Institute (SERI) is tasked with immediate launch of a one-year pilot program, which will provide $150,000 within the current fiscal year. The City has set aside $300,000 for the program, with the goal of helping 100 families harvest rainwater at their homes. The program is slated to be extended for an additional three years.

ASU and Smithsonian Team on Water Management Exhibition

WaterSim America, a new interactive computer simulation created by Arizona State University and the Smithsonian Institution, will be touring Florida, Illinois, Minnesota, Idaho, and Wyoming this year. Designed for the general public, the exhibition shows the complexity of state level water management, especially in the face of drought and climate change. ASU's Decision Center for a Desert City (DCDC), which works with water leaders to support informed decision-making, and the Smithsonian's Museum on Main Street, which brings exhibitions to small towns across the United States, conceived this project, part of the Smithsonian's "Water/Ways" exhibition, as a way to educate people about what can be done to effect positive change in the management of their water.

Researchers at DCDC modified the Center's WaterSim program to work with water issues on a state level. Each state has its own model in the WaterSim America simulation. The model can be asked to show what would be the impact of a certain water management policy, population growth scenario, or drought condition. When water demands and supply fall out of balance, users try to bring them back into balance through policy choices. Users learn through interaction about how physical and social factors could affect their state's water future.

NSF Funds NAU Project for Food-Energy-Water System Map

Food, energy, and water are connected in complex ways, and understanding these connections has become a priority for policy development. The National Science Foundation has awarded Benjamin Ruddell, an associate professor in NAU's new School of Informatics, Computing and Cyber Systems a $3 million grant to create and exploit the first detailed mapping of the Food, Energy, and Water System (FEWS) of the United States. The project ,"Mesoscale Data Fusion to Map and Model the U.S. Food, Energy and Water (FEW) System," brings together an interdisciplinary team to integrate multiple system components, such as regional trade, river basins and aquifers, irrigation districts, crop belts, states, tribes, counties and cities, power grids, and climate, for a comprehensive view of their dynamic interactions. The map and its associated data will be used to examine FEWS network trade-offs between performance and sustainability, vulnerability to stresses and shocks, and the role of cities. A publicly accessible web site will enable visualization of how local actions propagate throughout the food, energy, and water system. This work builds on the U.S. National Water-Economy Project, which mapped the U.S. hydro-economic network, in support of efforts by municipalities and corporations to improve their sustainability and resilience with respect to water.

Arizona Agriculture Using Recycled Water

by Jean E. McLain, Associate Director, WRRC

Agricultural production is vital to Arizona, contributing over twelve billion dollars to the State's economy each year. It is also by far the largest water-consuming sector, accounting for about 70 percent of water demand in Arizona. With water shortages looming, water recycling could give some agricultural operations a much-needed additional water supply.

While no federal regulations exist pertaining to recycled water use for agricultural irrigation, there are recommendations set forth by the U.S. government. Originally drafted in 1980, the United States Environmental Protection Agency (EPA) Guidelines for Water Reuse established minimum standards and criteria recommended for the use of recycled water for agricultural irrigation. The EPA guidelines, which were updated in 2004 and again in 2012 to conform to advances in water treatment technologies, provide states with criteria to establish their own regulations on the use of recycled water.

Using the EPA guidelines as a model, the State of Arizona has established regulations on the use of recycled water for agricultural irrigation. These regulations are being revisited (see Guest View this issue), but the rules governing agricultural irrigation are not likely to change substantially.

Arizona's recycled water standards establish five classes of recycled water, each requiring a specific minimum treatment in order to meet a limited set of numeric water quality criteria (TABLE 1). Class A is the required minimum quality of recycled water for irrigation of food crops, including vegetables that are eaten raw, while Class B suffices for surface irrigation of an orchard or vineyard. Forage, fib r, and seed crops require even less stringent (Class C) water quality. Though Arizona's agriculture industry is extremely diversified, producing cotton, alfalfa, wheat, citrus, and fresh vegetables, all of which can be legally irrigated with recycled wastewater, the majority of crops currently being irrigated with recycled water are non-edible crops such as alfalfa, feed corn, cotton, and grasses.

Most agricultural use occurs near metropolitan areas, where high demand for freshwater sources exists and where water does not have to be moved great distances from wastewater treatment plants (WWTPs) to agricultural fields.

It is diffi ult to gauge the full extent of recycled water use for agriculture in Arizona, but a study by a University of Arizona graduate student, Jeremy Cusimano, found that in 2012, permitted reuse amounted to 140,000 acre-feet (AF) in Central and Eastern portions of the state. In addition, the Gila River Indian Community receives 40,000 AF in treated water from the cities of Chandler and Gilbert. In the Yuma area an abundant and extremely low-cost supply of Colorado River water has precluded widespread use of recycled municipal or industrial wastewater for agricultural irrigation.

In addition to permitted use, incidental reuse for agricultural irrigation from rivers that contain treated effluent is undoubtedly common, as treated wastewater is often discharged from WWTPs into dry riverbeds. For example, approximately 50 miles southwest of Phoenix, downstream irrigators in the Gila Bend area use the treated wastewater that dominates the flow of the Gila River.

In many cases, the use of recycled water for agriculture is a money-saving measure. While recycling water is energy-intensive, performing wastewater recycling on site or close to an agricultural field reduces the energy needed to move water longer distances or pump water from deep within an aquifer.

On the other hand, growers can face several challenges with recycled water use. Often, recycled water is only readily available when irrigation demand for crops is low, such as in the winter months. In summer, increased demand for water to irrigate parks and other municipal green spaces decreases the availability of recycled water for agricultural irrigation.

Water Class	Water Quality Criteria
A+	• 24-hour average turbidity ≤ 2 NTU (measure of clarity); • No detectable fecal coliform bacteria in four of the last seven daily water samples taken, and • The maximum concentration of fecal coliform bacteria in a single water sample < 23 per 100 mL; • Total nitrogen < 10 mg per L.
A	• 24-hour average turbidity ≤ 2 NTU (measure of clarity); • No detectable fecal coliform bacteria in four of the last seven daily water samples taken, and • The maximum concentration of fecal coliform bacteria in a single water sample < 23 per 100 mL.
B+	• The concentration of fecal coliform bacteria in four of the last seven daily water samples taken < 200 per 100 mL; • The maximum concentration of fecal coliform bacteria in a single water sample is < 800 per 100 mL. • Total nitrogen < 10 mg per L.
B	• The concentration of fecal coliform bacteria in four of the last seven daily water samples taken < 200 per 100 mL; • The maximum concentration of fecal coliform bacteria in a single water sample is < 800 per 100 mL.
C	• The concentration of fecal coliform bacteria in four of the last seven daily water samples taken < 1000 per 100 mL; • The maximum concentration of fecal coliform bacteria in a single water sample is < 4000 per 100 mL.

TABLE 1. Arizona Recycled Water Standards. Source: Arizona Administrative Code, Title 18, Chapter 11, Article 3

Growers also may be reluctant to increase dependence on recycled water due to instability in long-term supply. In many cases, newly constructed WWTPs provide growers with recycled water only temporarily until supplies are diverted to other uses. For example, if urban development occurs near a WWTP, recycled water can be transferred away from agricultural use to irrigate urban landscapes.

Even when recycled water is readily available, growers may be reluctant to utilize it for crop irrigation. One issue, perhaps the most difficult to overcome, is the negative public perception that may remain regarding the use to recycled water for food crops. A 2008 survey of Arizona residents by Channah Rock, a University of Arizona researcher, and colleagues at Northern Arizona University found that while 58 percent of Arizona residents supported the use of recycled water for irrigation of non-edible crops, far fewer, - 28 percent, - found this policy acceptable for edible crops. Thus, it would be likely that growers with a range of water supply options may choose not to irrigate with recycled water.

Another issue associated with recycled water use is salinity. Recycled water typically contains a concentration of total dissolved solids that ranges from 800 to 1400 parts per million (PPM), and can be higher in some cases. In comparison, water delivered through Central Arizona Project canals in 2013 averaged about 600 PPM.

The high salt concentration of recycled water can be managed in agriculture by periodically applying a sufficient amount of excess irrigation water to flush salts below the root zone. Put simply, a grower can maintain the root zone salt balance by applying enough excess water to carry the same amount of salt out of the soil as the water itself brings in. If recycled water is readily available in adequate supplies, the cost savings of using recycled water instead of CAP or groundwater may make applying excess irrigation water to leach salts worth the additional cost. It is also important to note that many crops irrigated in Arizona with recycled water have a fairly high tolerance to salinity; these include barley, wheat, Sudan grasses, date palms, and cotton.

Finally, grower concerns may be related to the presence of contaminants of emerging concern in recycled wastewater. Though wastewater technology has made rapid advances in the production of a clean, safe water, very low (parts per trillion) levels of contaminants, including pharmaceuticals and cleaning agents, may remain. Some recent research has suggested that plants have the ability to take up such contaminants and thus, bring them into the human food supply. Many of these studies, however, involved hydroponic systems and excessively high concentrations of contaminants, while well-controlled field studies do not show uptake for the most part. Clearly, this is an area requiring more attention.

As Arizona's population increases and demand for fresh water supplies escalate, the agriculture industry will probably become more dependent on recycled water. As Arizona grows, recycled water supplies will grow and will be available to meet more of the State's water demand. With the growing availability of recycled water, it is important both to monitor its use in agricultural irrigation and to provide growers with a full accounting of its benefits and concerns regarding its use.

Student Spotlight

Brendan Murphy, Computer Science and East Asian Studies

Brendan Murphy is a third-year undergraduate student and National Merit Scholar at the University of Arizona, working towards a BS in Computer Science and a BA in East Asian Studies with a Japanese language emphasis. He currently is the president of the Japanese Association of the University of Arizona, working to create an environment of cultural exchange between the Japanese and local students.

Before entering the University of Arizona, he served as a missionary for The Church of Jesus Christ of Latter-Day Saints in the southern part of Japan, sharing his beliefs in Fukuoka, Hiroshima, Nagasaki, Okinawa, and even the Sakishima Islands, learning both the Japanese language and culture, skills which he today employs mostly in club activities, translation, and in working with Japanese-related linguistic databases.

At the WRRC, Brendan works as a Student Systems Administrator, handling both simple and complex computer troubleshooting, service, and maintenance. As one of the only employees with no background in water-related research, his activities often involve figuring out creative solutions to IT problems unique to the center.

Brendan plans to continue on in interdisciplinary research and is currently looking towards a Master's program in computational linguistics, a field where he hopes to be able to combine his background in computer science, linguistics, and Japanese.

Arizona Water Resource is published quarterly by the University of Arizona Water Resources Research Center. AWR accepts news, announcements, and other information from all organizations.

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Guest View

After 90 Years of Reusing Reclaimed Water in Arizona, What's in Store?

by Chuck Graf, Arizona Department of Environmental Quality

Arizona has a long history of putting treated wastewater to beneficial use, in fact, 90 years of history. In 1926, at Grand Canyon Village on the South Rim, the firs wastewater treatment plant in the US built specifically for water reuse began supplying water for power generation, Santa Fe Railroad steam locomotives, and flushing toilets. The local power station and steam locomotives are long gone, but reclaimed water continues to be used to this day for landscape irrigation and, yes, for flushing toilets.

Payson Green Valley Lake
Source: Chuck Graf

It wasn't until 1972, though, that the Arizona Department of Health Services adopted the state's first rules governing reclaimed water quality and use, some of the first in the nation. Fast forward another decade to 1983, when Arizona's largest treatment plant, at 91st Avenue in Phoenix, began supplying about 60 million gallons per day of reclaimed water to the Palo Verde Nuclear Generating Station west of Buckeye. Palo Verde, the largest nuclear power generator in the US, is unique in the world for being wholly cooled by reclaimed water.

In 1999, the Arizona Department of Environmental Quality (ADEQ) received clear authority from the Legislature to regulate the beneficial reuse of reclaimed water, and in 2001, ADEQ transformed the program by adopting rules that foster reuse while protecting water quality and human health. Independently, the Arizona Department of Water Resources (ADWR) was administering a program that allows accrual of credits for recharge of treated wastewater in Active Management Areas to offset limits on groundwater pumpage. These programs, which spurred a dramatic increase in the volume of wastewater treated for reuse and recharge, established Arizona as a national leader in the regulation and practice of reclaimed water reuse.

Three regulatory components mesh to create Arizona's well-regarded reclaimed water program. First, as part of its aquifer protection program, ADEQ sets stringent treatment standards for new and expanding wastewater treatment plants. These standards include reduction of total nitrogen to below drinking water limits and removal of fecal coliform bacteria, an indicator of pathogens, to a routinely non-detect level. Second, water quality standards are designated in rule for fi e reclaimed water quality classes, which are tied to allowed end uses based on human health protection. Last, an uncomplicated but effective system of permits for end users has stimulated the expansion of safe reclaimed water use.

So, how is Arizona doing? Astonishingly well, I think. Of Arizona's one hundred largest wastewater treatment plants, 93 percent distribute reclaimed water for reuse. Almost 60 percent of the plants deliver Class A+ reclaimed water, the best quality of reclaimed water under ADEQ's classification s heme.

If we look at reuse volumes, the numbers are also astonishing. According to an ASU study, 82 percent of all treated wastewater generated within the Phoenix Active Management Area (60 percent of Arizona's population) is beneficially reused or re harged.

With this much reuse already occurring, what are the trends? First, communities currently reusing reclaimed water often have excess water in the winter when turf and landscape demands are reduced. Consequently, expect to see more recharge of excess water at new or expanded recharge facilities to gain credits from ADWR. Second, expect to see a transition from lower-valued uses, such as turf irrigation, to industrial or other higher-valued uses. Third, expect to see more reuse by smaller communities. Currently, only 40 percent of the 200 or so smaller wastewater treatment plants under ADEQ permit are distributing reclaimed water for reuse. Although volumes might be small, the supplies may be critical in rural areas in view of drought and other drivers. Also, expect to see more plans for multi-purpose community enrichment projects, such as the Gilbert Riparian Preserve and Payson Green Valley Lake. In this vein, reclaimed water is becoming so valuable that riparian areas dependent on its flows are coming under pressure. Therefore, expect to see more vocal support for considering environmental needs and riparian enhancement as a valid end use for reclaimed water. Finally, there is a groundswell of interest by communities in determining whether potable reuse can be a viable part of their water portfolios.

Time has marched on since 2001 when ADEQ last adopted reclaimed water rules. New concerns and needs have arisen, and treatment and monitoring technologies have advanced impressively. For this reason, on January 1 of this year, ADEQ opened a docket with the Secretary of State to revise its reclaimed water rules. ADEQ received more than 300 comments during informal listening session workshops held around the state earlier this year. ADEQ anticipates revising the rules in two or three installments, aiming for adoption of the first installment, after formal public comment, at the end of 2016 or in early 2017. This first installment will clarify ambiguities, correct errors, and fold some less complex technical and administrative improvements into the rules. It will also introduce a new structure to the rules, in which regulatory provisions for the current categories of reused waters—reclaimed water and gray water—will reside under the umbrella of a new designation—recycled waters. Follow-up rulemaking will address more complicated technical issues. such as reviewing the suitability of the reclaimed water quality standards in light of current knowledge and considering the adoption of criteria for potable reuse if warranted by the current state of science and technology.

To stay on top of ADEQ's rulemaking effort and be notified of opportunities for public comment, please send an email to reuserulemaking@azdeq.gov.

The Invisible Water

by Sharon B. Megdal

Water policy discussions around the globe are focusing on groundwater and how to improve its governance and management. Growing water demands and changing climate's influence on temperature and precipitation patterns have underscored the importance of groundwater – the invisible water.

Groundwater meets about 40 percent of Arizona's annual water uses. While the Colorado River, which also satisfies about 40 percent of Arizona's annual needs, is receiving a lot of attention, with the Central Arizona Project's "Protect Lake Mead" campaign and other efforts to raise awareness of work being done to forestall and maybe even avoid shortage, efforts to manage our groundwater resources wisely deserve at least equal attention. Those of us who work in the water sector in Arizona know how important groundwater is to communities and economic activities throughout the state. We regularly cite the centrality of Arizona's 1980 Groundwater Management Act, which implemented a strong regulatory framework for groundwater utilization in designated Active Management Areas. But because these provisions do not apply statewide, even here in Arizona, where groundwater management seems second nature, groundwater overdraft continues to be a challenge.

National and global attention is focusing on the importance of good groundwater governance and management. The www.groundwatergovernance.org site published a series of important documents as part of multi-year project to share information on good groundwater governance practices. The project's purpose was "to influence political decisions thanks to better awareness of the paramount importance of groundwater resources and their sustainable management in averting the impending water crisis". I had the pleasure to participate in the early phases of this effort.

Recently, I have been involved in two other collaborative efforts to improve groundwater governance and management. The Groundwater Visibility Initiative (GVI) represents a joint effort of two national organizations, the American Water Resources Association (AWRA) and the National Groundwater Association (NGWA). I was part of the small, dedicated group that planned the GVI workshop held in April 2016. One outcome is the recent article "Making Groundwater Visible", which appeared in the September 2016 issue of AWRA's publication, *IMPACT*. The article, which reports on the results of the workshop, points to how groundwater's physical invisibility has led to its omission from many water policy, governance, and management discussions. The key findings are summarized in the article as follows: (1) Governing and managing groundwater require working with people; (2) Data and information are key; (3) Some "secrets" remain; (4) We need to take care of what we have; (5) Effective groundwater management is critical to an integrated water management portfolio that is adaptive and resilient to drought and climate change; and (6) To be robust, policies of the agriculture, energy, environment, land-use planning, and urban development sectors must incorporate groundwater considerations.

The second effort emerged from the 9th International Symposium on Managed Aquifer Recharge (ISMAR9), which was held in Mexico City in June 2016. A working group formed to develop the document "Sustainable Groundwater Management Policy Directives", which was published in English and Spanish and has its own six summary points or directives. (I) Recognize aquifers and groundwater as critically important, finite, valuable and vulnerable resources. (II) Halt the chronic depletion of groundwater in aquifers on a global basis. (III) Aquifer systems are unique and need to be well understood, and groundwater should be invisible no more. (IV) Groundwater must be sustainably managed and protected within an integrated water resource framework. (V) Managed Aquifer Recharge should be greatly increased globally. (VI) Effective groundwater management requires collaboration, robust stakeholder participation, and community engagement.

Engagement has been a key focal area in water governance efforts, such as the Water Governance Initiative by the Organisation for Economic Co-operation and Development, in which I participate. An overview of a substantive report on stakeholder engagement produced through this OECD initiative was published in a special issue of the journal Water: Water Governance, Stakeholder Engagement, and Sustainable Water Resources Management. WRRC colleague Susanna Eden and collaborator Eylon Shamir joined me in guest editing this collection of papers, which are all freely available online at // www.mdpi.com/journal/water/special_issues/water-gov. I encourage readers to take a look at this collection of papers, several of which relate to Arizona groundwater. "Modes and Approaches of Groundwater Governance: A Survey of Lessons Learned from Selected Cases across the Globe", by Varady et al. considers Arizona water banking as one of its case studies. Ballester and Mott Lacroix look at public participation in water planning in the Ebro River (Spain) and Tucson basins. Eden et al. report on the stakeholder participation component of a project that used hydrologic and climate modeling to help water users and managers understand how climate variability affects groundwater storage and recharge in the southern end of Santa Cruz Active Management Area. Mott Lacroix and Megdal's article on the "stakeholder engagement wheel" drew from multiple Arizona regions, and Chief et al. consider Arizona tribal nations' water use in their paper, "Engaging Southwestern Tribes in Sustainable Water Resources Topics and Management".

Finally, I would be remiss if I did not mention the important work on groundwater assessment being carried out along the US-Mexico border. The binational Transboundary Aquifer Assessment Program has produced a report on the San Pedro Aquifer in English and Spanish and is completing a similar report for the binational Santa Cruz Aquifer.

Groundwater is a critically important resource for Arizona and much of the world. People are coming together to emphasize the need to understand this resource and manage it better. At the University of Arizona Water Resources Research Center, we endeavor to contribute to efforts to share best practices for groundwater assessment, governance, and management. Please visit http://wrrc.arizona.edu/programs-research to find out more.

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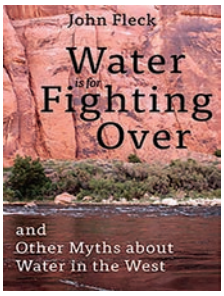
Resources

Water is for Fighting Over and Other Myths about Water in the West

by John Fleck

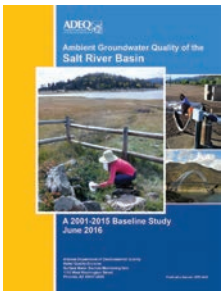
Island Press, 2016



In *Water is for Fighting Over and Other Myths about Water in the West,* author John Fleck has written that rarity, an optimistic book about western water. Although he acknowledges the seriousness of our water resource problems, he emphasizes the history of cooperation, conservation, and innovation that helped solve past challenges. Telling a series of stories about individuals and communities and how they have made a difference through actions that reflect the spirit of collaborative problem solving, he provides a hopeful view of our water future.

Ambient Groundwater Quality of the Salt River Basin: A 2001-2015 Baseline Study

by Arizona Department of Environmental Quality, June 2016



The study, conducted by Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program, characterized the groundwater quality of the Salt River basin from 2001 to 2015. For the study, samples were collected from 45 wells and 30 springs. The Salt River basin is composed of four sub-basins: the Black River, White River, Salt River Canyon, and Salt River Lakes. The basin as a whole, with its backbone rugged mountains has minimal groundwater storage capabilities. And estimated 178,000 acre-feet of natural recharge occurs each year and aquifers store about 8.7 million acre-feet down to a depth of 1,200 feet. In terms of drinking water quality standards and salinity levels, the Salt River basin has some of the best groundwater in Arizona. The most pristine groundwater is in the uppermost Black River sub-basin and concentrations of measured constituents typically increase as the water moves to the lower sub-basins.

The report and a summary fact sheet can be found at https://www.azdeq.gov/node/882.

Investigation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse

By California State Water Resources Control Board

Draft Report released September 8, 2017

California undertook the task of investigating the feasibility of developing regulatory criteria for direct potable reuse of water. They convened two panels to provide advice: scientists and engineers with expertise in the various applicable subjects and stakeholders who would be affected by any regulatory actions. The 43-page Draft Report to the Legislature contains findings and recommendations that include the determination that the development of regulatory criteria is feasible if knowledge gaps are addressed. The panels investigated public health questions about health effects of contaminants, recycled water treatment technologies; the use of multiple barriers and sequential treatment processes; fail safe mechanisms; and monitoring needs. The primary knowledge gaps concern reliability of the treatment process when there is no environmental buffer. The report recommends that research to address knowledge gaps proceed simultaneously with efforts to develop criteria so that research results can be used to inform the development process.

The Draft Report can be accessed at http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/draft_report_to_legislature_dpr_public_review.pdf.