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From the Publisher

Turn off the tap. Replace your toilet. Get rid of the grass. And don’t overwater. We’ve all heard conservation messages, many of us have changed our habits, and some are adjusting to mandatory restrictions. Are we making a difference? Yes, especially at the residential level. In spite of this progress, water demand will continue to rise in the Southwest, especially once economic recovery begins, and changing climate will limit the supplies we currently rely on. Conservation can provide a cushion during short-term drought or extend the time until more expensive new water sources are required. But consider that the water providers, who lead the call for conservation, depend on water sales to pay their bills. How can they sustain their operations? Raising the rates would not be much of a reward to scrimping customers. Some conservation issues have yet to be worked out. Meanwhile, go fix that dripping faucet.

Thanks to all the contributors to this issue, who as always represent a diversity of sectors and geographic locations. We are also grateful to our record number of advertisers for 2009 (page 43), as well as our generous sponsors (page 9). You are all critical to our continued production and success.

Betsy Woodhouse, Publisher

Correction

A miscalculation in the sidebar on page 21 of the Sept/Oct 2009 issue of Southwest Hydrology gave incorrect information about the scale of CO2 sequestration needed to achieve atmospheric CO2 stabilization. In fact, if the 8,100 largest CO2 sources were captured at 80% efficiency, a global storage target of 100 bmt in 100 years could be achieved in less than eight years. The 100-year target could also be reached if the 8,100 sources captured just 6% of their emissions per year.

Outdoor (over)irrigation is a major source of residential water use across the Southwest and a primary target of water conservation programs. Scenes such as this, in Clark County, Nevada, in 2000, are becoming increasingly rare. Photo by Lynn Betts, USDA Natural Resources Conservation Service.

This publication is supported by SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas) under the STC Program of the National Science Foundation, Agreement No. EAR-9876800. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of SAHRA or of the National Science Foundation.
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Water conservation is usually the first option utilities turn to when supplies suddenly run short. Increasingly, utilities are turning to conservation not just to survive short-term drought, but as a means to increase overall efficiency of water use; the saved water is a “new” supply for the future. But to effectively include conserved water as part of their water portfolios, providers must be able to quantify the savings, identify where additional savings might be achieved, and understand why some programs don’t catch on. This issue’s features consider existing and potential savings in a variety of sectors, as well as methods to quantify savings and design effective savings-measurement programs. Finally, we consider the catch-22 of water providers who promote conservation yet depend on water sales to remain fiscally sound.

**Sustaining Agriculture in an Uncertain Future: The Role of Water Efficiency**

Heather Cooley, Juliet Christian-Smith, and Peter H. Gleick

The Pacific Institute envisions a future with sustainable, healthy agriculture that is far more water efficient than today. Just how viable this future is depends on several variables, including the ability of multiple stakeholders to get on the same page.

**Making Every Drop Work in California’s CII Sector**

Ronnie Cohen, Kristina Ortez, and Crossley Pinkstaff

The commercial, industrial, and institutional (CII) sector remains an elusive target for conservation advocates but offers opportunities for significant water savings. What can be done to convince hard-to-reach profiteers and industrialists that conservation benefits them as well?

**Water Efficiency Programs for Verifiable Savings**

Maureen Erbeznik and Joanne Rector

No water utility wishes to embark on a conservation program that fails to save water or costs a fortune to implement. Properly designed evaluation, measurement, and verification processes can lead to effective conservation programs—provided utilities pitch it to customers correctly.

**Residential Savings: How Much and at What Cost?**

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Detailed Water-Use Data Without Customer Involvement

William B. DeOreo – Aquacraft Inc. and Fiona Sanchez – Irvine Ranch Water District

Accurate information about customers’ water-use patterns and efficiency levels is essential for planning or evaluating any water conservation program—but obtaining high-quality data can be difficult. One approach uses mailed surveys in which the customer reports the types of water-using fixtures and appliances in the home. Another attempts to select random samples of volunteer homes for site visits and audits. What is needed is a truly random and anonymous procedure for collecting detailed end-use data from single-family homes that allows water use to be fully characterized. The results from a properly selected sample can be applied to the entire population to determine the remaining conservation potential.

Quality Data, Minimal Interference

An example of such an approach is the California Single Family Home Water Use Efficiency Study funded by the California Department of Water Resources. Data collection and analysis were conducted from 2006 through 2008 on 780 homes statewide. While final results are pending, its methodology can be shared, including procedures for sampling and obtaining data and the information this type of study can provide.

Three main data sources are available, including the single-family billing database, flow-trace files collected from customers’ water meters, and aerial photography of lots from GIS sources. None require customer involvement, so the entire study is conducted in an unbiased and controlled manner. Samples are chosen at random from the population of single-family accounts, and data are collected from sources that are either publicly available or owned by water agencies. All results are kept anonymous, thus maintaining customer confidentiality.

Flow Trace Tells All

The basis of this methodology is the flow-trace analysis using the Trace Wizard program developed by Aquacraft Inc. Most residential water meters have internal magnets that spin between 60 and 100 pulses per gallon of flow. The data loggers used for the study collect these pulses at 10-second intervals, providing a very accurate record of the flow versus time—the flow trace. Experience has shown that water-use events in flow traces can be categorized into individual end uses such as baths, showers, toilet flushes, clothes washing, leaks, and dishwashers running, allowing indoor end use of water to be analyzed in detail. Gallons per household per day for each end use can be identified, as well as gallons per toilet flush or laundry load and flow rates of showers (see upper figure, below). Use also can be compared between groups (see lower figure), providing a level of detail that is impossible with other practical-to-implement techniques for analyzing water. The data can also

![Graph showing water use over a two-hour period.](image)

This typical flow-trace segment shows the water use of a clothes washer (light blue; two loads), toilets (green), faucets (yellow), and leaks (dark blue) over a two-hour period.

![Bar chart showing breakdown of end uses.](chart)

A breakdown of end uses for two study groups, one in 1995 (green) and one in 2006 (orange). Note that the 2006 set had lower water use for toilets and clothes washers, but higher use for most other categories.
be used to determine how much of the population has adopted use of high-efficiency fixtures and appliances.

Outdoor water use is determined as the difference between the metered annual consumption and projected indoor use from the flow trace (or in some cases from the minimum billing month). GIS analysis combined with local evapotranspiration data provide the theoretical irrigation requirement for lots in the study. This allows the application ratio and excess water used for irrigation to be determined for each home.

The flow-trace methodology applied to the California Single Home Water Use Study arose from data logger studies dating back to 1999. Techniques now permit highly detailed, anonymous studies to be conducted on the water-use patterns of truly random samples of customers, providing accurate and detailed information that can be applied to the entire population to estimate system-wide savings potential.

Contact William DeOreo at bill@aquacraft.com and Fiona Sanchez at sanchezf@irwd.com.

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Contact William DeOreo at bill@aquacraft.com and Fiona Sanchez at sanchezf@irwd.com.
NM Dairy Discharge to Be Regulated

In April, New Mexico Gov. Bill Richardson signed a bill that modified the state Water Quality Act to require the Water Quality Control Commission (WQCC) to adopt regulations for the discharge of dairy wastewater to protect groundwater quality. Dairy regulations were expected to be completed within one year.

In May, the New Mexico Environment Department (NMED), which provides technical services for WQCC, released a discussion draft of new regulations that address issues such as how groundwater is best protected near dairies, the lining of wastewater lagoons, and monitoring-well requirements. NMED held public meetings regarding the draft throughout June; negotiations followed in July and August. The final regulations ultimately are scheduled to be adopted in March 2010 following a hearing by WQCC.

In a presentation on the draft rulemaking process, NMED noted that “because industry requested more certainty, consistency, and detail, these regulations are much more specific than conditions of recent permitting actions.” Nevertheless, in June, after the draft regulations were issued, the Clavis [New Mexico] News-Journal reported that dairy farmers were seeking standard practices to prevent pollution. The article also noted that the dairy industry and NMED disagree on how monitoring wells should be used, with dairies arguing that wells too close to leaking lagoons could serve as conduits for pollutants that would otherwise be filtered out before reaching the water table.

NMED estimates that 65 percent of the state’s dairies have polluted the underlying groundwater.


CA Eases Graywater Standards

In July, the California Building Standards Commission adopted new graywater standards. The standards were developed by the Department of Housing and Community Development as a result of Senate Bill 1258 passed in 2008. They address the construction, installation, and alteration of graywater systems for indoor and outdoor uses, and were designed to encourage the use of graywater technology by not requiring permits and including fewer mandatory requirements. Graywater is the wastewater that drains out of washing machines, bathroom sinks, bathtubs, and showers. With the new standards, a family of four could potentially divert 22,000 gallons of water per year using graywater from the laundry system alone to supplement nonpotable indoor (if treated) and outdoor water uses. The commission hopes the new standards will encourage the use of graywater, reduce the state’s overall water consumption, and increase public awareness about water conservation.

The San Diego Union-Tribune reported that 1.7 million graywater systems have been installed statewide, and that most are illegal because homeowners have avoided the permitting process. The new standards were expected to take effect in 2011, but the ongoing drought caused the commission to adopt the regulations early on an emergency basis. Homeowners must still follow state guidelines.


Solar’s Water Use Raises Concern

Solar energy plants being built in Arizona will use a lot of water, Tom Whitmer of the Arizona Department of Water Resources (ADWR) warned the board of directors of the Bullhead Regional Economic Development Authority in July, reported the Mohave Daily News.

According to the Daily News, Whitmer noted that almost 50 solar power plants have been proposed on Bureau of Land Management land in Arizona, including the three plants proposed in Mohave County that use water-intensive technology. Concentrated solar plants tend to use wet cooling rather than dry cooling because it is more energy efficient and can generate more profit, but it also uses four times as much water.

The Daily News added that ADWR opposed pending legislation to streamline the approval process for solar plants on federal land. But the agency has no jurisdiction over such plants.

In July, the U.S. Senate Committee on Energy and Natural Resources approved the American Clean Energy Leadership Act of 2009 (S.1462), opening it to full
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Senate debate. The bill is a compilation of several energy bills and includes multiple provisions regarding the balance of energy efficiency and water efficiency.

If passed, the bill would require, among other things, a study of water use associated with developing fuels in the transportation sector, the development of strategies to maximize water- and energy-use efficiencies in producing electricity, the identification of ways to reduce water use in energy-intensive U.S. Bureau of Reclamation projects, and the establishment of a grant program for the development of technologies to conserve energy and promote water conservation.


Grand Canyon-Area Mine Lands Evaluated
In July, Secretary of the Interior Ken Salazar announced the segregation of one million acres of federal lands near the Grand Canyon for two years while the Department of Interior (DOI) evaluates whether to withdraw these lands from new mining claims for an additional 20 years, the maximum allowable by law.

During the conventional two-year segregation, the U.S. Bureau of Land Management will lead studies and analyses of the region. The process will include public input through the National Environmental Policy Act. The U.S. Geological Survey began an intensive, short-term investigation of the area shortly after Salazar’s announcement; results are expected in early 2010.

Both segregation and withdrawal actions prohibit new mining claims in the designated areas but do not prohibit ongoing or future mining exploration or extraction operations on valid, pre-existing claims, of which there are over 10,000.

In June 2008, House Natural Resources Committee Chairman Nick J. Rahall and Raúl M. Grijalva, chairman of the Natural Resources Subcommittee on National Parks, Forests, and Public Lands, approved an emergency resolution to compel DOI to withdraw lands, but it was never implemented. The congressmen now are sponsoring legislation, the Grand Canyon Watersheds Protection Act of 2009, that would permanently withdraw one million acres of federal land near Grand Canyon National Park from future mining claims.

Grijalva’s subcommittee held a planned hearing on the legislation following Salazar’s announcement. According to The Associated Press, a University of Nevada, Las Vegas hydrologist testified that uranium levels in a canyon creek are three times higher than the U.S. Environmental Protection Agency’s recommended limit for water supplies, and that this is the result of mining from more than a decade ago. In addition, AP reported, the Southern Nevada Water Authority expressed concern about potential contamination of the Colorado

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River, which provides most of its water. However, the director of the Arizona Department of Mines and Minerals testified that the elevated uranium concentrations result from erosion rather than mining, and another scientist testified that modern mining techniques are much improved over those used previously that may have caused contamination.

The segregated lands are within portions of the Grand Canyon watershed next to Grand Canyon National Park in northern Arizona, an area that contains significant environmental and cultural resources as well as substantial uranium deposits.


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**Texas Agencies Battle Over Water**

In August, the San Antonio Water System (SAWS) filed a $1.23 billion lawsuit in the Travis County State District Court for breach of contract against the Lower Colorado River [of Texas] Authority (LCRA). The suit involved a joint water-sharing project the two agencies have been developing since 2002.

The project began after the 2001 Texas legislature authorized LCRA to transfer up to 150 acre-feet per year of Colorado River water to “a municipality outside its service area” contingent on certain requirements related to the environment, lake water levels, water-conservation efforts on behalf of the municipality, and protection of and benefit to Colorado basin interests. San Antonio, in need of water for development, was the target municipality.

As part of the 2002 agreement, SAWS funded feasibility studies to comply with the legislative requirements, and planned to fund conservation and water-development measures if the project moved forward. But earlier this year, LCRA announced that preliminary scientific findings indicated the joint project would not meet all legislative requirements and that no water would be available for San Antonio.

SAWS claims LCRA’s decision was not based on science. The agency said in a press release that “LCRA incorrectly assumed that the results of technical studies could be altered by unilateral “policy assumptions” made by LCRA’s board of directors. The policy assumptions, according to SAWS, are related to “lucrative promises of a potential coal plant” in LCRA’s service area.

As a result, SAWS seeks financial recovery for an amount defined as the difference between the project cost of 90,000 acre-feet of water for 80 years and the total cost of acquiring the same amount of water from another source. SAWS has already invested over $43 million in project studies.

LCRA responded that the need for more water to meet growing demands, environmental concerns, and lake-level requirements were the primary factors contributing to their decision: “Updated projections showed that more water than was previously estimated would be needed for cities and industries in the Colorado basin.”

In September, LCRA responded to the lawsuit with a court filing stating that the agency owes SAWS at most $18 million, or half the cost of the feasibility studies.

The two agencies attempted mediation without success in early summer. San Antonio has struggled to find water sources since 1993, when the state legislature capped the amount of pumping allowed from the Edwards Aquifer to protect endangered species in springs it feeds.


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**Nevada Test Site Monitoring Expanded**

In May, the Nevada Test Site office of the U.S. Department of Energy’s National Nuclear Security Administration announced the drilling of nine additional groundwater characterization wells in the vicinity of Pahute Mesa, more than 100 miles northwest of Las Vegas. These wells are on or near a Nevada Test Site location that hosted 82 underground nuclear tests between 1965 and 1992.

A 1997 report predicted that tritium and carbon-14 would migrate off the test site within 50 years of the area’s first detonation in 1965. In February 2009, a new report based on computer modeling confirmed the expected movement outside the site boundary, initially in the area of Western Pahute Mesa. The Nevada Test Site office identified the...
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need for more monitoring wells to help refine a 3-D contaminant transport model of where and how quickly the radioactive contamination is moving.

There is currently no evidence of offsite contamination based on samples from the 40 wells and springs surrounding the test site, and no immediate risk to the public. However, onsite groundwater contamination has been identified near locations of historic nuclear tests.

In July, the Las Vegas Review-Journal reported that groundwater in a recently completed onsite well had 3,000 times the safe drinking-water limit for tritium. The paper also noted that when the groundwater moves offsite, it will be within an area of an Air Force range not accessible to the public.

The new wells will cost between $5 million and $7 million each, including pad construction, excavation and lining of sumps, new roads, and drilling to depths of 2,500 to 3,700 feet. According to the paper, the project will cost $68 million over the next three years and will use $12 million of stimulus funds.


Mohave Power Plant Closed

In June, the owners of the Mohave Generating Station in Laughlin, Nevada, including majority owner and operator Southern California Edison, announced the station would be decommissioned and dismantled in the coming months.

The decommissioning means extra water for the Southern Nevada Water Authority (SNWA), reported the Las Vegas Review-Journal, because it no longer has an obligation to provide the plant with up to 19,000 acre-feet of water per year, as agreed in 1993. The plant never required more than 13,000 acre-feet per year and has used just a few hundred per year since its closure in 2005, but now SNWA is free to use the entire amount for other purposes.

The plant capacity was 1,580 megawatts, enough to power more than one million homes. It closed after the owners were required to install emission-control upgrades and the lack of new water and coal agreements made it too costly to proceed. According to the Review Journal, the deadline for air-pollution-reduction upgrades arose from a lawsuit by environmental groups concerning emissions-related haze above the Grand Canyon. Although operations ended in 2005, until the decommissioning announcement was made, there was still a chance the plant would resume operation.

Other owners of the plant include the Salt River Project, NV Energy, and the Los Angeles Department of Water and Power. They will leave the transmission switchyard in place, leaving open the option of using the site for energy generation in the future. The owners are considering selling the site or constructing a renewable energy project.


Smelt and Salmon Restrictions in the Delta

In June, the National Oceanic and Atmospheric Administration (NOAA) released a final biological opinion stating that water pumping in California’s Central Valley by the Bureau of Reclamation jeopardizes the continued existence of several threatened and endangered species under the jurisdiction of NOAA’s National Marine Fisheries Service.

NOAA provided several options for operating the water system to benefit these species, including increasing cold water storage and flow rates. Reclamation provisionally accepted NOAA’s recommended changes to its pumping operations, and said it would begin to implement the biological opinion’s near-term elements as it carefully evaluates the complete findings.

Federal stimulus monies will help mitigate costs of some of the recommended measures, including $109 million for construction of a pumping plant that allows unimpeded passage for salmon and $26 million for restoration of a salmon stream tributary to the Sacramento River.

NOAA estimated that following the recommendations of the biological

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opinion would reduce the volume of water that can be delivered from the Sacramento-San Joaquin Bay-Delta by five to seven percent per year. The California Department of Water Resources estimated the impacts would be 10 percent per year.

Meanwhile, a group of San Joaquin Valley landowners sued several federal agencies, claiming they failed to protect the threatened and endangered species in the delta, reported the Stockton Record. The group also claimed that by allowing environmental conditions to deteriorate, the agencies have made it necessary to reduce the amount of water that can be pumped from the delta.

Also in June, according to the Sacramento Bee, the California Fish and Game Commission formally voted to list the longfin smelt as threatened under the state Endangered Species Act following recent evidentiary findings. The action did not bring additional water restrictions, as delta pumping limits had already been imposed in March. Earlier this year, the U.S. Fish and Wildlife Service chose not to list the longfin under the federal Endangered Species Act.

AZ Rejects Natural-Gas Storage Waiver

The Arizona legislature ended its 2009 session without passing a bill to exempt underground natural-gas storage facilities from the state’s aquifer protection program, reported the Arizona Daily Star in July.

According to the paper, the bill would have immediately benefited Multifuels, a Houston-based company that proposed storing natural gas in salt beds below Picacho Valley in Pinal County. The Arizona Department of Environmental Quality denied a permit for the facility to inject brine pumped from one formation into another part of the aquifer, a step necessary to create space for natural-gas storage.

To create a storage cavern, freshwater is injected into a salt formation, dissolving the salt deposits. The resulting brine is then pumped out, leaving a cavity, and reinjected into a deeper formation nearby.

The Daily Star reported in June that project opponents cited the collapse of two saltwater wells in New Mexico, which left huge sinkholes, as reason enough to terminate the bill. Supporters felt the bill was needed for securing long-term natural-gas supplies, and that the New Mexico wells were not comparable to those proposed in Arizona. The Arizona House passed the bill, but the Senate never voted on it.

Among the 24 current exemptions to the aquifer protection program are household activities, mining overburden returned to the site of excavation, surface impoundments used to contain storm runoff, and facilities using Central Arizona Project water for underground storage and recovery.


AZ Weighs Anti-Climate-Change Ruling

In June, the White House released a report, “Global Climate Change Impacts in the United States,” that detailed, among other things, rapid recent warming in the Southwest, declining spring snowpack and Colorado River flows, and an increasing scarcity of water supplies.

Several days later, the Arizona Senate voted to prevent the Department of Environmental Quality from “enacting or enforcing any new rules designed to deal with climate change”, reported Capitol Media Services. The bill in question would have blocked rules developed by the department last year, under Gov. Janet Napolitano, that set emission standards for new vehicles related to greenhouse gases. It would also end work on cap-and-trade systems within the state.

The bill was never heard in the House and therefore died in session.

Today, in the year 2050, California agriculture is thriving, leading the world in sustainable production, efficient water use, fair and humane treatment of its workforce, and protection of ecological services.

Severe drought, financial constraints, and growing environmental problems that peaked around 2010 forced many farmers and irrigation districts to change the way they operated. In particular, sustainable water management practices already implemented in some areas became much more widespread, including efficient irrigation technologies, improved irrigation scheduling, integrated groundwater management, and measures that enhance soil-moisture retention. Few farmers attempt to grow water-intensive crops due to stiff competition from urban and ecological water users. But many crops now use less water anyway because of genetic improvements in crop cultivars and better irrigation technologies.

The water crisis also led to long-overdue changes in water-use monitoring and reporting. Farmers began to push for change as unconstrained groundwater pumping and contamination began to hurt more farmers than it benefited. All groundwater use and quality is now monitored and managed by local groundwater management groups, with guidance from statewide standards. Long-term over-pumping of groundwater—one of the clearest measures of unsustainable water policies in the past century—has finally ended. Integrated groundwater management has nearly doubled the amount of water stored in active groundwater basins for use during droughts.

The California agricultural community has also put in place several institutional innovations. Water management institutions ensure the “reasonable and beneficial” use of water resources. Federal and state water contractors have repaid the cost of building major water infrastructure projects, including the Central Valley Project and the State Water Project. Pricing is now used as a tool to encourage wise water use, and most urban and agricultural water suppliers have adopted tiered rates where those who use more water pay more per unit of water. The additional revenue gained from these rate structures finances on-farm and district improvements, including better measuring and monitoring of water use.

Farmers and environmentalists have worked together to define specific ecosystem goals, such as restoring and maintaining healthy fish populations, reducing salinity, and protecting waterfowl habitats. These partnerships ensure environmental protection and increase the certainty of water supply to farmers. As a result, fish populations that managed to survive to the turn of the century remain healthy, and tourists come to see the spectacle of millions of ducks, geese, and cranes in the refuges of central and northern California.

What could agriculture in the western United States look like in the year 2050, given growing uncertainties over the reliability and availability of water? In a new report from the Pacific Institute, “Sustaining California Agriculture in an Uncertain Future,” we offer a vision of a sustainable, healthy agricultural community—one far more efficient in its water use than today. While the focus is California, we believe that articulating this vision can help initiate discussion to develop a shared strategy for addressing increasingly contentious water challenges across the Southwest.

Agriculture in 2050: Our Vision

Today, in the year 2050, California agriculture is thriving, leading the world in sustainable production, efficient water use, fair and humane treatment of its workforce, and protection of ecological services.
Achieving the Vision

We believe that achieving such a vision is possible, though clearly not inevitable. The challenge is finding the right path and policies to secure such a future. Many strategies will be needed to develop an agricultural sector that supplies food to the state and nation and supports rural livelihoods, while remaining consistent with long-term sustainable water use. One key approach is to improve the efficiency of water use. Water conservation and efficiency offers an inexpensive, flexible, and resilient means to adapt to pressures from competition over limited resources, drought, and climate change. In addition, today’s conservation efforts are likely to produce a competitive advantage that ensures agriculture will continue to play an important role in the West.

Water Conservation and Efficiency Scenarios

Agriculture uses 80 percent of the groundwater pumped and surface water withdrawn in California. In 2000, California agriculture used 34 million acre-feet of water to produce food and fiber valued at $33 billion (in 2007 dollars). Many options are available for improving the efficiency of water use in California agriculture. For our analysis, we chose practices that numerous studies indicate reduce water use while improving crop yield and/or quality. Many in the agricultural community have already implemented these measures but more can, and should, be done.

This analysis was performed using the same model that the Department of Water Resources uses in its statewide planning efforts. As a starting point, we used irrigated crop area from 2005 and crop water-use estimates for the years 1998, 2000, and 2001 to construct baseline estimates of agricultural water use in California during wet, average, and dry years, respectively. A literature review was conducted to develop plausible water savings estimates for each practice. The practices evaluated include:

- **Efficient Irrigation Technology:** shifting a fraction of irrigated crops from flood irrigation to sprinkler and drip systems. Statewide, 60 percent of California’s crops are still flood irrigated. For this study, we estimate potential water savings in a scenario where half of field crops continue to be flood irrigated and half are irrigated with sprinklers; additionally, 75 percent of orchard, vegetable, and vineyard acreage is irrigated using micro-sprinklers and drip, and the remaining 25 percent is irrigated using sprinklers.

- **Improved Irrigation Scheduling:** using local climate and soil information to help farmers irrigate more precisely to meet crop needs. We estimate that irrigation scheduling would reduce water use by 13 percent. The study assumed that 20 percent of farmers currently use these methods to schedule irrigation and projected the savings if all farmers used scientific irrigation scheduling.

- **Regulated Deficit Irrigation:** applying less water to certain crops (almonds, pistachios, raisins, and wine grapes) during drought-tolerant growth stages to save water and improve crop quality. The savings if all farmers used this practice is greatest potential for response.

The combined potential savings from implementing these three practices range from 4.5 million acre-feet in a wet year to 6.0 million acre-feet in a dry year (see chart, below). This could reduce California agricultural water use by 17 percent without changing total irrigated acreage or the current mix of crops. Reducing acreage and changing crop types could lower total water use further, but we do not evaluate such options here because they are not “efficiency” improvements.

Our results indicate that water conservation and efficiency improvements are particularly effective in dry years, when agricultural water demand is greater and competition for scarce water resources is more severe and costly. By investing in “drought-proof” strategies, farmers can reduce their vulnerability to drought-imposed water-supply constraints. Because climate-change predictions for the Southwest call for increased frequency and intensity of droughts, these measures will be especially valuable.

The failure to accurately account for agricultural water use contributes directly to the failure to manage it sustainably.

Potential water savings (in million acre-feet, maf) for wet, average, and dry years. Note that the baseline (before conservation) applied agricultural water use in this analysis was 26.6 maf for a wet year, 33.8 maf for an average year, and 35.4 maf for a dry year.
Making Every Drop Work in California’s CII Sector

Ronnie Cohen, Kristina Ortez, and Crossley Pinkstaff – Natural Resources Defense Council

This article is excerpted from the 2009 report, “Making Every Drop Work: Increasing Water Efficiency in California’s Commercial, Industrial, and Institutional (CII) Sector.”

In February 2008, California’s governor called for a 20-percent reduction in per-capita urban water use by 2020. To reach this target, all water users, including the commercial, industrial, and institutional (CII) sector will need to do their part. CII water use in California is estimated to be 2.5 million acre-feet (maf) per year—approximately one-third of total water use in the state’s urban areas. The biggest commercial and institutional consumers include office buildings, golf courses, and schools. Of industrial users, oil refineries, food-processing facilities, and high-tech manufacturers demand the most water.

Based on an evaluation of current water use and available water-efficient technologies, 710,000 to 1.3 maf of water per year (around 900 million gallons per day, mgd) could be cost-effectively saved in California’s CII sector. Such savings would result in lower water and energy bills, reduced wastewater charges, and reduced costs for water treatment. Furthermore, businesses would be helping to extend limited water supplies, reduce global-warming pollution, restore fisheries and other ecosystems, and improve water quality by reducing urban runoff.

Some businesses have achieved remarkable success implementing technologies and processes to improve water efficiency. A Chevron oil refinery in the East Bay Municipal Utility District service area will soon be using recycled wastewater to meet 8 mgd out of its 10- to 12-mgd demand. Intel’s processing plant in Arizona uses just 2.5 mgd water rather than the industry average of 8 mgd. Fetzer Vineyard has reduced water consumption by 24 percent, saving 8 million gallons per year.

Despite significant progress in CII water efficiency over the last decade, tremendous untapped potential remains. With all the benefits to be gained, why isn’t more water conservation occurring?

Lack of customer capital or awareness of financial assistance. Some businesses simply do not have the capital for large-scale retrofits. Some water agencies have rebate programs but lack the resources to promote them effectively.

Insufficient funding for rebate programs. Larger water agencies can offer an avoided-cost rebate (paying a business to save water) or a wide range of traditional rebates. But smaller agencies often rely on state or federal conservation funding, some of which is now limited by budget concerns.

Lack of technical assistance and shortage of trained staff. The lack of trained water agency staff capable of installing and maintaining water-efficient technologies continues to be a significant barrier to conservation.

Lack of data. Water resource management in California is handicapped by inadequate, incomplete, and potentially inaccurate information about water use. The Department of Water Resources Public Water Systems Survey is collected voluntarily, which impacts data completeness and accuracy, and does not include information from 2005 to the present.

Third-party lessors and misaligned incentives. Businesses that lease equipment from a third party responsible for both maintenance and operation may face an additional barrier when trying to retrofit appliances and process equipment. Since they are
generally not responsible for operating expenses, lessors lack incentive to increase equipment efficiency.

Relatively low water costs. Water and wastewater disposal may represent a comparatively small fraction of overall operating costs—yet another disincentive for businesses to make efficiency improvements.

Incompatible expectations for returns on investment. Businesses often make capital investment decisions with the expectation of short-term returns on their investment (ROI), whereas ROI for utility-based rebate programs may be spread out over years. This difference can hamper the investment strategies of both parties.

What Can be Done?
While targeted to California, the following recommendations for improving CII water efficiency may also apply to other states and sectors.

- Establish state efficiency standards for water-using products. This would spur innovation and bring more water-efficient technologies to market and into CII use.
- Establish performance-based water-savings targets that provide water agencies with flexibility to choose the measures appropriate for their region.
- Set water conservation as a higher priority than increasing supply. As occurred in the energy sector, this would motivate investment in water efficiency and recycling.
- Adopt a public goods charge on water sales to provide a dedicated funding source for water-efficiency programs, including expanded technical and financial assistance.
- Encourage partnerships with—and financial support from—energy utilities and wastewater agencies by offering preferential state funding.
- Streamline the process for recycled water use.
- Encourage volumetric pricing for sewer services. Studies show that a 10 percent increase in water price yields a 2 to 3 percent reduction in demand.
- Decouple water agencies’ sales from revenue so agencies have a means to recover additional money from customers if sales are below projection.
- Improve water-use data collection and management through establishment of statewide electronic water-use reporting and data-sharing systems.

Water districts across the Southwest devote considerable effort to promoting water conservation, yet many homes and businesses continue to waste water. Why? *Southwest Hydrology* spoke with water conservation managers to find out what reasons they have heard.

**Conservation Supports Growth**

Nearly all managers face customers who claim saving water will only support urban sprawl—“Why should I scrimp so somebody else can move here?” Doug Bennett at Southern Nevada Water Authority (SNWA) asks his audience how many have lived in Las Vegas more than five years; most are recent arrivals and have no real basis for supporting this argument.

But Bennett also points out that the conservation programs his agency offers to current residents are paid for by the next generation of residents, who will be held to even higher conservation standards.

Although anti-growth sentiment is often heard, managers believe it is the sentiment of a vocal few rather than the public majority, as overall per-capita water usage is declining. Furthermore, while none of the utilities promote growth as a reason for conservation, they all plan for increasing population.

**Conservation is Expensive**

This argument has merit, especially for outdoor conservation. Converting a water-intensive landscape to xeriscape with new plantings and an irrigation system is expensive, and because water is relatively cheap, the time for return on investment is long, even with rebates. Melissa Elliott at Denver Water hears this excuse most often. It can take 10 years to see a return; residents may not live in their house that long. Katherine Yuhas at the Albuquerque-Bernalillo County Water Utility Authority agrees cost is a valid objection, although her customers receive an even higher rebate if their new xeriscape uses harvested rainwater. She thinks a change in rate structure is needed to adequately address the issue.

Economic downturn is also impacting conservation efforts, noted both Elliott and other managers.
Residential Conservation: How Much and at What Cost?

Summarized from Evaluation and Cost Benefit Analysis of Municipal Water Conservation Programs, a report by the Water Conservation Alliance of Southern Arizona

What actual water savings can be achieved from municipal conservation programs? How do the costs of conservation programs compare to the volume of water saved? The Water Conservation Alliance of Southern Arizona developed the ECoBA (evaluation and cost benefit analysis) project to gather the hard data to answer these questions.

ECoBA’s goal was to provide data to decision makers to help them decide which water conservation program to implement first or next, or which to eliminate. The project analyzed utility records of 88 cases (one year of a particular water conservation program) in 42 programs from 11 states, primarily in the Southwest.

Programs included water audits, landscape retrofits, washing-machine rebates, toilet rebates and replacements, and conservation-device giveaways (such as low-flow shower heads and faucet aerators) applied primarily in single-family residences. In addition, a limited number of rate-change, ordinance, and conservation-class programs were reviewed but insufficient data were available for direct comparison.

The methodology examined participants’ water use two years prior to the program and two years afterwards. Their water use was then compared with that of a control group (average use for the entire utility or a subset population) to assess the amount of water savings that could be attributed to the program. The programs that were analyzed occurred between 1994 and 2003.

Besides determining actual water savings achieved, the program was designed to establish costs to the utility, other funders, and customers to attain those water savings. However, only direct costs and benefits that could be quantified for all programs were included; savings to the participants on sewer or other unquantified benefits may in fact be significant.

Researchers looked in-depth at the water-use patterns of the customers who took advantage of the conservation programs and the persistence of their water savings through time, and compared the actual water savings with standard predicted savings. The economic analysis focused on the cost to save an acre-foot of water and the cost to the utility per participant. Results are shown in the charts below. Several key or unexpected findings from the ECoBA project are notable.

Toilet distributions (giveaways) was the clear winner in terms of cost and water savings; the difference in water savings achieved by toilet distributions (228 percent of predicted water savings) and toilet rebate programs (63 percent of predicted savings) was surprising. The result may be because distribution programs allow a utility to assert total quality control by offering only highly efficient models, ensuring that toilets are installed properly, and also checking for leaks or other conservation opportunities in the household during installation.

Audit and washing-machine rebate programs seemed to attract significantly higher-volume water users than average, whereas landscape-conversion programs attracted low-water users. Landscape conversion and audit programs were so variable in their costs and savings achieved that program managers are advised to be especially cautious in structuring or targeting these types of programs. On average these programs cost the most to save one acre-foot of water.

Negative water savings per participant (see especially washing-machine rebates, below) indicate that control-group water use decreased more (or increased less) than participant water use. Negative cost per acre-foot saved indicates the utility incurred costs relative to the program and no water savings were attributable to those costs; in fact, an increase in participant water use occurred.

Email watercasa@cals.arizona.edu for the full report.
Water Conservation

The most widely recognized metric and practices add to the challenge. With conservation principles is difficult; is utilizing water in a manner consistent state…”. Evaluating whether an applicant to the conservation of water within the exercised … in a manner that is contrary to state that the permit “shall not be 

engineer required all water-rights permits with a target GPCD. And, aware of the many ways GPCD calculations can vary, it began a program to standardize them.

Need for Standardization

The New Mexico Office of the State Engineer (NMOSE) is charged with administering the state’s water resources. It has statutory responsibility over the supervision, measurement, appropriation, and distribution of all surface water and groundwater in the state. As in most southwestern states, municipal use is the principal area of increasing demand. Therefore, to better regulate municipal water use, the agency began to condition municipal water-rights permits with a target GPCD. And, aware of the many ways GPCD calculations can vary, it began a program to standardize them.

Apples to Apples: A Standardized Measure for Municipal Water

Cheri Vogel and John Longworth – New Mexico Office of the State Engineer

In the mid 1980s water conservation became a standard by which the New Mexico state engineer evaluated water-rights transfers. In 1997, the state engineer required all water-rights permits to state that the permit “shall not be exercised … in a manner that is contrary to the conservation of water within the state…”. Evaluating whether an applicant is utilizing water in a manner consistent with conservation principles is difficult; ever-evolving conservation technologies and practices add to the challenge.

The most widely recognized metric for water use is gallons per capita per day (GPCD). Should a continued reduction of GPCD over time equate to a measurement of conservation? The answer is complicated. Numerous aspects affect a drinking-water supplier’s GPCD, such as demographics, climate, economics, and availability of supply. These can change over time to influence GPCD, but the calculation of GPCD itself must remain constant if valid use comparisons are to be made. Yet staffing changes, public-image pressures, and other influences have caused drinking-water suppliers to modify their GPCD calculations, further complicating the evaluation of conservation efforts.

Apples and Oranges

NMOSE first looked at how other states determine GPCD. When the study began in 2007, Florida, Texas, Kansas, and Arizona all were using some form of standard GPCD calculation, for which the primary variables are gallons of water and population. Three of the states researched used total gallons diverted from surface or groundwater prior to treatment or storage, while one used gallons billed to customers. Other states not included in the original research subsequently reported including reuse, raw (diverted water that may have been stored), or diverted water. Two of the original states allowed systems to define their own populations, one used a seasonally adjusted population, while the fourth used the number of living units times a person-per-household average from the U.S. Census Bureau. These may seem like subtle variations but they make a significant difference in the calculation.

Looking within New Mexico, NMOSE found similar variations. Approaches used to estimate population, the most difficult variable to isolate, varied widely. The Census Bureau’s population is most commonly used for cities or counties, however political boundaries do not always coincide with water suppliers’ service boundaries. Some water providers incorporated miscellaneous populations such as tourists, undocumented workers, and estimated incoming commuter population based on commercial space. Some population figures were reduced based on estimates of homes within the service area having privately owned domestic wells, and connections assumed to be second homes. Other systems used a form of housing units multiplied by persons-per-household, where the latter figures were undocumented, “educated” guesses. These different approaches underscored the need for standardization.

NMOSE Methodology

NMOSE’s goal for a GPCD method focuses on tracking individual water delivery systems rather than comparing GPCD numbers between systems. This requires detailed information that allows each system to be analyzed separately. Therefore, the agency’s method provides subcategories of GPCD and requires a standard calculation of populations served. The subcategories include: system total, single-family residential, multi-family residential, CII (commercial, industrial, and institutional), other (as defined by the system), reuse, and non-revenue. The system total calculation is based on the total water diverted; all other categories use billed water except non-revenue, which uses the difference between diverted and billed. The population is calculated as the number of housing units multiplied by the Census Bureau’s average persons-per-household for occupied homes within the system’s service area. These details allow systems heavily influenced by a large industrial base to be distinguished from those that are primarily residential or that have spikes in commercial use during tourist season.

To assist with the actual calculation, NMOSE developed the GPCD Calculator, a freely downloadable Excel spreadsheet that organizes data entry and automatically calculates each subcategory’s GPCD.
Lessons Learned

NMOSE pilot-tested the new methodology and calculator with six New Mexico drinking-water systems ranging in size from 116 to 120,000 connections. The tests, as well as comments collected from national water-conservation specialists, allowed the agency to fine-tune the approach.

The review process provided valuable insight into the development of standardized water-use calculations. While no two methods for calculating GPCD are exactly alike, standardization is possible; however NMOSE had to be clear about how the data would be used in order to ease concerns over its regulatory use and each system’s public image. Keeping the calculations simple was also key; too many options led to complications and confusion. Defining populations is difficult even with a standard methodology;

The calculation of GPCD itself must remain constant if valid use comparisons are to be made.

variations in how connections are defined and multi-family units are counted further confound the issue. Finally, transition time is needed during which utilities may submit their existing GPCD methodology along with the new version.

NMOSE found that the biggest obstacle to fully implementing the new calculator is that drinking-water systems configure their data for customer billing, not water-use accounting. Billing software uses

billing cycles that often do not correlate to calendar months, and bills include adjustments for customer credits or fees. Additionally, when software is updated or water systems are sold, older data may be lost.

Finally, internal politics can make it difficult for billing departments to work with engineers, planners, or conservation staff. These problems can be addressed, but require commitment from senior management.

What’s Next?

Since starting the project, NMOSE has been contacted by several state and regional authorities interested in standardizing their GPCD methods. These entities report pressure from elected officials, city managers, and even customers to track their systems’ water use. In response, the American Water Works Association (AWWA) and the Alliance for Water Efficiency have teamed up to research and test methods for tracking water efficiency, including GPCD, in order to establish an accepted repertoire of water-use-efficiency metrics that can be used to uniformly compare use and savings across utilities. The results will be published in the Journal of AWWA.

New Mexico’s standard methodology was released as a beta version on March 16, 2009. It is now the standard method used for all water-rights permits required to submit a GPCD, and a standard component of water-conservation and water-management plans submitted to NMOSE. It provides the agency with a defensible method for evaluating water use in New Mexico’s water-supply systems.

NMOSE’s GPCD methodology and calculator are available at www.ose.state.nm.us/wucp_gcpd.html. Contact Cheri Vogel at cheri.vogel@state.nm.us.
Is it possible you may one day turn on the faucet and no water comes out? This once far-fetched premise doesn’t seem quite so absurd anymore.

Our water systems in the Southwest are under stress and may not be able to meet future water demand. Austin Water Utility posts restricted watering days for their customers. The website for the Metropolitan Water District of Southern California displays a water reserves gauge that is quickly heading toward empty. Southern Nevada Water Authority informs its customers that the Colorado River system is facing its worst drought on record. Population growth, overpumping of groundwater, drought, and deterioration of aging aqueducts and levees are impacting nearly every population center. In short, long-term water demand in the Southwest far exceeds supply.

Clearly, water customers must use less water in their households and businesses and stretch it further than ever before. Water conservation is the fastest way to effectively increase supply. But water agencies know they cannot simply ask customers to take the initiative to reduce their usage—the agencies must drive the process, quickly and effectively. One of the most effective means to cut per-capita water usage is to install high-efficiency products that save water without compromising customers’ quality of life.

Properly Gauging EM&V

In tough economic times, a water agency must be certain its programs will deliver. This is accomplished through a sound process of evaluation, measurement, and verification (EM&V). EM&V can be costly and time-consuming but the alternative, a program with underachieving water savings, is a far worse option.

Some water agencies choose to perform highly detailed data analyses and historically have been willing to pay their associated high price. Others opt for a lighter EM&V protocol, believing that the money saved allows them to reach more customers even if results differ from original estimates. The agency must decide which approach to use well in advance of program planning in order to be satisfied with the outcome and avoid being overrun by EM&V experts creating goliath databases and analyses far beyond the agency’s needs and budget.

Fortunately a healthy balance can be achieved between analyzing valuable data and spending precious budget dollars by following a few key steps during the early stages of EM&V and program design.

Get Only the Data You Need

Many water agencies begin by hiring a technical consulting firm to lead the EM&V process. The firm starts by creating a market-assessment database of customers in order to analyze the current water supply and usage patterns and identify prime water-saving opportunities. The database should provide a reasonable approximation of the number of customers in each residential and business type and their monthly water usage. Often the agency and consultant become caught up in creating a database that is excruciatingly precise, buying additional data from external sources or conducting an analysis of the full database. It is important to remember that the market-assessment database is simply a guide to the remaining opportunities. Analyzing a reasonable sample size—not the full database—and buying data selectively allow a representative database to be created without high cost.
Once created, the market-assessment database should be culled to identify three promising customer groups. The first contains customers with the highest water use per site or per customer type; these are obvious targets for high-volume water savings. The second group includes under-addressed markets that have never participated in past conservation programs: through creative program design, a previously untapped market may open and deliver savings. The last group contains customers who actively participated in conservation programs in the past and can be considered prospects for additional programs, such as large landscape properties that participated in a prior indoor plumbing initiative. These customers are more likely to take part in new programs.

Know What You Want to Get
Another key step in developing a budget-friendly EM&V process is to determine the desired information outcomes before designing the actual program. EM&V should go well beyond savings and cost figures to determine the efficacy of additional program metrics such as customer enrollment and satisfaction, internal processes, marketing and outreach, and product functionality. Do you wish to track water savings separately for a certain geographic area or a particular customer segment? Decide in advance so your program systems and procedures can capture the information you require. To deliver credible data on results, the EM&V process must be designed into every stage.

Find the Right Product
Once the strongest customer markets are identified, the water agency or consultant can research promising measures that match the prospects. The agency will need to verify the historical performance of the products or services under consideration to be confident they will operate properly, meet water-savings claims, and be well-received by customers.

To best manage the cost of product evaluation, agencies should rely on existing studies as much as possible and greatly limit costly pre- and post-metering. For most water-conserving measures, sufficient documentation already exists. Published papers, other water agencies, and industry organizations are good sources for inexpensive water-savings data.

Pitch It Correctly
Knowing your target customers and products is not enough. The agency must give the same attention to the program-delivery mechanisms, including marketing outreach, the customer-enrollment process, and the level of onsite support. Some products are well-understood by the customer and have been on the market for years—customers are comfortable installing their own showerhead or toilet, for example. Others are complicated, such as weather-based irrigation controllers (WBICs) which have been on the market only a few years. Customers can easily negate the value of the controller through incorrect installation or by bungling the watering schedule—as demonstrated in early WBIC pilots that produced poor water-savings numbers. Direct installation by program personnel or approved contractors is more effective in such situations.

Use Your Database
The EM&V database should be created prior to the start of the conservation program and used throughout to manage and refine operations. Initially, the database is created to define and benchmark goals and anticipated costs, water savings, customer response, and overall costs/benefits of the program. As the program rolls out, performance data are entered and compared to the original goals. Production numbers, customer response, and cost data need to be kept current so anomalies or potentially costly design flaws can be quickly identified and program corrections can be made. Over time, the results of post-installation inspections and customer feedback will factor into the overall evaluation of program effectiveness.

As water supply continues to be a serious and permanent issue, water agencies are stepping up to secure significant water savings through highly aggressive implementation tactics for customer programs. EM&V is an important part of this process. By managing the EM&V and design process properly, water agencies are finding the right balance between insight and direction without the sting of a high price tag. ■

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Can Water Providers Afford Conservation?

Gary Woodard – SAHRA, University of Arizona

Water utilities exist to provide water to their customers; as water supplies become increasingly scarce, utilities must find new sources. Conservation is a frequently considered option: it may be cheaper than finding or treating a new water source and can quickly produce the desired outcome of “extra” water. However, less water used means less water billed, and utilities depend on the income from water sales to pay their expenses. Although seldom voiced to the public, a serious concern for utilities is: What if conservation is too effective? If demand drops substantially or a rebate program is wildly popular, the utility may not be able to afford to conserve.

Depending on its cost structure, a utility’s net income can be significantly impacted by successful conservation programs. Most costs associated with operating a municipal water system are fixed, such as debt service and payroll. Costs directly tied to the amount of water delivered—mostly energy and chemicals—are about a third of total costs. Therefore, a 10 percent drop in demand might reduce a utility’s costs by only 3 to 4 percent, while revenues could fall 7 to 12 percent.

What Affects Finances?

Aggressively pursuing water conservation is not necessarily a bad financial decision, however. The extent to which a conservation measure or program affects a water provider’s finances depends largely on the primary reason conservation is pursued, the characteristics of the water supply being conserved, what is done with the conserved water, and aspects of the conservation measure itself.

Conservation programs carried out because “it’s the right thing to do” or even to comply with a legal mandate probably will cost the utility if it has an adequate water supply. But if an area is experiencing substantial growth and the alternative to water conservation is importing distant supplies, pumping from deeper wells, or treating lower-quality water, conservation can improve the utility’s bottom line by deferring system expansion and the integration of new, more costly water supplies. Programs that free up water for growth or environmental restoration or bank groundwater supplies for future generations could save the utility money over many years. More immediately, conservation may be a fiscally sound response to short-term drought or a treatment plant nearing capacity.

The long-term reliability of the existing supply, whether it is renewable, how far it must be transported, and the fate of the conserved water all impact the finances of a conservation program. If conserving a surface-water supply means unused water is lost downstream, the fiscal impacts will be greater than if that water—or local groundwater—is banked for future use. If conserved water is used to support growth rather than stored, the provider may become more vulnerable to future shortages.

Key financial aspects of the conservation measure itself include whether it is low-cost, such as a public relations-based program, or potentially high-cost, as with rebates for new appliances or landscape modifications. A scalable conservation measure, in which the program can be expanded or contracted based on public response, offers lower financial risk should the program prove unexpectedly popular. Southern California’s Water$mart program ran out of rebate funds several times this year and had to switch to a reservation system.

Is there a middle ground that reduces the financial risks of effective conservation while still rewarding conservation?

Declining Demand Also a Factor

Long-term declines in per-capita water consumption have heightened utilities’ fiscal concerns. A recent study by the Water Research Foundation (2009) found a pervasive decline in household water use averaging half a percent per year over the last 30 years. No strong correlations were found with geography, rates of growth, or conservation efforts.

Several water providers in the Southwest, including Phoenix Water, Tucson Water, Southern Nevada Water Authority, and Metro Water District of Tucson, report even steeper declines over the last six to eight years (see chart, right). Total water deliveries have remained level or declined, even as service-area populations and the number of hookups increased significantly. Possible explanations include:

- water conservation programs have become more effective;
- new homes have more water-efficient fixtures and appliances;
- turf-dominated landscapes are less popular, and even prohibited in some developments;
- drought has caused some gardeners to reduce or alter their landscapes;
- smaller households, smaller lots, and more neighborhood swimming pools have reduced the demand for backyard pools.
Defining the relative impact of each of these factors has proven difficult, but most municipal water managers cite efficiency standards for new water-using fixtures and appliances as the principal cause for reduced indoor use.

Aggravating the long-term decline in per-capita water demand is the current recession and drop in new home construction. This has resulted in dramatic decreases in hookup fees, which often pay for system expansions. Increasing numbers of vacant homes have also reduced revenues. This aggregate decline in demand, revenues, and hookup fees has made it difficult for utilities to meet fiscal targets and dampened their enthusiasm for conservation. Few, if any, are planning wholesale expansion of conservation programs. One utility planner commented that such programs have done as much damage to demand as they can afford.

Conservation Versus Revenue?

What can utilities do to limit the potential fiscal impact of conservation-triggered reductions in demand? They could implement water-rate structures that feature higher fixed fees covering meter-reading and billing costs, a large base volume of water charged, and relatively low charges for increments of water use above the base level. This would provide revenue stability—but minimal incentive for conservation. At the other end of the spectrum are rate structures in which the fixed base volume is small and rates increase with each incremental block of higher water use: this offers the greatest reward for conservation, but leaves utilities vulnerable to financial impacts of demand reduction. Is there a middle ground that reduces the financial risks of effective conservation while still rewarding conservation?

The Decoupling Option

One approach from the electric power industry is to decouple utility revenues from water delivered. A revenue target is set, and a rate structure is established that rewards conservation, such as with increasing rate blocks or seasonal rates. At frequent intervals, possibly monthly, rates are adjusted so that necessary revenues are generated regardless of fluctuations in demand caused by conservation or weather.

Proponents of decoupling claim this approach eliminates the utilities’ financial disincentives to vigorously promote conservation. They also claim conservation should lower costs, save consumers money, and preserve scarce natural resources. But skeptics claim decoupling is unfair to consumers, and that most of the recent decline in water demand is the result of factors unrelated to conservation. Others claim decoupling is inconsistent with established rate-making principles.

Whether decoupling is the solution is unclear. What is clear is that concerns about the revenue impacts of conservation measures are real and must be addressed.

Contact Gary Woodard at gwoodard@sahra.arizona.edu

Phoenix Demand Management Plan—A Paradigm Shift

Steve Rossi and Ray Quay – City of Phoenix

In Arizona’s desert environment, the adoption of a low-water-use lifestyle by municipal customers is a critical ingredient in maintaining community sustainability. However, while we wave the water conservation flag for our customers, we must be careful not to fall into the trap of using water savings as a new water supply.

In past decades, water conservation provided a mechanism to serve more customers with the same amount of water, thereby delaying water acquisition and infrastructure expenses. This view was based on assumptions that surface water availability is only occasionally affected by short-term drought. However, recent tree-ring-based reconstruction of river flows covering an 800-year period reveals dry periods of 20 to 30 years in both the Salt and Colorado river watersheds, and both typically experience shortage at the same time. In addition, further impacts to supplies could result from global climate change.

Scenarios incorporating such conditions—where surface water is the primary supply—effectively demonstrate that allocating conserved water to growth compromises a water provider’s ability to meet customer demand during shortages. The result is “demand hardening” whereby a greater percentage of a customer’s usage is nondiscretionary. With the buffer allocated to growth, both longstanding and new customers would need to endure lengthier and deeper water-use reduction mandates.

Avoiding this trap requires that communities set higher water-planning standards than those traditionally used. The standards must consider the essential water-supply needs of the community during extended shortages and ensure that new development brings with it sufficient water for both normal and shortage conditions. Instead of allocating conserved water to growth, the savings during non-drought periods may be stored to reduce the community’s vulnerability to future surface-water shortages.

It is important that we begin taking steps today to prepare for the inevitable long-term shortages. The long-term livability and economic viability of our communities lies in the balance.

Contact Steve Rossi at steve.rossi@phoenix.gov.
Agriculture, continued from page 19

The report also offers recommendations for capturing this conservation potential to build a stronger, more vibrant agricultural sector; these apply throughout the West. The most critical are:

- Local, state, and federal agencies should provide farmers with additional financial assistance and incentives to implement efficiency measures, such as rebates for efficient irrigation equipment and greater federal support through farm bill conservation programs.
- Water managers should implement water-rate structures that encourage efficient water use. Additional revenue generated from large water users could be used to finance on-farm and district-wide improvements.
- Local governments must create groundwater management authorities, particularly in areas with extreme overdraft.

Finally, one of the many challenges of studying water issues is the lack of consistent, comprehensive, and accurate estimates of actual water use. The failure to accurately account for water use contributes directly to the failure to manage it sustainably. Efforts are needed immediately to improve our understanding of agricultural water use, including surface-water diversions, groundwater use, crop-water consumption, and farm-gate deliveries. State-level coordination of water-use measurement, reporting, and data management and exchange are needed along with satellite-data analyses and local groundwater-monitoring and management programs.

Can a viable, sustainable agricultural future be achieved? Yes. But it will require the commitment of all parties to move from individually-focused interests to a deeper understanding of the interdependence between the agricultural and other sectors—including the environment—and recognition that cooperation benefits everyone.

Download the full report, “Sustaining California Agriculture in an Uncertain Future,” at www.pacinst.org/reports/california_agriculture/. Contact Heather Cooley at hcooley@pacinst.org.
and Fernando Molina at Tucson Water. In Denver, the number of rebates given for low-flush toilets continues to rise, but those for efficient washing machines—a larger investment—have recently declined: people replace washing machines that are broken, but not many

Some people don’t believe what they do makes any difference.

that are simply inefficient. Toilet and irrigation rebate programs introduced last fall in Tucson have been slow to catch on despite rebate increases in 2009.

Conservation? Huh?

Lack of awareness of or commitment to conservation remains an issue among much of the population, says Jean Witherspoon, formerly with the City of Albuquerque. Some people don’t believe what they do makes any difference, and some large residential users may have outrageous bills but don’t know or don’t care. Bennett at SNWA sees complacency as the biggest source of resistance to conservation: people are content with their lifestyles and water bills.

Denver Water identified more than 350 of its largest and most inefficient residential irrigators and offered them a full irrigation audit, assistance in making efficiency changes, and the opportunity for significant savings. The response rate was just 15 percent; clearly, neither economics nor ignorance were factors.

Several managers noted difficulty reaching people with the authority to make conservation changes in the commercial and industrial sectors. Frequently the person who pays the water bill lives outside the service area and is unaware of local conservation programs; meanwhile, building and grounds managers do not receive conservation messages.

How Will I Look (or Feel)?

The perception of changed social status or personal comfort is another argument against conservation. Bennett thinks peer influence can help or hurt. Ten years ago in Las Vegas, he found some homeowners worried what their grass-growing neighbors would think if they converted to xeriscaping. With time, education, and an attractive rebate program, public acceptance shifted and removing grass is now popular.

Likewise, Elliott believes the poor response to her efficiency audit offer was related to social pressure—the targeted neighborhoods were generally high-income areas where residents may feel judged by the look of their yards.

Bennett also meets people who think xeriscaping would hurt their lifestyle. And Witherspoon in Albuquerque is convinced some people are emotionally attached to their high-flow toilets and just don’t want to give them up!

Molina finds some opponents of conservation have simplified the message in their minds to “Do not use water,” which, if implemented, would be a hardship. Tucson Water realizes it must clarify that they’re asking people to simply use water more efficiently.

Laziness also is a factor. Elliott claims that getting customers to install a sprinkler system is one thing, but convincing them to make seasonal adjustments to their irrigation schedule is another: people just don’t want to mess with them, and few lawns die from excess water.

By the Sectors

When Albuquerque began its conservation program, it first targeted the residential sector to increase public buy-in. That worked; Yuhas has seen the best response from residents, with institutional facilities following suit. The commercial sector is responding, too, but like everywhere else, reaching the right people is a challenge.

In Denver, savings vary by sector. Comparing 2008 water use to pre-2002-drought use, the government sector was down 24 percent, commercial and multi-family down 23 percent, single-family residential down 16 percent, and industrial down only 5 percent. Elliott noted that some industries cannot change their processes easily or economically.

In contrast, water savings from conservation in Las Vegas are similar across sectors. One area where Bennett continues to see mismanagement of irrigation water is the landscaping of common areas, which represents about four percent of metered water use.

Different Approaches

Conservation programs vary according to local needs. Las Vegas spends three times the effort on outdoor conservation as indoor. The region receives return-flow credits for Colorado River water for nonconsumptive (most indoor) use, thus indoor savings do not extend the region’s resources. However, an extensive recycling provides infrastructure, energy, and environmental benefits.

San Diego sits literally at the end of the pipeline—the terminus of both the Northern California and Colorado River water systems. Groundwater is too saline for use. The city has promoted conservation for nearly two decades, but on July 1, implemented its first water-use restrictions. Kurt Kidman of the City of San Diego reports the switch met little resistance from customers, a response he attributes to strong advance publicity. The mandatory restrictions focus on outdoor water use whereas existing rebate programs target indoor fixtures. San Diego County figures show urban water use has dropped 24 percent compared to last year.

Tucson is still working out specific reasons for conservation, aside from compliance with state mandates. Molina believes any city’s conservation response should be appropriate to its needs. Tucson is not San Diego: it has groundwater resources to supplement Colorado River water in times of shortage. Nor is it Las Vegas: indoor savings have value.

To ensure it selected conservation strategies that would be effective and widely supported, Tucson convened a task force that evaluated 123 possible water-conservation strategies and selected 48 that were feasible and appropriate for the community. A cost-benefit analysis of that subset led to the recommendation of 22 strategies for adoption over the next five years, including the recently introduced rebate program. The selections are tied to overall water-resources management and extending the time until new water supplies are needed. As with every community, determining Tucson’s conservation needs is far more complex than simply importing programs from elsewhere.
Sacramento Top Delta Pesticide Source

Urban Sacramento appears to be the top contributor of pesticides to the Sacramento-San Joaquin Bay-Delta, according to new research from the University of California, Berkeley.

The purpose of the research was to find out where pyrethroid insecticides in the delta originate and what effects they have in the water bodies where they end up. According to the Sacramento Bee, the pesticides could be contributing to the collapse of the delta ecosystem by causing toxicity to tiny shrimp, a link near the bottom of the aquatic food chain. Pyrethroids can cause paralysis in the shrimp at a concentration of two parts per trillion.

Researchers collected water samples during both the dry season of 2008 and the wet season of either 2008 or 2009 from eight agricultural pump stations, six urban-runoff pump stations or storm drains, three municipal wastewater-treatment plants, and the Sacramento and San Joaquin rivers as they enter the delta. They also sampled transects along five creeks or rivers passing through urban areas after two to four rain events.

The scientists found that nearly all urban runoff contained the insecticides and caused toxicity to the shrimp. In addition, pyrethroids were present in two-thirds of effluent samples from wastewater-treatment plants, and in some cases caused toxicity. The Sacramento plant was the largest discharger of those studied, releasing at least 10 grams per day. Furthermore, three of the five creeks and rivers sampled, including the American River, showed toxicity repeatedly, over stretches up to 30 miles, after flowing through urban areas. The larger Sacramento and San Joaquin rivers can show localized impacts after storm events.

In contrast, only 30 percent of agricultural discharge samples contained pyrethroids. Shrimp toxicity was seen in only 10 percent of agricultural samples, but some of these occurrences were linked to the organophosphate insecticide chlorpyrifos.

According to the Sacramento Bee, pyrethroids are manufactured versions of insecticides produced naturally by some chrysanthemums. The pesticides have been used to replace more dangerous compounds such as diazinon and chlorpyrifos since about 2000. Pyrethroids are less harmful to humans and other mammals but turn out to be worse for aquatic life. They are commonly used by both pest-control companies and homeowners to kill insects.

The Bee reported that the California Department of Pesticide Regulation began a process to regulate pyrethroids in 2006. The regional water quality control board funded the Berkeley study and plans to declare several waterways impaired due to the presence of these insecticides.

Ogallala Quality Declining

Although water produced by the High Plains, or Ogallala, Aquifer is currently acceptable for multiple uses including human consumption, heavy water use and leakage down inactive irrigation wells are causing long-term gradual increases in concentrations of contaminants in the aquifer, according to a U.S. Geological Survey report issued in July.

In the future, contaminants such as nitrate and dissolved solids will be present from the water table to deeper parts of the aquifer where drinking-water wells are typically screened, creating implications for future use of the aquifer. In addition, once the aquifer is contaminated, remediation will be a slow process—the groundwater in some parts of the aquifer is 10,000 years old and travels slowly.

The High Plains Aquifer provides water to eight states including Colorado, New Mexico, and Texas, and is the most heavily used groundwater source in the country. USGS scientists analyzed water for more than 180 chemical compounds and physical properties in about 300 private domestic wells, 70 public-supply wells, 50 irrigation wells, and 160 shallow monitoring wells sampled between 1999 and 2004. The study also assessed the transport of water and contaminants from land surface to the water table and deeper zones used for supply, in order to predict changes in concentrations over time.

Currently, more than 85 percent of the 370 wells used for drinking water meet federal drinking-water standards, and most of the contaminants that exceeded standards were from natural sources.


Studies Agree: Colorado Deliveries Threatened

Two independent 2009 studies show water deliveries from the Colorado River may be significantly threatened over the next half-century. Both found that the current approach to managing the

continued on next page
Colorado River system is not sustainable. Climate-change models generally show that a 6 to 20 percent reduction in stream runoff in the Southwest by midcentury is likely, and both sets of researchers used this range to evaluate how reservoir storage and deliveries might be affected.

The first study, by researchers at Scripps Institute of Oceanography, updates their 2008 study that predicted a 50 percent chance that Lake Mead could dry up by 2020. The 2009 results showed that a 10 percent reduction in average annual runoff compared to current rates would mean water deliveries would not be met nearly 60 percent of the time by 2050. A runoff reduction of 20 percent increased the likelihood of missed deliveries to 88 percent. The authors emphasized that current deliveries are likely not sustainable and suggested that scheduled deliveries should be changed to more realistically reflect actual conditions.

The second study, by researchers at the University of Colorado, Boulder, analyzed how reservoir storage would be affected by 0, 10, and 20 percent decreases in Colorado River flow under various management strategies. For all climate-fluctuation and management-alternative scenarios tested, the risk of fully depleting reservoir storage in any given year remained below 10 percent through 2026. However, a climate-change-induced flow reduction of 10 percent would deplete reservoir storage more than 25 percent by 2057. A 20 percent reduction correlated to greater than 50 percent depleted storage.

The University of Colorado researchers point out that the resiliency of the system in the short term should not cause complacency, as policy options may be far more limited by 2026. Working to increase flexibility in water-resource management may help deal with the threats to the water supply caused by population growth, likely multi-year droughts, and potential climate-change-induced streamflow reductions.


Central Valley Groundwater Declining, Threatening Aqueduct

Groundwater levels are declining in the southern portion of San Joaquin Valley in California, USGS researchers reported in July. However, the abundance of coarse-grained soils in this area offers promise for large-scale artificial groundwater recharge.

San Joaquin Valley is part of the 400-mile-long Central Valley, which contains the largest groundwater system in California. The aquifer yields one-fifth of all groundwater pumped in the nation, much of it used for agriculture. Based on data through 2003, researchers found that, unlike in southern San Joaquin Valley, groundwater levels in Sacramento Valley and the northern portion of San Joaquin Valley are generally stable.

However, ongoing drought in the state is increasing pressure on groundwater supplies as landowners drill more and deeper wells and pump more water, causing groundwater levels to fall. This is consistent with previous droughts of the 1970s and 1980s.

According to the Sacramento Bee, the decline of groundwater levels, which has caused subsidence in the Central Valley in the past, threatens the stability of structures like the California Aqueduct, which transports drinking water to over 20 million people.

The Associated Press reported in July that the Metropolitan Water District of Southern California and other state water users have contracted with USGS to monitor 70 miles of the California Aqueduct by satellite, at a cost of $255,000. According to the article, current pumping due to the drought is approaching levels that in the 1970s caused the canal to bow several feet, requiring emergency repairs.

The research is part of the USGS Groundwater Resources Program’s $1 million, four-year study of Central Valley groundwater; see page 38 for additional information.
**Great Salt Lake Exhales Selenium**

The Great Salt Lake can remain healthy for birds despite its high selenium loads because it apparently vaporizes selenium into the atmosphere, reported the *Salt Lake Tribune* in June.

Excessive selenium in water bodies poisons birds, resulting in weakened egg shells, deformed chicks, and crippled embryos. The Kesterson Reservoir in California famously caused a massive die-off in birds in the 1980s as a result of elevated selenium.

Researchers at USGS and the University of Utah found that although the Great Salt Lake has no outlets to carry selenium away, chemical transformations of selenium in the salty water allow surface air to remove it, reported the *Tribune*. Additionally, a paper in *Environmental Science & Technology* suggests that phytoplankton and bioherms (mounds of organic material) may be producing volatile selenium. The estimated annual flux of volatile selenium into the atmosphere was 3,200 pounds per year. In a separate USGS report, the annual load to the lake was estimated to be about 3,450 pounds.

According to the *Tribune*, the state of Utah plans to fund additional studies regarding selenium in the food chain and its movement around the lake. Researchers also hope to determine if the rapid increase in selenium in the last 18 months is a long-term trend or part of a cycle.


**Gallium Improves Water Purification**

By replacing a single atom in a molecule widely used to purify water, researchers at Sandia National Laboratories have created a more effective decontaminant that lasts longer than purification products currently on the market.

The decontaminant is made by substituting an atom of gallium in the center of an aluminum-oxide cluster that is often used as a coagulant in water-purification processes. Gallium makes the reagent more stable and effective. The resulting coagulant maintains its electrostatic charge more reliably than conventional coagulants, allowing it to attract and bind contaminants exceptionally well. In addition, it resists converting to larger, less-reactive aggregates before it can react with contaminants, thereby providing a longer shelf life.

The substitution is performed by dissolving aluminum salts in water, dissolving gallium salts into a sodium-hydroxide solution, and then slowly adding the sodium-hydroxide solution to the aluminum solution while heating.

The research was published in the July 2009 issue of *Environmental Science & Technology*. The project, which also tested germanium but found it to be less effective than an all-aluminum coagulant, involved transmission electron microscopy of bacteriophages binding to the altered material as well as mass spectroscopy of the aluminum clusters in solution.

Sandia has applied for a patent on the material, which removes bacterial, viral, and other organic and inorganic contaminants from river water destined for human consumption and from wastewater in treatment plants prior to its discharge to the environment. The new reagent performs well under a wide range of conditions, including fluctuations in pH, temperature, and turbidity that are common in natural water sources.


**New Hydrologic Modeling Center at UC Irvine**

The University of California at Irvine has been awarded $2.5 million to use satellites and field research to more accurately determine how much water exists in California and where it is located.

The money comes from the University of California Office of the President and establishes a Center for Hydrologic Modeling led by James Famiglietti, a professor of earth system science and civil and environmental engineering specializing in hydrology and climate. The center’s research will focus on combining computer models with observations to ascertain how much water is in aquifers, soil, and snowpack. According to Famiglietti, “There’s been too large of a gap between decision-makers and scientists over the water situation in California. We’re going to help bridge that gap.”


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**New Aspects of Water’s Structure Uncovered**

Recent work at the U.S. Department of Energy’s SLAC National Accelerator Laboratory (operated by Stanford University) and several universities in Sweden and Japan is shedding new light on water’s molecular idiosyncrasies, offering insight into its strange bulk properties. In all, water exhibits 66 known anomalies, including a large heat capacity, high surface tension, and strangely varying density—reaching a maximum at about 4 degrees Celsius.

How ice molecules arrange themselves is well established: they form a tight tetrahedral lattice. According to the current textbook model, liquid water should have a similar but less structured tetrahedral form, since heat creates disorder and breaks bonds. As ice melts, the theory says, tetrahedral bonds tend to weaken and break apart, resulting in a smooth distribution around distorted, partially broken tetrahedral structures.

But recent experiments on liquid water by SLAC scientist Anders Nilsson and colleagues suggested instead that two distinct structures, either very disordered or very tetrahedral, exist regardless of temperature. They performed the experiments using small-angle x-ray scattering.

In a paper published in the Proceedings of the National Academy of Sciences, the researchers revealed the additional discovery that the two types of structures are spatially separated, with the tetrahedral structures existing in clumps made of up to about 100 molecules surrounded by disordered regions; the liquid is a fluctuating mix of the two structures at temperatures ranging from ambient to near boiling. As the temperature increases, fewer clumps exist; but they are always present to some degree, in clumps of a similar size. The researchers also discovered that the disordered regions themselves become more disordered as the temperature rises.

This more detailed understanding of the molecular structure and dynamics of liquid water at ambient temperatures mirrors theoretical work on supercooled water. In this state, theorists postulate, the liquid is made up of a continuously fluctuating mix of tetrahedral and more disordered structures, with the ratio of the two depending on temperature—just as Nilsson and his colleagues found to be the case with water at ambient temperatures.

This new work explains, in part, the liquid’s strange properties. Water’s density maximum can be explained by the fact that the tetrahedral structures have a lower density that does not vary significantly with temperature, while the more disordered, higher-density regions become even more disordered and therefore less dense with increasing temperature. Likewise, as water heats, the percentage of molecules in the more disordered state increases, allowing this excitable structure to absorb significant amounts of heat, which leads to water’s high heat capacity.

Lake Powell

Drought impact types:
- delineate dominant impacts
- agricultural (crops, pastures, grasslands)
- hydrological (rivers, groundwater, reservoirs)

Abnormally dry
- drought - moderate
- drought - severe
- drought - extreme
- drought - exceptional

28-Day Streamflow Average, as of October 7, 2009


Reservoir Storage as of October 1, 2009

Lake Mead

Lake Powell

Southwest Weather

June 15-Sept. 30 monsoon totals, compared to average:
- Albuquerque: 3.96 / 4.12 inches
- El Paso: 5.82 / 5.14 inches
- Phoenix: 0.87 / 2.77 inches (10th driest on record)
- Tucson: 2.86 / 6.06 inches (11th driest on record)
- Yuma: 1.86 / 1.29 inches

Most forecasts predict the summer’s weak El Niño conditions will strengthen to at least moderate levels over the fall and winter. Some models forecast strong conditions, which could bring increased winter precipitation to the Southwest.

In late September, the projected end-of-year reservoir storage in California was 68 percent, up from 57 percent in 2008.

MAF = million acre-feet; amsl = above mean sea level.
Vertical red bars indicate elevation range for the year.

Central Valley Hydro Model, Report Available

Groundwater Availability of the Central Valley Aquifer, California—Central Valley Hydrologic Model

U.S. Geological Survey

This report and model are the products of an investigation begun in 2005 to evaluate and project groundwater conditions resulting from present and planned land-use changes in California’s Central Valley. The research is one of 30 regional aquifer studies the USGS is conducting nationwide.

The three-dimensional hydrologic model (built using MODFLOW 2000) was designed to encompass the valley’s entire groundwater basin. It contains 20,000 cells one-square-mile in size and ten layers ranging in thickness from 50 to 1,800 feet. To help construct the model, scientists reviewed more than 8,500 drillers’ logs dating to the early 1900s, and monthly surface-water and groundwater data from 1962 to 2003.

The model was designed to help resource agencies assess, understand, and address issues affecting the joint use of surface- and groundwater supplies in the Central Valley. Users can simulate water-management scenarios and assess possible changes in both groundwater and surface-water supplies. The model also can take into account the conversion of farmland to urban use and the potential future effects of climate change. Model files can now be downloaded for public use.

The report describes the model and its construction, and what has been learned to date (see page 34 for report summary).

The report and model files are available at pubs.usgs.gov/pp/1766/.

New Concepts for Water System Management

Sustainable Water Systems: Step One – Redefining the Nation’s Infrastructure Challenge

The Aspen Institute

In 2008 and 2009, the Aspen Institute convened the “Dialogue on Sustainable Water Infrastructure in the U.S.,” a series of four meetings of leaders from the water utility industry; federal, state and local government regulators; and non-profit environmental groups. The goal was to develop policy recommendations addressing water infrastructure planning and management challenges for the future.

Three mandates emerged. First, the traditional definition of water infrastructure must evolve to embrace a broader, more holistic definition that includes manmade water- and wastewater infrastructure, as well as natural watershed systems. Second, this new definition should be embraced by public and private entities involved in water management, all of whom must ensure their decisions integrate environmental, economic, and social considerations. Finally, a watershed-based management approach is required for all water services to ensure integrated, sustainable management of water resources.

In the resulting report, the group recommended policy measures that support a financially and
environmentally sound path towards a sustainable 21st-century water infrastructure. The appendix lists anticipated roadblocks and offers strategies for addressing each one.

The full report is available at www.aspeninstitute.org/publications.

**California Preparing for Climate Change**

*2009 California Climate Adaptation Strategy Discussion Draft*

*California Natural Resources Agency*

California became the first state to develop a climate adaptation strategy with the August release of this document, which summarizes how climate change could impact the state and offers recommendations for managing specific threats. A 45-day public comment period followed the release, ending in mid-September.

Other state agencies involved in drafting the document include Environmental Protection, Business, Transportation and Housing, Health and Human Services, and the Department of Agriculture. The document focuses on seven different sectors: public health, biodiversity and habitat, ocean and coastal resources, water management, agriculture, forestry, and transportation and energy infrastructure. Rather than address the detailed impacts, vulnerabilities, and adaptation needs of each sector, those determined to be at greatest risk were prioritized.

Visit www.climatechange.ca.gov/adaptation/.

**ID Water Polluters Nationwide**

**Database of Water Pollution Violations**

*New York Times*

This interactive website developed by the *New York Times* maps more than 200,000 facilities nationwide that have permits to discharge pollutants and indicates whether the sites have had any Clean Water Act violations. A table for each state lists the facility name, city, last inspection date, number of violations, and fines. Information was obtained from U.S. EPA and the California State Water Resources Control Board.


**Hydromythology and the Ancient Greek World: An Earth Science Perspective Emphasizing Karst Hydrology**

*Cindy Clendenon, Fineline Science Press (2009)*

Reviewed by Richard J. Heggen – University of New Mexico

One might justify a *Southwest Hydrology* review of Cindy Clendenon’s *Hydromythology and the Ancient Greek World* by noting that the American Southwest boasts its own karst formations, the most notable being New Mexico’s Carlsbad Caverns. In a broader sense, however, Clendenon renews our tie to the roots of western civilization that most of us let slip after satisfying that long-ago undergraduate core curriculum hurdle. We were too anxious to get on to MODFLOW.

But let’s be honest; the plot of the Theis equation doesn’t come close to that of Homer’s Odyssey. *O Brother, Where Art Thou!* about a differential equation might lack a compelling soundtrack. It’s time to revisit some of our cultural roots.

An editor of the *Water Science Encyclopedia*, Clendenon holds a master’s degree in environmental science and water resources, but the book’s uniqueness isn’t on the science side, properly presented but rudimentary. Clendenon’s contribution lies in her thesis that the Mediterranean environment of disappearing and reappearing rivers and catastrophic geomorphology shaped the Western roots of the supernatural. Myth has genesis; in this case, one that’s significantly hydrologic. The book catalogs Hellenistic mythology related to such phenomena as earthquake-triggered karst collapses, lake-swallowing sinkholes, sub-sea sediment transport, tsunamis, altered shorelines, and lakes of fire.

Few readers of *Southwest Hydrology* may care to scientifically deconstruct so many Greek sagas, but those of us who recall...

continued on next page
the tale of Charon, the boatman who eternally ferries departed souls across the subterranean River Styx (for a fee, of course), will immediately agree that the story is about karst—the dissolution route to hell, so to speak, though the diabolic concept of hell had yet to be developed when Charon began his duty. (Clendenon notes that today’s Arcadian tourist-destination River Styx was yet later named and just flows to the sea.) Thales overestimated that water is the basis of all things, but Clendenon makes a compelling case that hydrology underpins many stories we perhaps thought baseless.

The strength of water resources as a discipline comes from its multidisciplinary nature. Isn’t it time to welcome the classicists? Or the other way around, isn’t it time for scholars of the humanities to acknowledge that earth science might provide some context? Here’s the evidence: Given MODFLOW’s CFP conduit flow module and requisite parameters, we could perhaps estimate the velocity of the River Styx. It’s more satisfying, however, to just read the book.

*The 520-page book is available for $28 at www.finelinesciencepress.com.*

### Reports on EPA, State Compliance Status

**State Review Framework**

**U.S. EPA**

In the past decade, the U.S. Environmental Protection Agency began conducting reviews of regions and states on a four-year cycle to evaluate Clean Water Act, Clean Air Act, and Resource Conservation and Recovery Act enforcement and compliance assurance programs. The reviews consider national and state data on enforcement, enforcement file reviews, commitments made in annual agreements, and discussions with senior management at the state and regional levels. If issues arise during the reviews, they are addressed collaboratively and agreed-upon measures will be implemented for future grant funding programming.

EPA completed the first round of reviews using protocol specified in the State Review Framework between 2004 and 2007; those reports are now available. The second round began in 2008 and is expected to be complete in 2012.

Access the reports at www.epa.gov/Compliance/state/srf/.

### Help for Natural Attenuation of Inorganics

**Site Characterization to Support Use of Monitored Natural Attenuation for Remediation of Inorganic Contaminants in Ground Water**

**U.S. EPA**

This paper discusses at what stage in the site characterization process solid-phase characterization techniques should be implemented. It describes two case studies where results of these techniques were critical in determining whether monitored natural attenuation could be used for groundwater cleanup. The case histories concern an industrial complex in Massachusetts affected by arsenic,
lead, and chromium; and uranium contamination in the vadose zone and unconfined aquifer at the Hanford site in Washington.

The November 2008 report is available at www.epa.gov/nrmrl/pubs/600r08114/600r08114.pdf.

Desal, Water Reuse Journal to Debut

Journal on Desalination and Water Reuse

International Desalination Association

This new publication, planned for release at the 2009 World Congress in November, will include peer-reviewed articles on the technical and scientific aspects of desalination. It is co-published by the American Water Works Association. The quarterly journal will be available to IDA members as well as to individual and institutional subscribers in both print and electronic formats.

For information about IDA Journal contact Leslie Merrill at lmerrill@idadesal.org.
## NOVEMBER 2009

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<tbody>
<tr>
<td>November 2-4</td>
<td>National Ground Water Association. Petroleum Hydrocarbons and Organic Chemicals in GW: Prevention, Assessment, and Remediation Conference (Nov. 2-3); Assessment of LNAPL Volume, Mobility, and Recovery (short course; Nov. 4); Petroleum Hydrogeology (short course, Nov. 4). Costa Mesa, CA.</td>
<td><a href="http://www.ngwa.org">www.ngwa.org</a></td>
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<tr>
<td>November 5-7</td>
<td>California Groundwater Association. 61st Annual CGA Convention &amp; Trade Show. Reno, NV.</td>
<td><a href="http://www.goldh2o.org/events/index.html">www.goldh2o.org/events/index.html</a></td>
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## DECEMBER 2009

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<tr>
<td>December 8-10</td>
<td>National Ground Water Association. Environmental Isotopes in Ground Water Resource and Contaminant Hydrogeology (short course, Dec. 8-9); Induced Infiltration and Artificial Recharge (short course, Dec. 9); Geothermal Diversification and Drilling Forum (Dec. 9-10); Endocrine Disrupting Chemicals and Pharmaceuticals in the Environment (short course, Dec. 9-10). New Orleans, LA.</td>
<td><a href="http://www.ngwa.org">www.ngwa.org</a></td>
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<tr>
<td>December 10-18</td>
<td>American Geophysical Union. AGU Fall Meeting. San Francisco, CA.</td>
<td><a href="http://www.agu.org/meetings/fm09">www.agu.org/meetings/fm09</a></td>
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## JANUARY 2010

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<tbody>
<tr>
<td>January 27-29</td>
<td>Colorado Water Congress. 52nd Annual Convention. Denver, CO.</td>
<td><a href="http://www.cowatercongress.org/annualconvention">www.cowatercongress.org/annualconvention</a></td>
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## FEBRUARY 2010

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## MARCH 2010

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<tbody>
<tr>
<td>March 24-26</td>
<td>University of California, Riverside. International Drought Symposium. Riverside, CA.</td>
<td>cmas.ucr.edu/drought-symposium</td>
<td></td>
</tr>
</tbody>
</table>
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