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Southwest HYDROLOGY
The Resource for Semi-Arid Hydrology

A bimonthly trade magazine for hydrologists, water managers, and other professionals working with water issues.

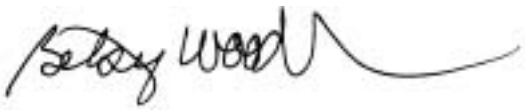
From the Editor

This issue marks the beginning of Southwest Hydrology's second year of publication, and the beginning of its distribution by paid subscription only. Thanks to all of you who have shown your support for, and interest in, the magazine by sending in your subscription. We hope you will encourage others to subscribe as well, for that is what will keep this magazine in production.

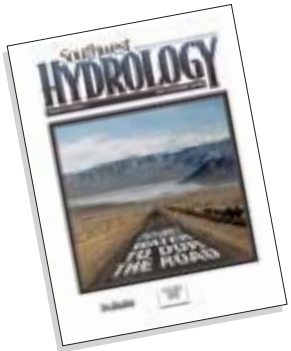
In this issue, we look at desalination as a new source of water to supplement our existing – and dwindling – resources in the Southwest. While ocean water is often the first source that comes to mind for desalination, other sources, including river water, brackish groundwater, recycled water, and oil- and gas-produced water, all are candidates. Desalination research and technology development, and even use, are well underway in every state in the Southwest. The cost of the technology has fallen in recent years, making it worthy of consideration in areas where local sources are depleted and the cost of importing water is high. However, the issues of waste disposal – particularly in inland areas – and inefficiencies of the process still make it an expensive alternative. The final article in the feature proposes where this technology might go in the future. We thank all of our feature authors for their contributions to this issue.

As we begin this second year of production, we'd like to reinforce our intent that this magazine be not only for you, our readers, but also by you. As travel and meeting budgets are cut, it is still important to communicate with each other about what's working, what's not, and in general, what's new. This magazine is an inexpensive, yet effective, forum for communication, and we strongly encourage your contributions.

We'd like to recognize all the contributors to this issue, listed on the opposite page. We'll look forward to your news, comments, and suggestions for upcoming issues.



Betsy Woodhouse
Editor



Composite photograph created to illustrate brackish water resources in the Southwest, which may be under consideration for desalination operations. Image was composed from photographs taken at Death Valley National Park by John Crossley (visit www.americansouthwest.net). However, no implication that desalination is being considered in the Death Valley regioin is intended.

Inside This Issue

Departments

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Will Desalination Provide the Water Supply of the Future?

As local water supplies become depleted and demand for water in the Southwest continues to rise, municipalities have begun considering other sources of water – brackish groundwater, recycled water, and seawater, made potable through desalination. The cost of desalination technology has come down in recent years, although it is still not competitive with treatment of fresh water. However, when local freshwater sources are no longer available and the costs of importing water are factored in, desalination may become economically feasible in some areas. Several desalination plants were built in the Southwest in the early 1990s, but an end to the drought that prevailed at that time resulted in those plants having never been used. Given the current drought, as well as an increased demand for water resources, their operation is again being considered, and many more are in the planning or construction phase.

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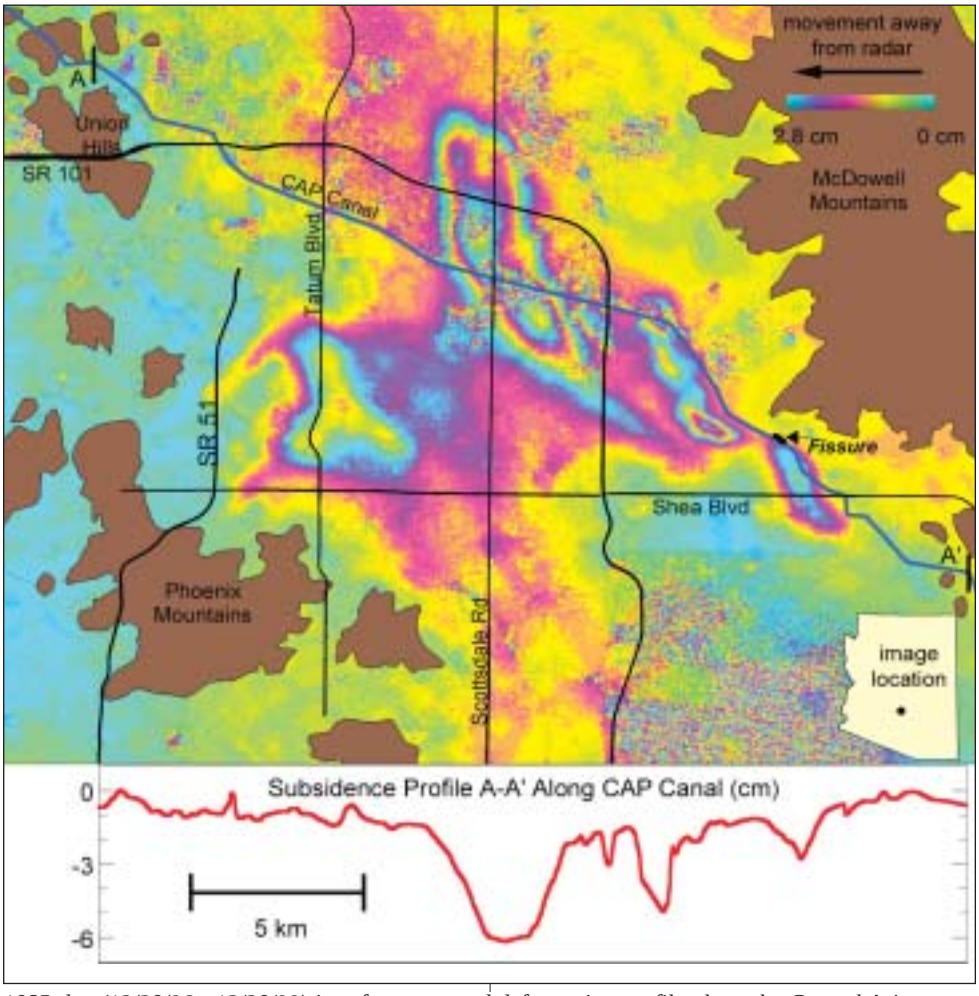
Southwest Hydrology was founded with the generous support of the Bunny Clutch.

NASA Helps ADWR Monitor Land Subsidence

Maurice A. Tatlow *- Arizona Department of Water Resources and* ***Sean M. Buckley, Ph.D.*** *– Center for Space Research, University of Texas at Austin*

For more than 60 years, scientists have known that the land surface in portions of Arizona is subsiding due to groundwater pumping. Until recently, effective monitoring of the extent and rate of land subsidence has been limited, owing to the cost, time, and resources needed to perform ground-based surveys. Today, however, the Arizona Department of Water Resources is using an emerging satellite technology called "synthetic aperture radar interferometry" (InSAR), a $1.3 million NASA grant, and the technical expertise of the Center for Space Research at the University of Texas at Austin and the Vexcel Corp. in Boulder, Colo., to monitor subsidence in Arizona.

Satellite InSAR provides high-resolution, wide-area mapping of earth-surface topography and deformation. The radar transmits a series of microwave pulses and records both the amplitude and phase of the backscattered responses from the surface. The phase difference between two radar images taken at different times, termed the interferogram, contains signals associated with surface topography and deformation as well as differences in the atmosphere and satellite position at the time of each acquisition. Isolating the deformation signal by applying phase corrections to satellite position and surface topography produces a differential interferogram in which one cycle of phase change represents a half-wavelength (2.8 cm) of surface movement toward or away from the radar. The final image created by the differential InSAR deformation spans approximately100 km by 100 km and can be used to map sub-centimeter deformation at a pixel resolution of roughly 50 meters.



1085-day (12/20/96 - 12/20/99) interferogram and deformation profile along the Central Arizona Project canal in central Arizona.

Variations in the atmosphere and changes in surface properties over time can limit the interpretation of the InSAR deformation measurements, since these variations can appear similar to subsidence phase signatures. As such, it is hard to discern interferometric phase signatures in highly vegetated areas.

The arid environment of Arizona is well-suited for InSAR, and the assembled team has successfully employed the technique to measure subsidence in Phoenix and Tucson with interferograms spanning time periods of up to six years. At least four areas of active subsidence spanning more than eight incorporated areas have been detected in the Phoenix metropolitan area. Maximum subsidence rates of these features are seven centimeters per year (cm/yr). In Tucson,

See Land Subsidence, page 27

Tree Rings, Ocean Temperature Shifts Used to Anticipate Megadroughts

From the U.S. Geological Survey

Not long ago, conventional wisdom held that you couldn't predict climate change more than a few days in advance. Then came the awareness of El Niño and La Niña, and forecast windows increased to as much as six to nine months, depending on the region and season. But a recent study in the Geophysical Research Letters suggests that opposing shifts in Tropical Pacific and North Atlantic Ocean temperatures may foretell persistence of disastrous, multiyear droughts across the North American continent.

Forecasts longer than six to nine months rely on two principles. The first is the well-defined relationship between sea surface temperatures and precipitation measurements on land. The second principle is the ocean's thermal inertia. If these slow shifts in ocean regime can be identified in their early stages, then perhaps they can be used to assess the probability of disastrous, multiyear droughts across the North American continent and elsewhere.

In this light, a team of researchers from the U.S. Geological Survey, University of Wyoming, and Middlebury College in Vermont evaluated multidecadal precipitation variability across a network of 750-year-long tree-ring chronologies from the central and southern Rockies. Their study suggests that the Great Plains, the Rockies, and the Southwest are stricken by the same megadrought when both the tropical Pacific turns cold and the North Atlantic warms for multiple years. The geographic scale of such megadroughts is determined by the failure of winter, early summer, and mid- to late-summer precipitation, each of which has specific links to tropical Pacific and North Atlantic sea surface temperatures.

The researchers found that the tree-ring records exhibit significant oscillations in precipitation that last between 40 and 70 years. Generally, multidecadal oscillations in the tree-ring record are not cyclical and are not always in phase across the Rockies, suggesting complex linkages between seasonal precipitation and ocean temperatures.

These oscillations can occasionally synchronize across the Rockies, particularly in times of megadroughts that affect large regions of the country for a decade or more, said Julio Betancourt, of the U.S. Geological Survey and the University of Arizona's Desert Laboratory, one of the authors of the study.

Because no comparable 750-year-long proxy records exist of sea surface temperatures in the tropical Pacific and North Atlantic, the demonstrated link between ocean temperatures and precipitation is limited to the last century. But according to Betancourt, in the context of shifting ocean climate, water and other resource managers in the Rockies and Southwest little cause for optimism about the drought ending any time soon.

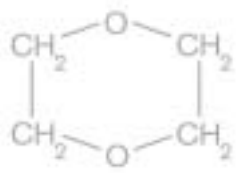
See Tree Rings, page 27

UV-Oxidation Applied to Remove 1,4-Dioxane at California VOC Remediation Site

Adam D. Festger *– Trojan Technologies*

In the early 1990s, the volatile organic compounds (VOCs) tetrachloroethylene (PCE) and trichloroethylene (TCE) were discovered in the vicinity of several city water supply wells near Stockton, California. An aggressive hydraulic containment/reinjection system was installed to contain the plume and protect the quality of the drinking water. The containment system currently operates at a flowrate of approximately 200 gallons per minute (gpm). This flowrate is sufficient to create a capture zone that protects nearby wells. Contaminants of concern at the site were originally limited to the traditional VOCs such as PCE and TCE. Recently, however, 1,4-dioxane was also discovered in the plume.

A combination of properties makes 1,4-dioxane a potent ground water contaminant. Used primarily as a stabilizer in chlorinated solvents, it is a semi-volatile, colorless liquid with a mild odor. It is also known as diethylene dioxide, diethylene ether, p-dioxane or, simply, dioxane. It is highly soluble in water, has a low affinity for carbon materials and does not readily biodegrade. This combination of properties makes 1,4-dioxane highly mobile in groundwater. In fact, 1,4-dioxane often travels farther and persists longer than the original host solvent.



Dioxane can be found commingled in plumes containing PCE, TCE, and particularly 1,1,1-trichloroethane (TCA). At one time, approximately 90 percent of the 1,4-dioxane produced went into the production of 1,1,1-trichloroethane (TCA), where it is present in concentrations of up to 15 percent by volume. Even though this use of 1,4-dioxane has now been phased out because of TCA's destructive effects on atmospheric ozone, 1,4-dioxane is being detected at a wide variety of solvent contamination sites across the United States. In addition to its use as a solvent stabilizer, 1,4-dioxane is used in the manufacturing of lacquers, plastics, varnishes, cellulose acetate membranes, organic pesticides, personal care products, and paper.

1,4-Dioxane has a moderate chronic toxicity and a low acute toxicity. The U.S. Environmental Protection Agency (EPA) has designated it as a probable human carcinogen of low carcinogenic hazard. In animal testing, 1,4-dioxane increased the incidence of cancer in the liver, lungs, gall bladder, and on the skin. The EPA Integrated Risk Information System (IRIS) Database lists the one-in-a-million cancer risk of 1,4-dioxane at 3 parts per billion (ppb) in drinking water. The California Department of Health Services has set an Action Level of 3 ppb, while other states have set actual standards. Florida and Michigan have 5 ppb and 85 ppb maximum contaminant levels, respectively.

See UV-Oxidation, page 27

EPA Provides Groundwater, Remediation, and Perchlorate Information

Three new information sources are available from the U.S. Environmental Protection Agency (EPA), including an Internet-based groundwater information site, a technology status report on soil and groundwater remediation, and a Web page containing information about perchlorate remediation.

The EPA's Groundwater Remediation Technologies Analysis Center (GWRTAC) launched **Groundwater Central©** which contains a resource links database and several integrated communication components. The smart search engine provides a one-stop shop to browse for a wide variety of information, from on-line publications to case studies, data repositories, vendors, and announcements for events. Communication center components integrated into Groundwater Central include a public discussion forum, public events calendar, and a chat room. For more information, visit http://www.groundwatercentral.info.

In January, EPA released the **Technology Status Report: Treatment Trains for Remediation of Soil and Groundwater (TS-03-01)**. This 167-page report was produced by the GWRTAC. It includes an appendix that contains 48 case studies where treatment trains were used to remediate groundwater or soil, either in situ or ex situ. For the purposes of this document, a treatment train was defined as the sequential use of unique remediation technologies to treat the same volume of contaminated soil or groundwater. Several summary tables and figures were generated from the compiled information, and interpretive text is provided. View or download the full report at http://www.gwrtac.org/pdf/train_full.pdf

The **Perchlorate Remediation Information Web page** is on the EPA's CLU-IN Web site. This page provides access to more than 40 technical reports, journal articles, Web pages, and other materials from public and private sources. Representing the latest advancements in the research and application of perchlorate treatment technologies, these resources provide up-to-date information in a number of formats, including treatability studies, cost and performance reports, case studies, presentations, and peer-reviewed literature. View and download the perchlorate remediation resources on CLU-IN at http://clu-in.org/perchlorate.

EPA Report Aids Compliance with Bioterrorism Act

Article originally appeared on Water Tech Online, Feb. 28,2003

The U.S. Environmental Protection Agency (EPA) has provided a detailed 23-page on-line report giving instructions to assist community water systems in complying with the Bioterrorism Preparedness and Response Act of 2002.

The report includes a section with frequently asked questions, a chart of key compliance deadline dates, steps for getting security vulnerability assessments certified, and even mailing labels for courier deliveries of items submittedto EPA.

Under the Bioterrorism Act, all community drinking water systems that serve more than 3,300 people are required to certify and submit vulnerability assessments and certify completion of emergency response plans to EPA. The deadline to certify and submit these assessments was March 31 for drinking water systems serving 100,000 or more people, and is Dec. 31 for systems serving 50,000-99,999 people and June 30, 2004 for systems serving 3,301-49,999, said the EPA.

Systems are required to certify completion of an emergency response plan within six months of submitting a vulnerability assessment, said the agency.

The EPA report is available at www.epa.gov/safewater/security/util-inst.pdf.

Visit www.watertechonline.com

EPA Settles with Union Pacific for CA Wetlands Violations

The U.S. Environmental Protection Agency (EPA) recently reached a settlement with Union Pacific Railroad that requires the company to pay $125,000 for alleged wetlands violations at two Santa Barbara County, Calif. waterways in the 1990s.

Union Pacific paid $55,000 for illegally discharging dredged materials into Carpinteria Salt Marsh during a project in 1997, and another $70,000 for similar violations in 1999 at Laguna Creek.

"Railroad tracks cross some of the most sensitive natural areas in California," said John Kemmerer, acting director of the EPA's water division in San Francisco. "Union Pacific has already restored the damaged wetlands and has taken administrative steps to prevent such mistakes in the future." He expressed hope that the penalties assessed for these Clean Water Act violations will deter others from damaging important natural resources.

Union Pacific failed to obtain a federal permit for trenching, dredging and filling activities in 1997 that damaged a portion of the 230-acre Carpinteria Salt Marsh, nearly half of which functions as a research and wildlife reserve run by the University of California Santa Barbara.

During the fall of 1999, the company also discharged dredged and fill materials into Laguna Creek without a federal permit as part of a bridge replacement project.

People wishing to place fill materials into wetlands, rivers, streams, and other waters of the United States must apply to the U.S. Army Corps of Engineers for a permit. The EPA works with the Corps of

Engineers to evaluate the permits, requiring applicants to provide the least environmentally damaging alternative possible.

Visit www.epa.gov/region09/

ADWR Project Focuses on Rural Water Affairs

Joe Gelt, *Editor – Water Resources Research Center, University of Arizona*

Rural water concerns are attracting increased attention in Arizona, and an Arizona Department of Water Resources (ADWR) study is one further indication of that growing interest. ADWR's Rural Water Resources Study will examine the availability of water supplies for future municipal and industrial growth and the ability of communities to withstand the effect of long-term drought. Other issues to be addressed include identifying conservation activities, impacts of exempt wells – those with less than 35 gallons-per-minute pump capacity – and effectiveness of current water management practices. The project involves collecting water-related information from varied sources and compiling a database and report.

Project Director Kathy Jacobs says the project is made up of several phases, with phase one consisting of mailing out questionnaires. Three sets of questionnaires will be sent out, with one set delivered to about 1,200 water companies outside Active Management Areas (AMAs), another set to planning directors of counties and tribes, and a third set going to incorporated jurisdictions, such as cities and towns outside AMAs.

Jacobs says that with information obtained from the survey, "We will have a much better idea of the types of problems that exist and how consistent the problems and issues are across the state. We will be able to assess the level of drought concern and the types of assistance communities want from the state."

Jacobs adds, "We want to reassure people that the survey information is not being collected for regulatory purposes. It is imperative that we get a good response to ensure that our database of issues and concerns is relatively complete. We are anxious for people to fill out the questionnaires." The key to the success of the project will be gathering as complete information as possible to ensure that community concerns are identified and future water supplies determined.

Jacobs says the risk and vulnerability of rural communities will be examined to better prioritize the issues. Strategies that have been adopted or are under consideration in individual communities will be shared with other groups if it appears that the strategies might be helpful. In considering possible outcomes, Jacobs says, "We will probably be looking at an array of tools and new information to address the multiple issues across the state. Also, the project will be providing input to state Representative Tom O'Halleran, who is conducting workshops and meetings throughout the state to collect information and boost interest in rural water issues."

Jacobs intends to have a status report completed by June, followed by a period of public comment, then a final report done in the fall. The planned result of these coordinated activities is to develop potential solutions to the water problems of rural areas, which would lay the groundwork for a possible legislative agenda coordinated by O'Halleran and presented next year.

For additional information about the Rural Water Resources Study, contact Kathy Jacobs at kljacobs@adwr.state.az.us

AZ/NV Interstate Water Banking Update

The Arizona Water Banking Authority (AWBA) approved and signed two agreements in December, thus completing the federal process necessary to store water on behalf of Nevada and create unused apportionment for the state's benefit.

The Storage and Interstate Release Agreement with the Central Arizona Water Project (CAP) and the Agreement for the Development of Intentionally Created Unused Apportionment with the Southern Nevada Water Authority, the Colorado River Commission of Nevada and the Bureau of Reclamation were the last two agreements required by a federal rule regarding off-stream storage of Colorado River water.

The AWBA was created by the Arizona State Legislature in 1996 to identify means to store unused portions of Arizona's allocation of Colorado River water to meet future needs. Without the AWBA, Arizona would not have used its full allocation until 2030. Most of the approximately 14 million acre-feet of water unused until that time would have gone to Southern California.

In spite of the previously outstanding agreements, Arizona began storing water for Nevada in the early 1990s. The total amount of water stored in Arizona by the AWBA and CAP on Nevada's behalf is now more than 116,000 acre-feet, which is almost 40 percent of Nevada's annual allocation of the Colorado River.

The agreements are on the AWBA Web site at www.awba.state.az.us

California Arsenic Standard May Become More Stringent Than EPA Limit

From article originally appearing on Water Tech Online, March 10, 2003

California environmental officials released a preliminary public health goal for arsenic in drinking water on March 7, recommending a level far below the federal standard that already has many states and communities complaining.

The Los Angeles Daily News reported that the California Environmental Protection Agency, through the Office of Environmental Health Hazard Assessment, proposed a limit of 4 parts per trillion for arsenic in drinking water. The current arsenic standard in California and the nation is 50 parts per billion (ppb), but drops to 10 ppb in 2006.

A draft public health goal will be used by state officials in creating a drinking water standard for arsenic, a naturally occurring carcinogen, and the standard will set the maximum allowable level of arsenic in drinking water.

"While the U.S. Environmental Protection Agency has lowered the federal arsenic standard from 50 parts per billion to 10 parts per billion, effective January 2006, California has traditionally led the nation with stricter water quality standards," said Jill T. Wicke, water system operations manager for the Metropolitan Water District of Southern California.

She said the California Department of Health Services (CDHS) is required to either accept the federal standard or use a lower value. CDHS is required by state law to set this standard by June 30, 2004, with compliance monitoring to start by January 2006.

For complete article, visit www.watertechonline.com

California Considers New Restrictions on Open-Pit Gold Mining

On March 1, *The Associated Press (AP)* reported that the California State Mining and Geology Board has proposed regulations that would require mining companies to refill all new open-pit metal mines and provide financial guarantees to protect taxpayers in the event of the company defaulting. These new regulations would be the nation's toughest restrictions on open-pit gold mining, according to *AP*.

AP stated that the proposed regulations were praised by environmental groups such as Great Basin Mine Watch and the National Parks Conservation Association. Alternatively, representatives from the mining industry said the regulation would effectively ban mining in the state because of the high costs involved in compliance, *AP* said.

State law already requires that mined areas be returned to a usable condition, and that public health and safety problems be eliminated, reported *AP*, but the mining board now says the stricter backfill regulations are needed to meet the goals of that law.

According to *AP*, the emergency regulations were prompted by Glamis Gold Ltd.'s proposal to mine federal land near the Fort Yuma Reservation of the Quechan Indian tribe near Winterhaven, on what the tribe considers sacred land. The mine could leave an open pit 4,700 feet by 2,700 feet, and 800 feet deep, along with piles of waste rock a mile long and up to 300 feet high, *AP* reported.

New Mexico Officials Stress Need for State Water Plan

Article originally appeared on Water Tech Online, March 3, 2003

New Mexico officials hope a proposed water plan – the first statewide blueprint for attacking New Mexico's water problems – will put an end to some in-state fighting over water rights.

Estavan Lopez, chairman of the Interstate Stream Commission, and John D'Antonio, a state engineer, have been before state House and Senate subcommittees on numerous occasions explaining their plan in conjunction with other water legislation, the *Las Cruces Sun-News* said.

One of the first steps will be determining exactly how much water the state has.

"New Mexico needs to begin to set aside very substantial sums to deal with the problems," D'Antonio said, according to the paper. "The state will have to plan very carefully and creatively, both technical and financial aspects of projects, seeking federal, state, local, tribal, and private funds whenever possible."

D'Antonio and Lopez told legislators there are three sources of water in New Mexico – rivers, aquifers, and precipitation – but that water is in short supply and that supply is being threatened. According to the article, officials said the survival of both urban and rural New Mexico depends on a stable and predictable supply of water.

The costs for coming to grips with the water plan are intimidating, the newspaper said. The plan carries an estimated price tag of $2.3 billion, including:

- $1.6 billion to current water supply systems either planned or in progress.
- $220 million to rehabilitate 38 flood control dams by 2010.
- $375 million to reach compliance with the federal guidelines on reducing arsenic levels in New Mexico's water.
- $100 million to create or maintain critical habitats for New Mexico's wildlife.

A proposed bill in the state House would give $1.3 million to increasing technical expertise and manpower – engineers, hydrologists and surveyors – to gather information and get a database up and running.

Visit www.watertechonline.com

Desalination Today

Lisa Henthorne *– Aqua Resources International*

Desalination is a water treatment process that removes salts from the water. One of the earliest forms of water treatment, its use is worldwide. Some of the applications of desalination include:

- Municipal desalting of brackish or seawater for drinking water production.
- Industrial and commercial applications for producing high purity water, boiler feedwater, process water, bottled water.
- Zero discharge applications that produce water for pharmaceutical, electronics, bio/medical, mining, power, petroleum, beverage, tourism and pulp/paper industries.
- Rigorous treatment of wastewater for reuse applications.

Desalination Technologies

Today, desalination has become a proven water treatment process. And, as the cost of desalination decreases as compared to the other conventional treatment means, it is developing into a price-competitive water treatment option for more and more communities.

At the end of 2001, an estimated 9,400 land-based desalting plants with capacity greater than 100 cubic meters per day (26,400 gallons per day) had been installed or contracted for installation throughout the world. According to the July 2002 International Desalination Association Worldwide Desalting Plant Inventory, worldwide installed capacity is now more than 8.5 billion gallons per day.

Desalination processes that use membrane technologies such as reverse osmosis (RO), nanofiltration (NF), electrodialysis (ED) and electrodialysis reversal (EDR) employ semi-permeable membranes to separate the feedwater into a high-purity product stream and a high-saline concentrate stream. RO and NF are pressure-driven processes that pump feedwater at sufficient pressure to overcome the osmotic pressure of the saline feedwater and that provide sufficient driving pressure to permeate water across the membrane surface, leaving the higher salinity concentrate water behind. RO and NF membranes are configured in spiral-wound elements (see Figure 1), and multiple elements are placed in series in a membrane vessel.

ED and EDR utilize electrical potentials to attract positive and negative ions from the saline feedwater, leaving behind the lower-salinity product water. ED and EDR membranes are configured in flat sheet modules. Membrane technologies are used in seawater, brackish water, wastewater, ultrapure, and many other industrial water applications. Desalination processes using thermal technologies, such as multistage distillation (MSF), multiple effect distillation (MED) and vapor compression (VC), utilize heat and reduced pressure to vaporize and condense pure water from seawater. Thermal desalination is also used in industrial applications.

Thermal technologies account for about 48 percent of worldwide desalting capacity with multistage flash distillation providing about 83 percent of that quantity. Membrane technology accounts for the remaining 52 percent of the worldwide desalination capacity with RO contributing 84 percent of that quantity.

Historically, thermal technologies are more mature, with the ancestors of today's technologies being developed in the 1920s and 1930s. ED technology dates from the 1940s and RO applications from the 1970s. EDR was an offshoot of ED, which came on the scene in the 1950s. Similarly, NF developed from RO technology in the late 1980s.

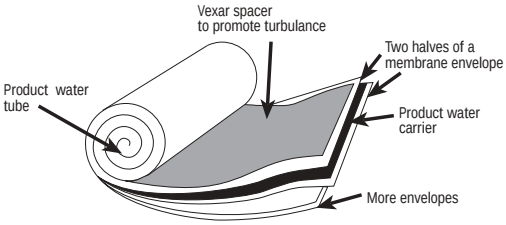


Figure 1. Spiral-wound configuration used in reverse osmosis and nanofiltration membranes.

Desalination Around the World

In the United States, membrane processes are the preferred technology, as they are more energy-efficient than thermal technologies. Thermal technologies are used primarily in the Middle East region, in cogeneration facilities that generate power and desalinated water. In these facilities, the energy to fuel the desalination process is a by-product of the power generation. Figure 2 demonstrates the distribution of installed desalination capacity by region on a global basis. As the figure indicates, the Middle East region leads the world in installed capacity, but North America and Europe now have significant desalination capability. Large-scale seawater desalination plants are now popping up in areas outside the Middle East region, including the Caribbean, Singapore, Israel and Hong Kong. All of these new large-scale plants are utilizing RO membrane technology. Domestically, Figure 3 demonstrates the distribution of technology in the U.S. desalination market. RO is the market leader, and continues to gain market share as large-scale seawater facilities using RO are now being developed here at home.

Desalination of brackish water sources has been the basis for most U.S. desalting for the past 30 years, but that is beginning to change at a fast pace, as the pricing for seawater desalination becomes cost-competitive with more conventional water

supply options for water-short coastal communities. The first large-scale seawater desalination plant began operating in March 2003 in Tampa, Fla, and, at full capacity will produce 25 million gallons per day (mgd) with expansion potential to 35 mgd. Earlier, smaller seawater plants are located in Key West, Fla. and Santa Barbara and Catalina Island, Calif. Additional large-scale facilities are in the planning or development stage in Florida, California and Texas. For large-scale facilities (20 mgd or larger) cost is now in the range of $2.00-$2.80 per 1,000 gallons of water produced. Brackish water desalination is considerably lower in cost, depending on the salinity and disposal options for the concentrate waste stream. For brackish water of salinity ranging from 1,000-5,000 milligrams per liter using surface disposal for concentrate discharge, the cost is approximately $0.75-$2.00/1,000 gallons of water produced. The capital cost for desalination projects is described in Table 1. Note that the range of cost is considerable, and is site- and capacity-specific.

Desalination Challenges in the Southwest

All desalination applications used today create a high purity product stream and a high saline concentrate waste stream. Disposal of the concentrate stream presents one of the biggest challenges to the use of desalination at inland sites. In seawater applications, disposal of the concentrate to the ocean is typical. For inland brackish facilities, concentrate disposal is generally to a surface water body but can include deep well injection, or disposal to a publicly owned treatment works. Other methods of disposal, including discharge to saline wetlands and enhanced evaporative techniques, have been studied, but nothing has been found to be economically and environmentally viable at this time. The U.S. Bureau of Reclamation and communities in Arizona, Nevada, Texas, and California have joined together to address this challenge.

Desalination in the southwestern United States is being used on a limited basis in small-to-medium facilities and is presently being evaluated by a number of communities in New Mexico, Texas, Arizona, California and Nevada for use on a large scale. As mentioned above, the biggest challenge for communities in the land-locked southwestern communities is concentrate disposal. Saline aquifers and surface water sources offer a significant resource of "new" water supplies for southwest communities needing to augment their future water supplies. In fact, some of these communities have no future water source other than desalination and water reuse. Therefore, it is critical that we find environmentally friendly and cost-effective concentrate disposal solutions to offer these communities.

Overall, desalination of seawater, brackish water and wastewater is growing as a method to augment water supplies in the United States and around the world. Desalination using membrane technology is growing at a rate of approximately 11 percent per year by installed capacity. As the cost for desalination continues to decrease, particularly in comparison to developing traditional methods of water supply, more and more communities will turn to this alternative to help them solve their water supply challenge.

Contact Lisa Henthorne at lisahenthorne@cs.com

Capital Cost for Seawater and Brackish Water Desalination Plants

	Total Installed Cost, $ per gal/day of production capacity
Brackish water desalination plants	0.95-4.50
Seawater desalination plants	2.80-5.00

Table 1:Capital costs for desalination projects.

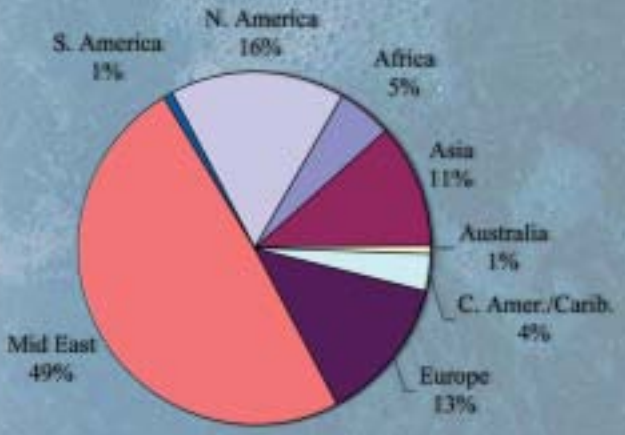


Figure 2. Distribution of installed desalination capacity by region. Source: Aqua Resources International from IDA/Wagnick Inventory, 2002.

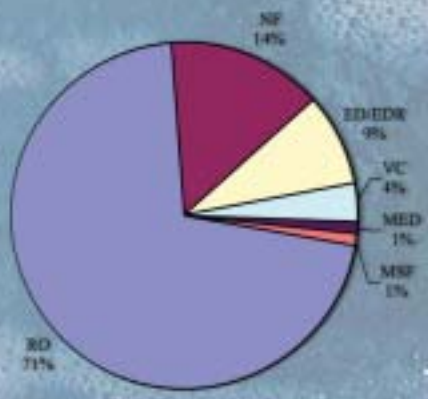
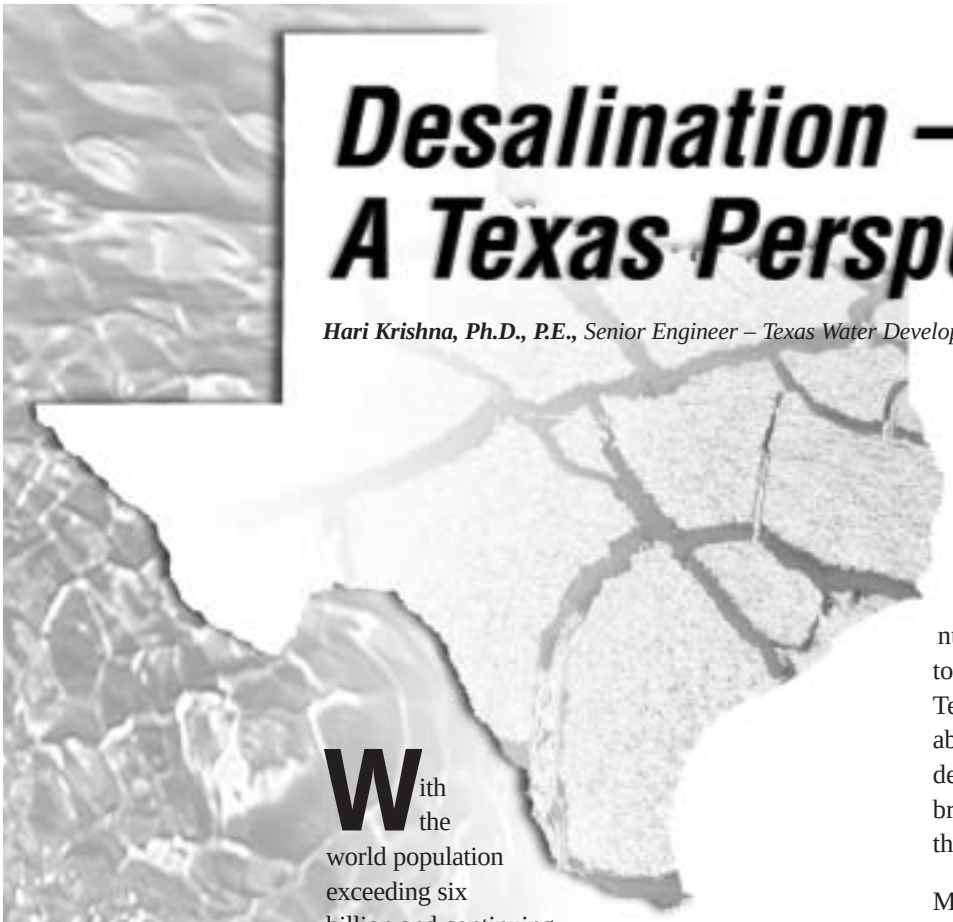


Figure 3. Distribution of desalination technology used in the United States by installed capacity. Source: Aqua Resources International from IDA/Wagnick Inventory, 2002.

Desalination – A Texas Perspective

Hari Krishna, Ph.D., P.E., *Senior Engineer – Texas Water Development Board, Austin, Texas*



With the world population exceeding six billion and continuing to grow rapidly, there is ever increasing pressure to satisfy the growing municipal, agricultural and industrial water demands of society. Since fresh water resources account for less than three percent of the entire global water budget, it is becoming necessary in many regions of the world to explore seawater desalination to meet future water demands.

Closer to home, the population of Texas is expected to double in the next 50 years. The 2002 Texas Water Plan indicates that about 900 cities and water user groups in Texas, representing nearly 38 percent of the state's population, could face water shortages during droughts within the next 50 years unless they reduce demand or develop additional water sources. According to the 2002 Texas Water Plan, supplies from existing water sources in Texas are expected to decrease 19 percent, from 17.8 million acre-feet per year (mafy) in the year 2000 to 14.5 mafy in 2050. While the available supplies are expected to decrease, municipal demand is projected to increase by 67 percent, and manufacturing demand is expected to increase by 47 percent over the next 50 years.

Desalination Solutions Widespread in Texas

The gap between diminishing supplies and increasing demands can be met through conservation strategies, by producing new supplies of water such as desalinated water, or through a combination of both methods. According to the International Desalination Association, the United States is ranked as having the second largest total desalination capacity of any country in the world. This is due to the numerous inland desalination plants that are used to treat brackish surface water and groundwater. In Texas, more than 100 desalination units produce about 40 million gallons per day (mgd). All desalination plants in Texas currently use either brackish surface water or brackish groundwater as their raw water source.

Municipal desalination in Texas accounts for 23 mgd while industrial desalination is approximately 17 mgd. Prominent municipal desalination sites in the state using surface water as their raw water source include Sherman (Lake Texoma), Robinson (Brazos River), and Lake Granbury, while Ft. Stockton and Kenedy use brackish groundwater.

Reverse Osmosis (RO) desalination systems are currently the most commonly used systems in Texas. Regardless of the technique employed, desalination offers many benefits and advantages over other conventional forms of water resource development. The most important advantage is that desalination provides a relatively drought-proof water resource. There is no need to build expensive dams or reservoirs nor deal with issues such as land submergence and flooding.

In Texas there are currently several private and public partnerships in desalination projects. In West Texas, the City of El Paso Water Utilities and Fort Bliss are collaborating to build the country's largest brackish groundwater desalination plant for municipal use. The 29 mgd Eastside Brackish Groundwater Desalination Plant will treat brackish groundwater from the Hueco Bolson aquifer and will provide about one-fourth of the city's water requirement. The Texas Water Development Board (TWDB) is partnering in the project by providing a $1 million low-interest loan for

the planning and preliminary design. There is likely to be an additional federal contribution for this project.

In North Texas, the City of Wichita Falls plans to complete this year a 15 mgd microfiltration and RO plant using water from Lake Kemp. In the Lower Rio Grande Valley, Harlingen has been using an RO plant to produce 3 to 4 mgd of good quality water for the local garment industry, using wastewater as the raw water source. The Southmost Regional Water Authority in Cameron County is currently building a 7.5 mgd desalination plant using brackish groundwater.

In the 2002 Texas Water Plan, desalination is recommended as a water management strategy to produce additional water supplies in four regions. The Far West Texas Region and the Coastal Bend Region use desalination of brackish groundwater as a strategy, while the desalination of coastal waters is recommended by the South Central Texas Region. Region B includes desalination in two recommended water management strategies. In addition, four other regions – Plateau, Rio Grande, Lavaca and Region H – include topics such as research and development of desalination and conducting feasibility analyses for new desalination projects. Thus, a total of eight out of 16 regions in Texas have expressed their interest in desalination-related projects.

Upcoming Desalination Projects

As demand for water increases and fresh water resources are depleted, desalination is likely to become increasingly important. Texas Governor Rick Perry tasked the TWDB in April 2002 with developing a recommendation for a large-scale demonstration seawater desalination project. His initiative paved the way for the state to gauge the level of interest and willingness from key municipalities and private developers in implementing desalination projects, and to identify potential sites for seawater desalination.

The TWDB, with input from members of the Regional Water Planning Groups and other water-industry representatives, created a process to formulate screening criteria and develop recommendations. In September 2002, the TWDB issued a request for Statements of Interest (SOI) and provided screening criteria for public and private entities to submit proposals for consideration.

In response to the request for SOIs, the TWDB received 10 project proposals, including one research-only proposal. In addition to those, three in-house proposals were prepared. A team of seven technical staff from the TWDB and the U.S. Bureau of Reclamation carefully reviewed all SOIs.

After review, the TWDB recommended the following three proposals:

1. The Freeport Desalination Project, submitted by Poseidon Resources and the Brazos River Authority, for a 25 mgd seawater RO desalination facility, to be located at the Dow Chemical complex in Freeport. The proponents requested state financial assistance to cover only the cost of product water conveyance.
2. The Corpus Christi project, submitted by the City of Corpus Christi, for a 25 mgd plant.
3. The Lower Rio Grande Valley project, submitted by the Port of Brownsville, Brownsville Public Utilities Board, and the Southmost Regional Water Authority, also for 25 mgd.

For Corpus Christi and the Lower Rio Grande projects, the TWDB recommended site-specific feasibility studies of a regional water-supply nature. Specific recommendations included:

1. Assessing combined uses of seawater and brackish groundwater sources to enhance the cost competitiveness of a desalination project.
2. Identifying and assessing regional partnerships that could include local entities with experience in desalination research.
3. Identifying and assessing water transfers resulting from net new water created by a desalination project that could enhance project benefits to other large water users or municipalities throughout the Coastal Bend, Lower Rio Grande, South Central and Lower Colorado planning regions.
4. Identifying and assessing power sources, expected costs and, if from a co-located facility, describing the impact of current and proposed regulations on use of this source, plus costs.
5. Assessing project funding and development alternatives.

Additional information on the demonstration desalination proposals and the recommendation report to the Governor is available on the TWDB web site, www.twdb.state.tx.us. Contact Hari Krishna at Hari.Krishna@twdb.state.tx.us

Bridging the Gap:

Desalination of Recycled, Brackish, and Ocean Water

***Darryl Miller**, General Manager – West Bay Municipal Water District*

Experiencing almost 15 percent growth since the 1990 census, the population of Southern California has increased by nearly two million new people in 13 years. Current water supplies are strained to meet this growing population. Compounding the issue, recent droughts have stressed local groundwater resources and diminished snow-pack runoff from the mountains. Further, the federal government has restricted California's use of the Colorado River supplies, and imported water supplies from Northern California are shrinking due to environmental mitigations.

Many of the Southern California communities live in water-starved areas, and it's important to consider where the region's water will come from in the future. One Southern California water agency is proactively seeking ways to bridge the gap by expanding its knowledge of desalination. West Basin Municipal Water District (West Basin) has been using reverse osmosis (RO) technology to desalinate water since 1993. Desalination removes virtually any mineral and most biological or organic chemical compounds from water, but specifically, it removes salt.

West Basin is a public agency that wholesales imported water to local cities, mutual water companies, private companies and investor-owned utilities in a 200-square-mile area of southwest Los Angeles County, Calif. that encompasses 851,000 people. West Basin currently supplements its supply by desalinating recycled water and brackish water, and hopes to use the same RO technology to desalinate ocean water. The West Basin Water Recycling Facility produces 27,000 acre-feet of recycled water annually; the Marvin Brewer Desalting Facility produces 1,200 acre-feet of brackish water annually; and the Ocean Water Desalination Demonstration Project performs research on 30,000 gallons each day.

Desalinated Recycled Water

The cornerstone of West Basin's recycling program is the West Basin Water Recycling Facility. Using secondary effluent from the City of Los Angeles' Hyperion Treatment Plant (HTP), West Basin produces five qualities of "designer recycled water": tertiary, nitrified, softened RO, pure RO, and ultra-pure RO. The latter three are produced using desalination technologies:

Softened RO Water — Softened RO water is used in the West Coast Basin Barrier Project after pre-treatment by either lime clarification or Micro Filtration (MF), followed by RO. The Barrier project is a series of 153 wells constructed along the Southern California South Bay coast to protect the coastal groundwater aquifers against saltwater intrusion from the Pacific Ocean. Softened RO water is combined with potable water and injected into the wells to form a fresh water barrier. Approximately 7,300 acre-feet of softened RO water are produced annually; the rate at which it is provided to the local users is at about $470 per acre-foot. This is about 10 percent less than the $510 per acre-foot cost of imported water supplies.

Pure RO Water — Pure RO water is secondary treated water from HTP that has been treated with MF and RO. This water is used for low-pressure boiler-feed water for a local refinery. Approximately 6,500 acre-feet of pure RO water are produced annually.

Ultra-Pure Reverse Osmosis Water — Ultra-pure RO water is secondary treated water from HTP that has been treated with MF once and RO twice. The salt levels are reduced from approximately 750 parts per million (ppm) to less than 5 ppm; delivery of this quality water is guaranteed 24 hours per day year round. This water is used for high-pressure boiler-feed water for a local refinery. Approximately 2,600 acre-feet of ultra-pure RO water are produced annually. It is provided to the local users at a cost greater than imported water, but comparable to that of the refinery that uses the ultra-pure water.

Solid waste from the RO waters is dried, caked, and then taken to a landfill for cover. The liquid waste brine is piped back to the HTP, combined with other liquid waste, and discharged into the ocean five miles offshore.

Brackish Water Desalination

West Basin is also using RO technology to desalt brackish groundwater for drinking water needs. The Marvin Brewer Desalting Facility began operations in 1993 and has the capacity to treat up to 1.3 million gallons a day (mgd). Salt concentrations of 3,600 ppm in brackish groundwater are reduced to 400 ppm in the facility, with

approximately 1,200 acre-feet of drinkable water produced each year. Liquid waste brine is piped into the county sewer line. Without RO technology, this brackish groundwater could not be used as potable water.

Ocean Water Desalination

West Basin has recently taken steps to investigate whether desalinating ocean water from the Pacific Ocean would be considered a viable option for supplementing its water supplies. Ocean water desalination is already in use around the world by countries that do not have a sufficient supply of water, and also by military and cruise ships. The benefits associated with ocean water desalination are numerous. It is a new, virtually limitless supply of water that is drought-proof (independent of changes in weather patterns), independent of water rights, and a source of high-quality water.

In May 2002, West Basin began operating an Ocean Water Desalination Demonstration Project using MF and RO technology to desalinate ocean water. Co-located with a power plant, the demonstration project obtains its source water from the power plant's feed line and returns its discharge to the power plant's outfall line, where it is discharged back into the ocean. Approximately 30,000 gallons per day are processed through the facility, with raw ocean water salt levels of 35,000 ppm being reduced to 350 ppm. More than 500 analytical tests are performed monthly. During the course of this project, the West Basin seeks to study raw ocean water, desalted water quality, brine discharge quality, and the effectiveness of RO membranes. Using knowledge gained from the demonstration project, West Basin ultimately plans to develop a full-scale ocean desalination plant serving 20 mgd to its service area.

West Basin's $1.2 million Ocean Water Desalination Demonstration Project has been made possible by support from federal, state, and local agencies and organizations, and national research groups (see end note.)

United States Desalination Coalition

West Basin hopes that the Ocean Water Desalination Demonstration Project and any future projects related to ocean-water desalination will become regional and national assets through open and collaborative efforts. The company has partnered with four other Southern California agencies to form a non-profit organization called The United States Desalination Coalition, which seeks legislative funding for seawater and brackish groundwater desalination and for transporting the treated water for municipal use. Public agencies from other states, including Florida and Texas, have already expressed interest.

For additional information, please contact Art Aguilar at (310) 660-6205.

The Ocean Water Desalination Demonstration Project is supported by: Association of California Water Agencies, American Water Works Association Research Foundation, California Avocado Growers, California Department of Water Resources, Calleguas Municipal Water District, East Bay Municipal Water District, Long Beach Water Department, Los Angeles Department of Water and Power, Metropolitan Water District of Southern California, Municipal Water District of Orange County, National Water Research Institute, Poseidon Resources, Inc., San Diego County Water Authority, Tampa Bay Water, U.S. Bureau of Reclamation and West Basin.

The Public Opinion on Desalination: Survey Results

In May 2002, West Basin Municipal Water District conducted a statewide poll in California of 601 registered voters, focusing on a variety of topics relating to water and desalination. The poll results indicated that 70 percent favored desalination as a future drinking water supply for the following reasons:

- *Reduced dependence on imported water*
- *Improved quality of local water supplies*
- *Increased water available for environmental use*
- *Increased water available for agricultural use*

Fifty-two percent of poll respondents indicated that they would support the increase of imported water from Northern California to Southern California. Although most respondents also thought of water supply as a future issue, not one currently facing California, the support for water agencies trying to "bridge the gap" was apparent. With this voter support, West Basin seeks to actively pursue ocean water desalination as a future water source.

Desalination of Inland Brackish Water:
Issues and Concerns

Mike Hightower *– Sandia National Laboratories*

According to the World Water Development Report (United Nations, 2003), by 2025, more than 50 percent of the nations in the world will face water stress or water shortages. As in so much of the world, access to fresh water is an increasingly critical issue in the southwestern United States. Growth in the Southwest has led to increased demand for water and to unsustainable water management practices, resulting in falling water tables with ground subsidence and associated building and utility damage, and reductions in surface water and groundwater quality and availability.

In the search to address these challenges, one area that can no longer be overlooked for increasing water supplies is the application of desalination technologies to treat brackish surface and groundwater resources. Much of the United States, including the Southwest, contains extensive brackish groundwater resources (Krieger et al., 1957). Since much of this supply underlies more easily accessible and higher-quality fresh water resources, it has remained primarily untapped. As fresh water supplies become more limited, however, desalination of these brackish water resources will become more common.

Desalination Trends in the Southwest

From Virginia and Florida to New Mexico and California, desalination plants are being installed across the country in an effort to supplement fresh water supplies for a wide range of industrial and domestic needs. The growing interest in the Southwest and other inland areas in applying desalination includes:

- Enhancing domestic water supplies. Many southwestern water districts are evaluating brackish groundwater desalination to supplement limited fresh water supplies and provide water for a wide range of industrial and municipal uses.
- Fossil energy production. Large volumes of saline or brackish water are commonly co-produced in oil and gas production. Using desalination technologies to treat this water may offer oil-producing areas a beneficial use for this water.
- Treatment of impaired surface water. Many of the river systems in the Southwest suffer from salt buildup caused by surface runoff, agricultural irrigation practices, urban uses, and evaporation. Desalination of these impaired rivers will become increasingly important to meet more stringent water quality standards for domestic and ecological-based total maximum daily load requirements.
- Industrial and domestic water pretreatment and reuse. As water conservation and reuse become increasingly important, desalination-based water- and waste-water treatment technologies could meet water quality standards for water reuse in various applications.

The many applications of desalination are being evaluated and pursued by municipalities and industries across the Southwest. El Paso, Las Vegas, Phoenix, and Tucson all are considering desalination plant options to supplement or improve water supplies. Cities such as Scottsdale, Ariz. and Ft. Stockton, Texas have already built and are operating desalination facilities. Even mid-sized cities like Alamogordo, N.M., with a population around 30,000, is planning to construct an approximately 10 million gallon-per-day (mgd) desalination plant to help supplement its fresh surface and groundwater resources to meet future growth. Pat McCourt, City Manager for Alamogordo suggests, "The cost of acquiring new fresh water supplies has increased to a level that desalination of local brackish water is now competitive with developing and bringing in fresh water from remote locations." As an example of other desalination applications, oil companies, in cooperation with federal and state resource management agencies in New Mexico, Colorado, and Texas, are evaluating the treatment and desalination of oil- and gas-produced water for supplementing river flows during drought, rehabilitating rangeland, and cooling water for power plants.

Inland Desalination Concerns

Desalination research and development efforts since the mid-1960s have led to improvements in the performance and costs of brackish and sea water desalination, but additional progress is still needed. By the late 1990s, there were more than 12,500 desalination plants in operation in the world, generating more than six billion gallons of fresh water per day and accounting for about one percent of the world's daily production of drinking water (Martin-Lagardette, 2001). Many of these systems have been built in coastal areas for sea water desalination. Desalination in inland areas, like the Southwest, has lagged behind coastal desalination applications. Most water professionals agree there are three major concerns critical to the wider use of desalination in inland areas. These include addressing the environmental issues of concentrate and salt disposal, improving desalination efficiency, and

reducing the costs of inland desalination.

There are several concentrate disposal methods practiced today: surface water discharge, discharge to sewers, deep well injection, land application, evaporation ponds/salt processing, and brine concentration. The feasibility of each disposal option depends primarily on location and desired efficiency. Surface water discharge is used extensively in coastal applications where coastal water can be used to dilute the concentrate, providing an inexpensive and often environmentally benign disposal option.

The other methods, while viable, have disadvantages. In inland areas, concentrate disposal options, including surface water discharge, sewer discharge, and land application, can increase the salt load in the receiving waters and soils, which contaminates water resources and reduces soil fertility. Evaporation ponds often require large land areas and are appropriate only in arid climates with low land values. Like other brine concentration techniques, they typically require impervious disposal areas to prevent contamination of fresh water supplies and soils. Deep well injection is not permitted in many states, but those that do allow it, including Texas and New Mexico, require permits, monitoring wells, and completions in deep contained aquifers to ensure that fresh water supplies are not contaminated.

Concentrate disposal may be the biggest roadblock to widespread inland desalination. Mike Gritzuk, Director of the Phoenix Water Services Department, likens the potential accumulation of salts and the possible long-term negative environmental impacts from inland desalination as "a train wreck in slow motion." New research into areas such as concentrate reuse and salt sequestration technologies is needed to address the environmental issues with inland desalination concentrate disposal.

Desalination efficiency is also an important issue for the Southwest, according to Bruce Johnson, Assistant Director of the Tucson Water Department. Today, common desalination systems have recovery efficiencies of 60 to 85 percent for brackish water desalination (U.S. Bureau of Reclamation, 2002). Unfortunately, this means that 15 to 40 percent of the available water is not used and often must be disposed, wasting potentially valuable water resources and requiring additional pumping. Improving recovery efficiencies to 90 or 95 percent could significantly reduce concentrate disposal volumes, extend the supply of brackish resources, and potentially reduce overall desalination costs.

To reduce costs, many coastal desalination plants are designed to treat large volumes of water, often 50 mgd or greater, and are co-located with coastal power plants to take advantage of common intake and outfall structures and less expensive power. These strategies enable coastal facilities, such as the Tampa Bay Desalination Facility, to maintain desalination costs as low as $2.00-$2.50 per 1000 gallons of water produced. Similar facilities in inland areas may cost twice as much to operate because of smaller plant sizes, higher concentrate disposal costs, higher water pumping costs, and higher energy costs (U.S. Bureau of Reclamation, 2002).

While there have been significant strides in desalination over the past several decades, additional improvements in desalination efficiency, cost effectiveness, and concentrate disposal are still needed for desalination to become widely used as a long-term, environmentally friendly enhancement for fresh water supplies in inland areas. The recently completed "Desalination and Water Purification Technology Roadmap," coordinated by Sandia National Laboratories and the U.S. Department of the Interior, Bureau of Reclamation (2003) identified the requirements needed to direct future desalination research in the United States (see pages 22-24). This roadmap should help ensure that the concerns above will be addressed, which will accelerate the use of desalination and supplement our limited fresh water resources to help meet the growing demands for water in the Southwest.

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Waste ponds at the Yuma Desalting Plant

Yuma Desalting Plant: 2003

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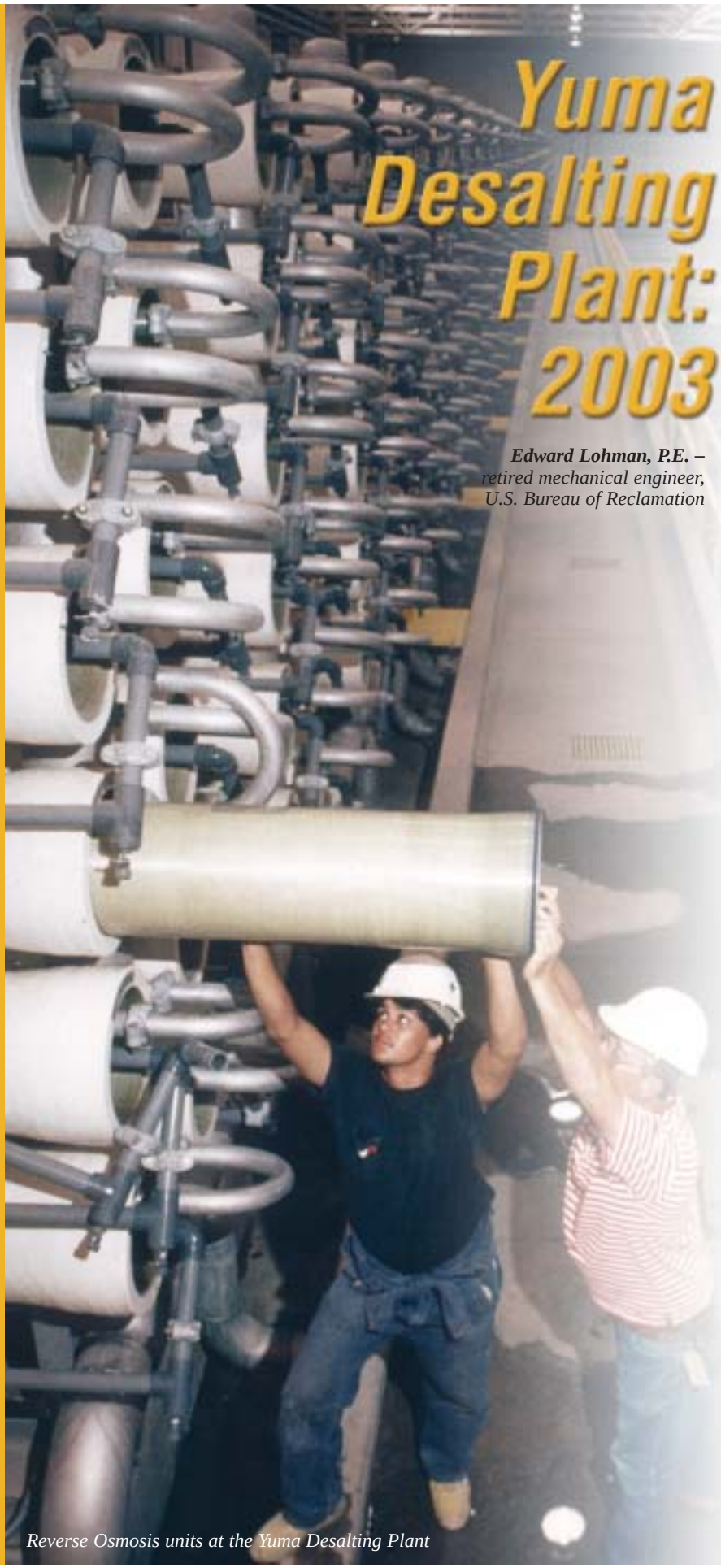


Reverse Osmosis units at the Yuma Desalting Plant

The Yuma Desalting Plant is a 72 million gallon-per-day, reverse osmosis plant located adjacent to the Colorado River in Yuma, Ariz. The U.S. Bureau of Reclamation constructed the plant during the 1980s at a cost of about $245 million to serve two purposes: salinity control and water recovery for the Colorado River.

Salinity Control

The salinity of the Colorado River at its source high in the Rocky Mountains is about 50 parts per million (ppm). Before development of the West, the salinity at the northern Mexico border was about 400 ppm. During the 1960s, the salinity at the border increased to concentrations as high as

Yuma Desalting Plant; Colorado River in the background.

1,200 ppm. This increase was caused by the return flows of numerous irrigation projects and cities along the river, where unabsorbed irrigation water percolated through mineral-rich soils and dissolved the minerals. In order to keep the groundwater table from rising and drowning the plants, this saline water was drained back to the river, thus increasing its salinity for downstream users.

In 1961, Mexico expressed concerns that the high salinity in that country's portion of the Colorado River allotment was causing lower crop yields in the Mexicali Valley. The United States subsequently agreed to control the salinity to not more than 115 ppm above the salinity of the river arriving at Imperial Dam, which is located just north of Yuma. To accomplish this goal, the agriculture return flows from the Wellton Mohawk Irrigation and Drainage District, east of Yuma, were diverted to the sea at the Gulf of California.

Water Recovery

Today, the Colorado River is allotted fully among the seven Colorado River basin states and Mexico. Bypassing of the saline water from the Wellton Mohawk Irrigation District results in a loss to the river system of approximately 108,000 acre-feet per year. The Yuma Desalting Plant is designed to recover about 75 percent (or 73,000 acre-feet per year) of this lost water, and deliver high quality water to the Colorado River for eventual use in Mexico. If the plant, which is currently not in use, were to be operated, the remaining 25 percent of the water containing the

concentrated salts would continue to bypass the river system and be discharged to the sea in the Gulf of California. To make up for the loss of water attributable to this waste stream, canal lining or groundwater pumping within the United States could be considered in the future.

Decreased Water Supplies

Construction of the Yuma Desalting Plant was completed in 1993, but the facility operated, for testing, only in 1994. Since then, water storage in the Colorado River reservoirs has been adequate to meet all requirements. However, this year the river system storage has dropped to 61 percent of capacity, and continued drought in the river basin may require operation of the plant in the near future. Further affecting distribution of Colorado River water, on Jan. 1, 2003, California's water diversions were cut back to its authorized allotment of 4.4 million acre feet when the California water agencies could not agree on a long-range plan to limit water usage to their apportionment.

Stakeholders, Effects of Opening Plant

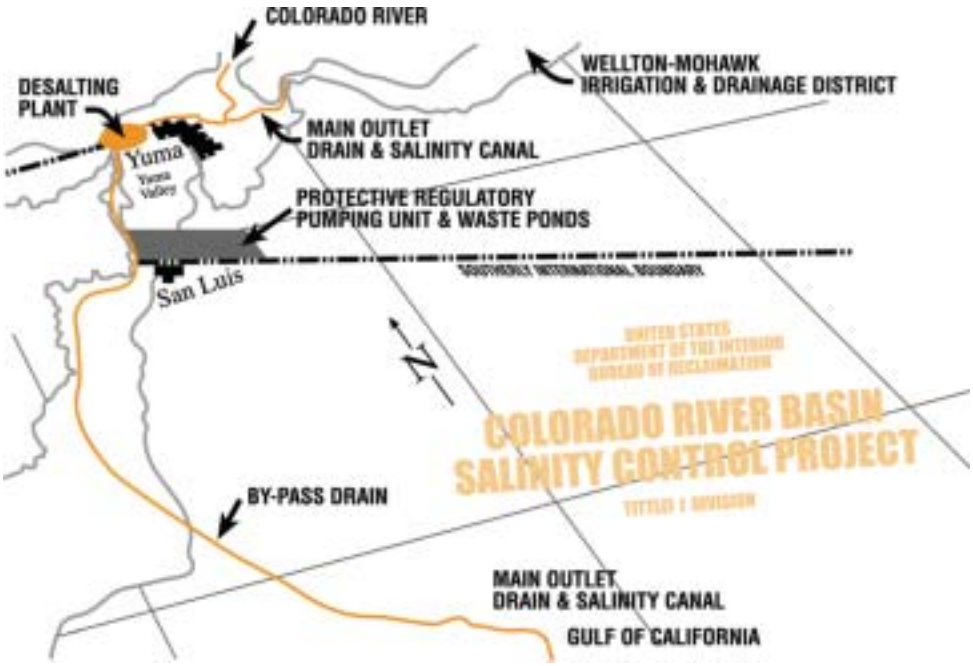
There are many stakeholders involved in the potential operation of the Yuma Desalting Plant, including:

- The federal government, which would have to foot the bill.
- Mexico, which is concerned about its water allotments, quality of the water received and the border environmental issues.
- The water agencies involved in obtaining their allotment of water for each of the seven basin states.
- The many agriculture irrigation districts along the river concerned with the integrity of their water supplies.
- The Southern California cities receiving Colorado River water.
- Arizona cities along the river, as well as cities such as Phoenix and Tucson that receive Central Arizona Project water.
- The various Colorado River, and other, Indian tribes.
- Federal government agencies, such as the Bureau of Reclamation that would have to operate the plant, the Environmental Protection Agency, Fish and Wildlife, and the Army Corps of Engineers.
- Arizona Department of Environmental Quality.
- The many environmental groups, each with its own interests.

In addition to concerns of these stakeholders, opening the plant will affect regional water supplies and wetlands in many other ways. For instance, the bypass of the Wellton Mohawk drainage water over the past several decades has created a viable marshland within Mexico. This marshland is located in the old river delta at the north end of the Gulf of California and is called the Cienega de Santa Clara. If the Yuma desalting plant were opened for operation, the amount of water entering this marsh would decrease by approximately 75 percent, and the salinity would increase to about 8,200 ppm. This reduced flow and higher salinity would adversely affect the current marshland and related habitat. This issue has been a point of contention for some environmentalists and will probably have to be addressed before the plant is placed in operation.

Plant operations would also result in a waste stream mixture of calcium carbonate and magnesium hydroxide sludge, as well as sand and algae from the desalting plant

See Yuma Desalination, page 25

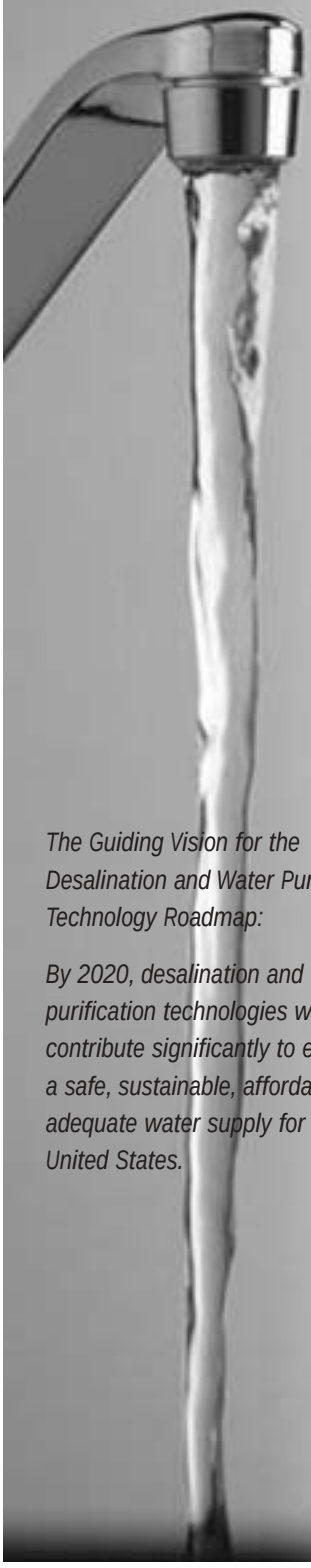


The Future of Water Development in the Southwest

– The Development of the Desalination and Water Purification Roadmap

Tom Hinkebein, Ph.D. *– Sandia National Laboratories*

In 2002, Congress authorized the U.S. Bureau of Reclamation to work with Sandia National Laboratories to develop a plan for research and implementation of desalination technology. The goal in developing such a plan is more widespread use of desalination technology in water-scarce regions. An executive committee of 11 desalination experts from the public and private sectors was formed to develop a consensus on areas of desalination research and development that may lead to technological solutions to the water supply challenges facing the United States. The committee's conclusions are presented in a report titled "Desalination and Water Purification Technology Roadmap – A Report of the Executive Committee," published in January 2003 by the U.S. Bureau of Reclamation. The following article summarizes some of the non-technical points in the Roadmap.



The Guiding Vision for the Desalination and Water Purification Technology Roadmap:

By 2020, desalination and water purification technologies will contribute significantly to ensuring a safe, sustainable, affordable, and adequate water supply for the United States.

In recent years, much attention has become focused on desalination in the Southwest. Many states and municipalities are now considering desalination as the means to a supplemental water source for the future. As local water supplies diminish, drought continues in the region, and the cost of imported water rises, desalination begins to look like an attractive alternative. However, as the technology currently exists, desalination is not a magic solution to our water-supply challenges. While the technology soon may exist to make desalination feasible, other barriers may hinder its success. The degree of commitment to water supply research and development will strongly influence how soon it is economically viable. The next steps in research must be chosen with a coordinated, integrated strategy.

SHOWSTOPPERS: BARRIERS TO SUCCESS

No matter how good a technological solution is, its effectiveness may be limited by local, state, or federal policies and regulations. The following barriers were identified in the Roadmap process.

Jurisdictional and Organizational Issues. Despite revolutionary improvements, the widespread application of desalination technology can be blocked by:

- The divergence of water quality standards across jurisdictions.
- The separation of regulatory authority over concentrate disposal from authority for other aspects of water resource management.
- The inability of multiple communities to share costs of desalination and water supply purification facilities sited in one community or disposal facilities sited in another.

Public Perceptions of Purified Water. As bottled water labels colorfully illustrate, the public is drawn to the illusory image of their water having sprung in virgin purity from some mountain stream. The unromantic reality that all water on the planet is and must be reused is susceptible to manipulation and exploitation to foment public opposition to desalination and water supply purification technologies and facilities.

Controversies about Growth and Development and Facility Siting. In many communities, significant growth pressures have affected residents' perceived quality of life. Other communities are developing where people have fled to avoid growth and urbanization. In such communities as these, desalination and water supply purification technologies that enhance the availability and sustainability of usable water supplies may become enmeshed in local or regional controversies concerning land use, population, transportation, and environmental protection if water supply improvements are seen as promoting, or at least facilitating, more growth and development.

Creation of Industry-wide Standards. At present, there are no industry-wide performance standards for the desalination and water purification technologies discussed in the Roadmap. In addition, no single, unbiased source of information exists regarding the performance of these technologies. This lack of independent performance testing contributes to the slow adoption of these technologies. Without solid, unbiased performance data, fiscally conservative and often risk-averse public water agencies are hesitant to install desalination or water purification facilities.

FUTURE SCENARIOS

When setting a course for the future, it is helpful to evaluate alternative scenarios. In a Business-as-Usual scenario, the nation continues with limited public sector support of desalination technology research and development (R&D) and the current level of investment in private sector research programs. An alternative scenario, the Renewed-National-Commitment scenario, calls for an increased commitment to water supply R&D and the development of revolutionary water purification and desalination processes.

Both scenarios ultimately result in the widespread installation (with public sector cost-sharing) of desalination and water purification technologies that are able to upgrade a variety of impaired waters and thus ensure a safe, sustainable, and affordable water supply. The difference lies in the time until that point is reached, and what happens in the meantime.

The greatest disadvantage of the Business-as-Usual scenario is the cost of installing and using the currently available technologies. The cost of treating impaired water with these technologies is several times higher than that of conventionally treated fresh water. Communities with diminishing fresh-water supplies face either the high cost of importing water, or expensive desalination treatment (see "Desalination Coalition Formed"). With R&D supported only at its current low levels (see "R&D Investments"), efficient and economical next-generation desalination and water purification technologies will not become available for at least four decades, if ever.

Under the Renewed-National-Commitment scenario, wherein the research and development activities proposed in the Roadmap are completed, the timeline on which these revolutionary technologies become available will be accelerated by perhaps two decades. Concurrently, such public sector support will result in faster improvements to existing desalination and water purification technologies, resulting in cheaper and more effective technologies becoming available in perhaps as little as a

Continued on next page.

Desalination Coalition Formed

Water supply agencies in Southern California, Texas, and Florida have formed a desalination coalition for the purpose of mutually pursuing federal funding to offset the construction and operation costs of desalination facilities. The coalition will promote a coordinated strategy with the goal to make seawater desalination cost competitive.

Southern California water agencies supply water to roughly half of the population of California. Even though California has the fifth largest economy in the world, Southern California is unable to afford water purification and desalination plants without public sector funding to offset some portion of the up-front capital cost. If the economic powerhouse that is Southern California can't afford current-generation technologies without assistance, then smaller communities across the nation have even less of an opportunity to employ needed desalination technologies.

R&D Investments as a Percentage of Sales

At present, it is estimated that the U.S. water purification industry invests an estimated $5 million to $10 million annually in desalination research and development – less than one percent of sales. When compared with other industries – such as the semiconductor industry, which invests nine percent of sales in R&D, it becomes obvious that U.S. firms that build desalination and water purification plants conduct very little basic or applied research and development.

R&D and its Impact on Federal Cost-Sharing

Federal cost-sharing of water infrastructure projects has been an historical fixture. Today's water planners continue this trend as they seek federal dollars to offset some of the installation costs for desalination and water purification plants. Projections suggest that one billion dollars will be spent domestically on these plants in the coming years. Assuming a conservative 10 percent federal cost share for these projects, the United States is facing a $100 million cost-share bill.

Dedicating even one-tenth of this amount to advance the state of the art in desalination and water purification technologies offers the nation the chance to reduce its cost-share bill; as these technologies become cheaper and more efficient, fewer cost-share dollars will need to be doled out.

decade. While the Renewed-National-Commitment scenario will not eliminate the need for public sector cost-sharing of desalination and purification plants, it will likely reduce the amount of cost-share money required over time as cheaper technologies become available more rapidly. (See "R&D and its Impact on Federal Cost-Sharing," previuos page)

NEXT STEPS

Water – where it is found, who owns it, how and for what it is used – presents a web of complex issues. Technological development must be conducted in context – technologists must consider where their technology will be used, under what conditions, with what constraints, and by whom. The context is defined by components of the roadmapping process (illustrated below), which consists of the following complementary activities:

From the Desalination and Water Purification Technology Roadmap, U.S. Bureau of Reclamation, 2003.

- **Create new technology**. Deciding which research proposals to fund when many are presented is a daunting task. Historically, much of the decision has been qualitative – a reviewer's opinion of the principal investigator or the "interestingness" of the proposal. Such qualitative analyses are inappropriate when judging focused, targeted research projects. Thus, a comprehensive framework must be developed so that research projects are selected based on their ability to meet, or contribute to meeting, the metrics of the Roadmap.
- **Characterize the resource**. Mapping and characterizing saline aquifers is an important part of the process to improve water availability for the nation. It is essential to know the size, delineation, and quality of our national water resources.
- **Address implementation issues**. Greater attention should be paid to issues found in areas where the need for desalination is acute. The complexity of these issues in terms of environmental, ecological, economic, regulatory, ownership, and other concerns demands a focused approach to identifying the core issues and developing a framework within which interested parties can work to resolve them.
- **Commercialize and implement**. Freeing the road of deployment and implementation issues will not alone cause the widespread adoption of desalination technologies. The barriers found within the industry itself and within the public will have to be mitigated or removed. Educating the public regarding the safety of desalinated water and the benefits that it provides will be important to smoothing the path for deployment. Working with the industry to develop incentives for early adoption of new technologies will speed their introduction to the marketplace. Developing independent testing facilities and creating comprehensive cost-modeling software

tools will also serve to mitigate barriers to commercialization.

- **Collaborate at the global scale**. The world-wide deployment of desalination technologies can be an important component in enhancing national as well as international security.

The complete Roadmap is available at www.usbr.gov/water/content/roadmapreport.pdf
Contact Tom Hinkebein at tehinke@sandia.gov

Yuma Desalination, continued from page 21

pretreatment process. This waste, about 325 tons per day, is planned to be disposed of in drying ponds constructed on the Yuma Mesa near the Mexican border. Each pond covers one to two acres and is 13 feet deep. This sludge disposal area is sufficient for more than 50 years of plant operations. As ponds are filled and dried, they will be covered with soil to blend into the desert landscape. The buried sludge eventually will become a limestone-like deposit.

The future of the Yuma Desalting Plant and the solution for water supply and quality along the Colorado River are still unknown. With so many stakeholders and potential operational effects to take into account, it will be a considerable challenge to identify an operating scenario that would be satisfactory to all. However, as drought conditions continue in the Southwest, it seems likely that operation of the Yuma Desalting Plant will be seriously considered.

Contact Edward Lohman at edwlohman@cs.com

Water Systems Council Initiates Wellcare Hotline

For years, the U.S. Environmental Protection Agency has operated a Safe Drinking Water Hotline to answer questions from public water system users and others. Now the Water Systems Council has created Wellcare®, a hotline strictly for those with questions about wells or well water. Water Systems Council is the only national organization focused solely on individual wells and well-based systems not regulated under the Safe Drinking Water Act. The Safe Drinking Water Hotline receives as many as 300 calls per month related to private wells, and will now refer these calls to the Wellcare hotline. Contact the hotline at 1-888-395-1033.

Visit: www.wellcarehotline.org; www.watersystemscouncil.org

AWWARF Approves $12 Million for Research

In January, the American Water Works Association Research Foundation (AWWARF) Board of Trustees approved $7.78 million, with an additional $5 million in Congressional funding, to sponsor 30 solicited research projects related to the drinking-water community.

These projects will be procured competitively via a Request for Proposal (RFP) process. They are listed according to four strategic goal areas: efficient and customer-responsive organization, environmental leadership, high-quality water, and infrastructure reliability. Within each category, between five and nine RFPs are listed.

Proposals must be postmarked by either May 5 or July 15, as specified in each RFP. All projects require a minimum of 25 percent of the total project budget to be contributed by the contractor, either in direct funding or as in-kind matching of such items as personnel costs, analytical and support services, facilities, and consulting services. AWWARF is especially interested in receiving proposals that include both participation and contribution of resources from water utilities in the research effort.

The AWWARF is a non-profit organization dedicated to advancing the science of drinking water.

RFPs are available at www.awwarf.com/newprojects/2003paras.htm

Arizona Hydrological Society Plans 16th Annual Symposium

The Arizona Hydrological Society (AHS) announces its 16th Annual Symposium to be held Sept. 17-20, 2003 at the Mesa Centennial Center near Phoenix. This year's theme is "Sustainability Issues of Arizona's Regional Watersheds." For information on exhibitor space or sponsorship for the symposium, contact Dave Christiana at dchristiana@cox.net. Contact Pete Kroopnick at PKroopnick@brwncald.com for information regarding the technical program. AHS is also holsting its Biennial Symposium on Groundwater Recharge on June 5-7.

Visit www.azhydrosoc.org for current symposium information.

NGWA Meeting Focuses on Southwest Issues

The National Ground Water Association held the Southwest FOCUS conference in Phoenix, Feb. 19-21. Attended by approximately 125 people, the meeting featured speakers from Arizona, California, Colorado, Nevada, New Mexico and Texas, who addressed primarily issues of water supply and emerging contaminants. Dr. Herman Bouwer, of the U.S. Water Conservation Laboratory and a member of the advisory board for this conference, was awarded an NGWA Award for Outstanding Achievement for his contributions to the advancement of hydrology. A field trip prior to the meeting toured a TCE-contaminated groundwater remediation project site and the Granite Reef Underground Storage Project. The conference offered a rare opportunity for attendees from across the Southwest to meet, collaborate, and learn about issues, approaches, and results common to the semi-arid region.

Visit www.ngwa.org

Nevada Water Resources Association Holds Annual Conference

The Nevada Water Resources Association (NWRA) met Feb. 26-28 in Sparks for its annual meeting, which focused on the issue of growth versus supply. In addition to sessions concentrating on the theme, sessions on hydrologic research, water contamination and treatment, water quality investigation and technology, conservation, and groundwater contamination were offered. Many of the sessions featured a panel format, and conference organizers brought together speakers with diverse perspectives, resulting in lively discussions. The focus on growth versus supply was addressed by several eloquent speakers from the legal and economic arenas, as well as by hydrologists and water managers from urban and rural Nevada.

Approximately 175 people attended the conference, and helped to raise about $3000 for NWRA scholarships through an auction. In addition, Mr. William Nisbet was awarded the NWRA Lifetime Achievement Award for his dedication, exceptional support, and participation for more than two decades to NWRA. He has been a consultant for 35 years with his company, Chilton Engineering, in Elko.

Visit www.nvwra.org for more information.

Land Subsidence, continued from page 6

two areas of subsidence have been observed within the city limits and a third has been noted 13 km to the south. Maximum subsidence rates in Tucson are 2-3 cm/yr.

The interferograms generated thus far are being used as an integral part of several on-going studies that address the impact of subsidence on Phoenix-area infrastructure and water resources. Two of the subsidence features impact flood retention structures managed by the Maricopa County Flood Control District. The Central Arizona Project canal crosses through multiple features in northeast Phoenix (see figure, page 6). In addition, an interferogram was recently used to predict where fissures, or earth cracks, would likely occur. Subsequently, one previously undocumented fissure (see figure) has been found and is now being monitored.

The utility of InSAR measurements has been demonstrated for the Phoenix and Tucson metropolitan areas. With the support of NASA, ADWR plans to implement an ongoing InSAR monitoring program to generate reliable, routine, and affordable land subsidence measurements for the purpose of water resource management within Arizona.

Contact Maurice Tatlow at matatlow@adwr.state.az.us for more information.
See related article, page 29.

Tree Rings, continued from page 7

The study could help predict future droughts and their consequences for the Southwest. “Since climate on these time scales is obviously not cyclical, the next best hope for long-term drought prediction lies with identifying precursor states in oceanic climate, similar in fact to the way we use Tropical Atmosphere Ocean moorings to predict and monitor El Niño or La Niña,” said Betancourt.

Information on the relationship between sea surface temperature and North American climate could eventually be used to help guide more effective and long-term water management. For example, the current megadrought is playing a major role in resetting plant demographic clocks across the Rockies through wildfires, insect outbreaks, and tree mortality from physiological stress. Given the longer growing season associated with global warming, the species present in the region now would be more likely to be replaced by other native and non-native species, producing long-term vegetation changes.

The full publication is titled “Patterns and sources of multidecadal oscillations in drought-sensitive tree-ring records from the central and southern Rocky Mountains,” by Steve Gray at the University of Wyoming, Julio Betancourt of the U.S. Geological Survey, Chris Fastie of Middlebury College and Steve Jackson of the University of Wyoming. Contacts: Julio Betancourt, 520-670-6821, ext. 107, jlbetanc@usgs.gov; Steve Gray, 307-766-6377, sgray@uwyo.edu

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UV-Oxidation, continued from page 8

For several years, a treatment train consisting of granular activated carbon and air stripping was used at Stockton to remove VOCs. However, it was discovered that these systems were not effectively removing 1,4-dioxane. Its low affinity for carbon renders the carbon ineffective and its low vapor pressure and high solubility prevent significant partitioning into the vapor phase in an air stripping system. To remedy the problem, UV-oxidation using UV light and hydrogen peroxide (H_2O_2), was chosen to destroy the 1,4-dioxane. This process relies on the in-situ generation of highly oxidative hydroxyl radicals by way of the UV-photolysis of H_2O_2. In full-scale UV-oxidation, H_2O_2 is injected into the water stream prior to passing through the UV reactor. This technology, provided by Trojan Technologies, has been used in Stockton for more than 18 months, and has successfully reduced the concentrations of 1,4-dioxane from nearly 110 ppb to less than 1.0 ppb.

For more information about 1,4-dioxane, including treatment by Trojan’s UV-oxidation systems, contact Adam Festger, Technical Communications Coordinator for Environmental Contaminant Treatment at Trojan Technologies, afestger@trojanuv.com, 520-297-3637.

The Trojan UV-oxidation system at Stockton.

Modeling Tip: Modeling Outcropping or Pinching Layers in Visual MODFLOW

Reprinted with permission from Waterloo Hydrogeologic Inc.'s E-News, February 2003

MODFLOW is a three-dimensional groundwater flow model originally developed by the U.S. Geological Survey. The model is based on a finite difference formulation of the groundwater flow equation requiring all model layers to be continuous across the entire model domain. Each layer is required to have a finite layer thickness in order to assure conservation of mass and, hence, the stability and accuracy of the solution. As such, geologic layer pinchouts or outcropping of geologic units at the surface cannot be explicitly represented using a finite difference grid. However, two different approaches can be used to get around this problem:

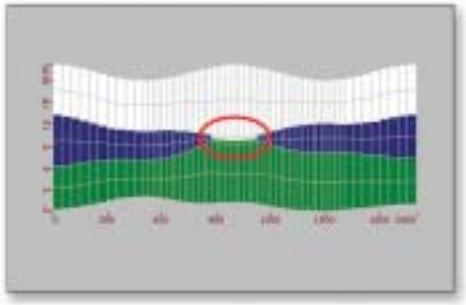

Figure 1: Deformed Grid Approach

(1) Deformed Grid Approach: Geologic layer surface elevations are imported to the model layer surfaces in order for the shape of the model grid to represent the shape of the geologic units. In places where the geologic units pinch out, the model layers are pinched down to a very small thickness. Visual MODFLOW allows the user to specify a minimum layer thickness when importing surface elevations for each model layer. Once the model layer surfaces are imported, the user can simulate the pinchout by assigning appropriate property values to the cells in the pinchout section (see Figure 1).

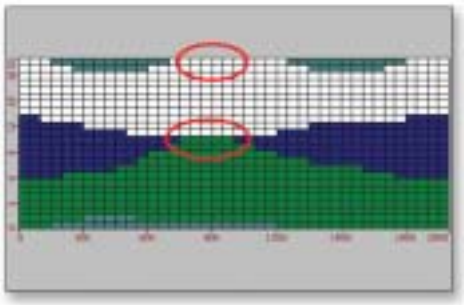

Figure 2: Fixed Grid Approach

(2) Fixed Grid Approach: The finite difference grid consists of uniformly flat horizontal layers. The grid cell property values are assigned as needed in order to represent the shape of the geologic units. This approach fully respects the finite difference assumptions and will result in a more stable solution than the previous approach,.however, it is much more difficult to design and modify and is not as attractive for presentation purposes (see Figure 2).

Visit www.flowpath.com

USGS Releases New Software for Estimating Flood Flows

In February, the U.S. Geological Survey (USGS) announced the release of new software that allows users to estimate flood flows for streams throughout the United States. The new software, Version 3 of the National Flood Frequency (NFF) Program, provides estimates of flood flows having recurrence intervals of two years to 500 years for user-selected sites on rural and urban streams.

The NFF software compiles more than 2,000 flood-flow equations developed by the USGS for 289 regions of the nation into a single, user-friendly package. The equations relate the flood flows to physical and climatic characteristics, such as the land area that drains to the site of interest and the mean annual precipitation for the area. Users can enter the characteristics into NFF to obtain flood-flow estimates for their

sites of interest. Different regions require different characteristics as input for solving the equations. The estimates are provided onscreen as tables or as plots, and users can save the output to files on their computers.

"This new software has been anxiously awaited by federal, state, and local government agencies, and by the engineering and consulting communities," said Kernell Ries, a USGS hydrologist who compiled the report that documents the software. "The estimates provided by NFF are often used as a basis for determining flood-plain areas on the Federal Emergency Management Agency's flood insurance rate maps, and by other agencies for making planning and management decisions. In addition, the estimates are used to design bridges, culverts, and flood-control structures."

A previous version of the software was released in 1994, and since then, new equations have been developed for more than 30 states. The report, titled "The National Flood Frequency Program, Version 3: A Computer Program for Estimating Magnitude and Frequency of Floods for Ungaged Sites," compiled by K.G. Ries III, and M.Y. Crouse, has been released as U.S. Geological Survey Water Resources Investigations Report 02-4168. Digital copies of the report and the software can be downloaded from the NFF Web page, http://water.usgs.gov/software/nff.html. The Web site also contains links to documentation to assist users in solving the equations for each state. Paper copies of the report, which include a CD-ROM of the software, can be purchased at U.S. Geological Survey, Information Services, Box 25286, Denver, CO 80225-0286, telephone: (303) 202-4700. The NFF software runs only on computers with Windows operating systems.

Satellites Reveal Ground Subsidence from Water-Level Declines in Parts of Mojave Desert

The earth has subsided as much as four inches in parts of the Mojave Desert in Southern California, according to U.S. Geological Survey (USGS) scientists. Using the satellite-mapping process known as "interferometric synthetic aperture radar" (InSAR) (see related article on page 8), scientists have detected large earth-surface depressions near the agricultural areas of Lucerne Valley, El Mirage, Lockhart, and Newberry Springs in the southwestern portion of the Mojave Desert. The subsidence occurred between 1992 and 1999 and is linked to declining water levels.

"The magnitude of subsidence in some of the areas is significant," said Michelle Sneed, USGS scientist and lead author of the study, "The compaction of the aquifer systems in these areas may be permanent."

The USGS study, in cooperation with the Mojave Water Agency, found that land subsidence was linked to water-level declines of more than 100 feet between the 1950s and the 1990s. Land subsidence can disrupt surface drainage; reduce aquifer storage; cause earth fissures; and damage wells, buildings, roads, and utility infrastructure. "Earth fissures several feet wide and deep have been observed in Lucerne Valley," Sneed said. The USGS reports that continued monitoring of some areas of the Mojave Desert is warranted because groundwater levels continue to decline, and pumping-induced land subsidence, documented by this study, likely will increase.

The U.S. Geological Survey report, "Detection and Measurement of Land Subsidence Using Interferometric Synthetic Aperture Radar and Global Positioning System, San Bernardino County, Mojave Desert, California" by Michelle Sneed, Marti E. Ikehara, S.V. Stork, Falk Amelung, and D.L. Galloway, can be found at: water.usgs.gov/pubs/wri/wri034015/.

Solar Energy Leader Initiative to Further Solar Use in Water Management

International Center for Water Technology, California State University, Fresno

On March 27, The International Center for Water Technology (ICWT), based at California State University, Fresno, announced it signed a memorandum of understanding with solar energy industry leader World Water Corporation. This step was taken to further ICWT's partnership with industry and to encourage widespread adoption of water and energy technology that is economically and environmentally beneficial.

The New Jersey-based World Water Corporation is a solar energy company that develops and installs water and irrigation pumping equipment utilizing new technology. The company recently dedicated a proprietary state-of-the-art, 50-horsepower, solar-irrigation pump system – the only one of its size in the world – at the Mendota, Calif.-based D.T. Locke Ranch.

The ICWT will launch a major Solar Initiative during Summer 2003 to encourage farmers, water districts and other agricultural water users to utilize solar energy to pump a significant amount of their annual irrigation water during peak electrical usage periods. The new technology provided by World Water and high efficiency arrays by other firms will enable an evolutionary shift in renewable energy sources for agricultural water pumping.

With the new Solar Initiative, ICWT hopes to accomplish the following goals:

1. Reduce and/or shift peak water pumping energy demands.
2. Promote small-scale distributed generation in agricultural areas of utility grids that are transmission-constrained.
3. Promote renewable energy as an alternative to energy sources that have a significant negative impact on the environment.
4. Educate farmers and water purveyors about programs and incentive rebates that produce a favorable economic climate for the adoption of solar-power, water-pumping systems.
5. Encourage and investigate the use of water and irrigation technology that is energy-efficient.
6. Provide for a more informed decision-making process for farmers and water purveyors to reduce overall water and energy consumption, wherever possible.

Visit www.icwt.net

Six from Southwest Among the Newly Elected to National Academy of Engineers

The National Academy of Engineering (NAE) recently announced the election of 77 new nationwide members and nine foreign associates. Election to the NAE is among the highest professional distinctions an engineer can achieve. Academy membership honors those with significant contributions to the field of engineering through their practices, literature and new advancements.

There are currently 2,138 U.S. members of NAE and 165 foreign associates. Among the newly elected, those from the Southwest who perform water-related research include:

Glen T. Daigger, Senior Vice President and Technology Director, CH2M Hill Inc., Greenwood Village, Colo. For combining the theory and practice of wastewater-nutrient control and for improving the practice of environmental engineering worldwide.

Christine A. Ehlig-Economides, Global Account Manager and Consultant, Schlumberger Oilfield Services, Houston. For contributions to the testing of wells and the characterization of reservoirs, including the management, integration, and visualization of data from multiple disciplines.

Charles V. Jakowatz Jr., Manager, Signal Processing and Research Department, Sandia National Laboratories, Albuquerque, N.M. For innovations in synthetic-aperture radar-image processing critical to military applications and environmental monitoring.

Roy E. Olson, L.P. Gilvin Centennial Professor, Civil Engineering Department, University of Texas, Austin. For furthering our understanding of the properties of clays and for contributions to geotechnical engineering design.

Soroosh Sorooshian, Regents' Professor of Hydrology and Water Resources and Director of the NSF Science and Technology Center at the University of Arizona in Tucson. For the development of flood-forecasting models used worldwide in hydrologic services.

Harold J. Vinegar, Senior Research Consultant, Shell International Exploration and Production Inc., Houston. For the invention and development of well logging, core analysis, and thermal methods of oil exploration and production and for environmental remediation.

Visit www.nae.edu

Shlomo P. Neuman Receives 2003 Horton Medal

University of Arizona Regents' Professor of Hydrology and Water Resources Shlomo P. Neuman has been named the 2003 Robert E. Horton Medalist by the American Geophysical Union (AGU). The award recognizes outstanding contributions to the geophysical aspects of hydrology. It was established in 1974 in honor of Horton's contributions to the study of the hydrologic cycle. He is considered the father of modern hydrology.

Neuman's fields of specialization are subsurface hydrology and contaminant transport. He has made seminal contributions to the areas of pumping test design and analysis, flow in multilayered geologic media, finite element simulation of subsurface flow and transport, estimation of aquifer parameters, fractured rock hydrology, peat hydrology, geostatistics, and stochastic analysis of heterogeneous geologic media. He is a member of the U.S. National Academy of Engineering, and a fellow of the American Geophysical Union and the Geological Society of America. He is a former associate editor of Water Resources Research and a member of the editorial board of Stochastic Hydrology and Hydraulics.

Visit www.agu.org and www.hwr.arizona.edu.

California Water Service Group Names New VP, CFO, and Treasurer

On Feb. 26, the California Water Service Group Board of Directors appointed Richard D. Nye as Vice President, Chief Financial Officer and Treasurer, effective March 1, 2003. He will succeed Gerald F. Feeney, who is retiring.

Nye began his career in finance at Texas Instruments, Inc. working in the Consumer Products and Geophysical Services Groups. He subsequently held management positions at Halliburton Company and Frito-Lay, Inc. Prior to joining California Water Service Group, he served as Vice President of Finance and Administration and Acting Chief Financial Officer at Cornerstone Propane Partners, L.P.

California Water Service Group is the parent company of California Water Service Company, Washington Water Service Company, New Mexico Water Service Company, and CWS Utility Services. The subsidiaries provide regulated and non-regulated water service to more than two million people in 98 communities.

Visit www.calwater.com.

Simunek, Burkstaller Join DBS&A

Daniel B. Stephens & Associates, Inc. (DBS&A) announced on Feb. 3 the addition of Jirka Simunek, Ph.D. and John Burkstaller to the firm. Simunek joined the firm as a Soil Scientist to enhance DBS&A's capabilities in the numerical modeling of chemical and transport processes. Dr. Simunek has particular expertise modeling variably saturated porous media using the HYDRUS code.

Mr. Burkstaller joined DBS&A as Vice President of the firm's Water Resources Division. Mr. Burkstaller has experience with water and wastewater treatment

systems, water supply planning, water quality, and water rights issues. Most recently, he served as Chief Technical Officer for El Paso Water Utilities, managing planning, engineering, developer services, and project administration for the El Paso-area water and wastewater utility.
Visit www.dbstephens.com.

Merger in *Southwest Hydrology*

The publishing and scientific communities were abuzz in late March as two of the foremost powers in the industry combined forces. Betsy Woodhouse, hydrologist and publisher of *Southwest Hydrology* magazine, and Howard Grahn, CFO of *Southwest Hydrology*, and hydrologic consultant, joined forces in a private March 22 wedding at an undisclosed location in the Sonoran desert. Although the pair has worked in several cooperative projects in the past, this formal union is expected to set a high standard for both the scientific and publishing communities.

A spokesperson who asked to remain anonymous stated, “This merger is not unexpected by industry watchers, but it certainly raises the bar for all of us.” Others hailed the merger as “a much-needed move forward for science and information management.”

Glen Peterson Honored for Drinking-Water Quality Efforts

Glen D. Peterson, a director of the Metropolitan Water District of Southern California (Metropolitan), recently received the Public Health Appreciation Award by the California Department of Health Services in recognition of his efforts to improve drinking-water quality and public health.

The award citation says, in part, "For the past five years, Mr. Peterson championed the issue of fluoridation before the Metropolitan board and has become an outstanding advocate. The Metropolitan board recently voted to fluoridate [water treated at] the district’s five treatment plants. Because of Mr. Peterson’s commitment and dedication, fluoridated water will be a reality for almost 18 million residents of Southern California."

Metropolitan board Chairman Phillip J. Pace commented, "Glen has served with distinction on Metropolitan’s board for 10 years, and has always been a strong advocate of drinking-water quality. His support of fluoridation was one of the persuasive factors in our board’s action."

Under Peterson’s leadership as chairman of the Metropolitan board’s communications committee in 1999-2000, Metropolitan launched award-winning pilot consumer information programs about water quality.
Visit www.mwdh2o.com

Richard E. Greene New EPA Region 6 Administrator

Effective March 31, Richard E. Greene became the new regional administrator of the U.S. Environmental Protection Agency’s (EPA) Region 6, which covers Arkansas, Louisiana, New Mexico, Oklahoma, and Texas.

EPA Administrator Christie Whitman cited Greene’s experience in urban issues, new technology and scientific research, and creation of public/private partnerships in appointing him to the position.

Greene most recently served as the executive director of the Arlington Technology Incubator, a joint venture between the Arlington Chamber of Commerce and the University of Texas at Arlington, created to move products from the laboratory to the marketplace. He also helped secure $2.3 million for workforce development and planning the construction of a facility to house emerging young technology companies that conduct research in the fields of biotechnology and nanotechnology.
Visit www.epa.gov/region6/

James Turner Reappointed to MWD Board

James F. Turner of Oceanside, Calif. was recently reappointed to the Metropolitan Water District of Southern California’s (Metropolitan) Board of Directors. One of four representatives of San Diego County Water Authority, he will serve on Metropolitan’s engineering and operations committee; the budget, finance, and investment committee; and the desalination subcommittee.

Turner replaced Harold W. Ball, who retired from Metropolitan’s board. Turner had previously served on the board from January 1999 through December 2000.

Metropolitan Water District of Southern California is a cooperative of 26 cities and water agencies servicing 18 million people in six counties. The district imports water from the Colorado River and Northern California to supplement local supplies.
Visit www.mwdh20.com

Business Directory

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GEO-SPATIAL ANALYST/RESEARCH ASSISTANT

Process, analyze spatial datasets using GIS, image processing tools; ERDAS Imagine; ArcIMS, ArcView, ArcInfo. Design, implement remote sensing, GIS projects in hydrology, public health, agronomic modeling, related applications. Create visual products from GIS data using 3-D views. Acquire, update, maintain GIS vector/raster databases as required. Must have Master's in Earth Sci., Geography, Engineering or equivalent, one year exp.; including one year exp. in hydrology, public health, agronomic modeling or related applications. Must have knowledge of ERDAS Imagine, ENVI, ESRI products; ArcIMS, ArcView w/ spatial, 3-D analyst, ArcInfo, ArcSDE. Must have theoretical knowledge of remote sensing image processing, GIS concepts, map server systems. Send resume w/ cover ltr to Univ. of North Dakota, Attn: Gary Johnson, Box 9007, Grand Forks, ND 58202. AA/EOE

SENIOR ENGINEER

Geomatrix Consultants has an opening for a senior level engineer in Phoenix. Requires Arizona registered PE with 15-20 years experience; work in multidisciplinary teams on civil, water, wastewater, and environmental projects. For additional requirements, position description, and application information, visit www.geomatrix.com under Careers—Phoenix. EOE.

Southwest Hydrology offes one column inch of ad space without charge for job openings

HYDROGEOLOGIST:

HydroSystems, Inc. (HSI) has an opening for a mid-level hydrogeologist. HSI, a Tempe, AZ-based consulting firm is searching for a team-oriented professional hydrogeologist with 3-5 years experience. The successful candidate will be a person who excels in a team environment of continuous improvement of technical and professional skills in both office and field applications. The position requires expertise in drilling oversight, soil sampling and geophysical log interpretation, structural geology, and marketing, budgeting, reporting, and permitting. Dependent on experience and education, HSI offers competitive compensation, and benefit package. Consulting experience and professional registration are desirable. For immediate consideration fax resume to MM at 480-517-9049.

SENIOR HYDROGEOLOGIST:

Environmental consulting firm is seeking a Senior Hydrogeologist to work on all aspects of ground water related projects. Experience in surface and ground water flow and fate and transport modeling is required. Candidates should have consulting experience and strong communication and writing skills. California registration is desirable. The successful candidate will work in a well established, dynamic firm on projects including water resources, contamination issues, and client contact.

Send your resume including a list of 3 references to: TEAM Engineering & Management, Inc., PO Box 1265, Bishop, CA 93515 or email to mail@teambishop.com.

Hydrolab Joins Hach

From article originally appearing on Water Tech Online, March 11, 2003

Hydrolab Corp., a water quality monitoring company, has joined the Hach family of companies, officials announced in a March 2003 news release. Hydrolab's sensors monitor water quality in marine environments around the world.

In addition to probes, Hydrolab manufactures portable and lightweight data displays for use in the field.

The company's broad customer base includes universities, environmental groups, and governmental agencies devoted to protecting water quality.

Hach provides advanced analytical systems and technical support for water quality testing, with solutions for lab, process and field.

For complete article, visit www.watertechonline.com. Also visit www.hydrolab.com.

INTERA Wins EBJ Achievement Award

The Environmental Business Journal (EBJ) recently announced its annual EBJ Business Achievement Awards for small, medium, and large firms. Among small firms (less than $20 million), INTERA was awarded an honorable mention for "its management- and employee-funded buyback from Duke Engineering and its first-year performance of $11 million in revenue and EBIT of 20 percent," according to EBJ. The EBJ awarded gold, silver, and bronze medals to firms in each category, and INTERA was one of only five companies to receive an honorable mention for 2002. The EBJ solicits the industry for nominations via email, Web site, and word of mouth, and awards are determined by an internal committee and selected advisory board members. INTERA is a Texas corporation with offices in New Mexico and Colorado as well.

Visit www.intera.com.

R.W. Beck Acquires Texas Consulting Firm

Management consulting and engineering firm R.W. Beck, Inc. announced in March that it has acquired water, wastewater, stormwater, electric, gas and solid waste consulting firm Reed, Stowe & Yanke, LLC (RS&Y) of Austin, Texas.

Effective March 1, RS&Y, a 12-person firm with a reported $1.5 million in billings for 2002, became known as a division of R. W. Beck, a 61-year-old firm based in Seattle. Founded in 1942, R.W. Beck is a management consulting and engineering firm with offices nationwide that provide services to the public and private sectors in the areas of energy, water resources, solid waste, and telecommunications.

Visit www.rwbeck.com

Ground Water Monitoring Offers Monitoring Solutions and More

Ground Water Monitoring LLC (GWM) was established in 2001 to provide alternative solutions in groundwater monitoring services. It currently operates in New Mexico and Colorado. The recently incorporated company is a partnership of retired and former U.S. Geological Survey Water Resources Division (USGS-WRD) employees.

GWM provides groundwater monitoring services, data storage and retrieval, and Geographical Information Systems (GIS)-based data presentation services to federal, state, and local governments, and to the private sector. The company also offers well scheduling, network monitoring, water-level measurements, and sampling. GWM can assist in the design, coordination, and application of new monitoring networks, and in the upgrade and modification of existing monitoring networks. By combining technical and practical experience, the company aspires to bring to its clients achievable, long-term economic value for their investments.

GWM President Edward D. Villanueva has 19 years of experience with USGS-WRD and 18 years in the private sector, working on both the national and international levels. In addition to his technical expertise, Villanueva has extensive experience in business management and human resources development.

Contact information: (877) 313-8445 or GWM30@msn.com

Haestad Methods Introduces GISTalk™

On March 10, Haestad Methods, a provider of Geographic Information Systems (GIS)-based hydraulic modeling solutions, launched its latest on-line discussion group, GISTalk, accessible at www.haestad.com/forums. This free on-line forum provides a place for GIS professionals to ask questions and raise issues regarding geographic and geospatial information systems and receive feedback from colleagues and Haestad Methods' GIS experts.

Professionals interested in joining GISTalk can subscribe by visiting www.haestad.com/lists or by e-mailing GISTalk-subscribe@lists.mycivil.com.

DBS&A Senior Scientist Granted U.S. Patent For Water Run-Off Siphon

Daniel B. Stephens & Associates, Inc. (DBS&A) of Albuquerque announced in March that James Kelsey, Senior Scientist with DBS&A, has been co-awarded a patent for the development of a drainage system that enhances water quality, recharges groundwater, and controls erosion. According to U.S. patent No. 6,467,994, this invention provides an "apparatus and method for beneficial use or handling of run-off or collected water."

The system diverts storm water into a subsurface infiltration trench to seep slowly into the soil. A unique design feature makes the trench self-cleaning and prevents clogging of the system.

Siphoning trenches inexpensively allows for:

- Removing viruses, pesticides, or other compounds.
- Increasing groundwater recharge.
- Promoting plant growth to reduce erosion.

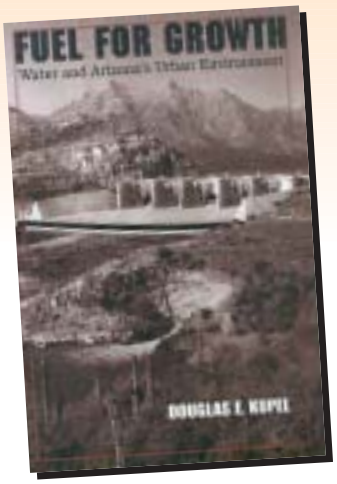
According to the U.S. Environmental Protection Agency, the first one-half inch of rainwater, called first flush, washes chemicals such as oil, gas and antifreeze from pavement. If the first flush is diverted to the subsurface instead of flowing down an arroyo directly to rivers and streams, as the newly patented system is designed to accomplish, most of the chemical contaminants, including viruses and other compounds, will be consumed by microbes in the soil. Furthermore, channeling runoff water into the ground also reduces evaporation, increasing groundwater recharge. Finally, the new drainage system, by directing storm water underground, is also expected to prevent earth and vegetation on the surface from flooding and washing away, thereby reducing erosion.

Contact Mr. James Kelsey at jkelsey@dbstephens.com or (505) 822-9400.

Fuel for Growth: Water and Arizona's Urban Environment

by Douglas E. Kupel. University of Arizona Press. Tucson AZ.
294 pages. $39.95.

Reviewed by Barbara Tellman



In Fuel for Growth: Water and Arizona's Urban Environment, Douglas E. Kupel weaves the history of water infrastructure in Arizona into the general context of Arizona history, using Tucson, Phoenix, and Flagstaff as case studies. He shows how the history of water development in each of the three cities differs because of their different environments and physical circumstances. Kupel challenges some widely held beliefs about how and why water development in the West happened and stresses the significant roles of municipal population growth and increased water demand.

The book is divided into chapters by era, with developments in each of the three cities discussed in every chapter, emphasizing municipal and quasi-municipal providers. It begins with a discussion of water infrastructure in prehistoric times followed by a discussion of the Spanish period. Kupel relates the development of Arizona water law and political issues to the necessity of providing a water supply. In addition to describing infrastructure such as dams and wells, Kupel discusses economic aspects, such as the transition from private ownership to municipal ownership of much of the infrastructure of water supply systems in Tucson. In his chapter on the Depression Era, for example, he discusses the financial impacts of the time as they relate to lower demands for water and reduced funds for construction. In Phoenix, he relates, the Depression began after a general failure of older redwood pipelines that needed replacement. Kupel says, "Faced with an ample water supply and a stagnant economy, Phoenix officials looked for ways to market the resource to keep revenues flowing into the general fund and pay off the debt incurred by the construction of the pipeline" (p. 112). This may partially help to explain the difference in water-use ethics over the years in Phoenix and in Tucson. Other chapters include discussions of the post-war boom period, the Central Arizona Project (including Tucson's CAP fiasco), Indian water rights, and many other topics, in historic context.

This book is well-researched and thorough, but not intimidating to the general reader. Kupel has done an admirable job of condensing a large amount of information into a readable volume. Matters that Kupel discusses only marginally and that should be the subject of other works are:

- •. Water quality and the development of wastewater infrastructure in the cities.
- The role of non-municipal water providers in regional water management or lack thereof.
- The impacts of urban water infrastructure on the environment, such as loss of surface flow in the Santa Cruz River and the Salt River.
- Provision of water and wastewater infrastructure in rural areas.

Twenty interesting historical photos nicely illustrate dam building, reservoirs, pipelines, wells, and urban growth. Nine maps provide geographic context. An extensive reference section cites source material, including consultant reports, newspaper articles, official documents, and books.

This is an excellent contribution to a much-neglected field – the role of infrastructure in shaping history and how historical events, in turn, shape infrastructure. While water politics are sometimes included in histories of Arizona or of individual cities, infrastructure is usually taken for granted. This book is a fine start toward filling that gap.

Visit www.uapress.arizona.edu

Review of PetraSim

John E. McCray, Ph.D. *– International Ground Water Modeling Center*

PetraSim is an interactive pre-processor and post-processor for the TOUGH2, T2VOC, and TETRAD codes. PetraSim is the only fully integrated interface for TOUGH2 and T2VOC and the only modern interface for TETRAD. This review focuses on use of PetraSim for TOUGH2 and T2VOC, which simulate multiphase transport of fluids (gas, water, NAPLs) and heat in porous and fractured media. TOUGH2 and T2VOC have been used for more than a decade to simulate problems ranging from unsaturated zone transport and heat transfer at Yucca Mountain, geothermal-reservoir engineering, density-driven gas transport of VOCs, partitioning-tracer tests, and various remediation schemes (such as SVE, air sparging, pump and treat). The input for these codes is complex, and data entry is generally accomplished through text-based input files. While some firms have developed proprietary GUIs, they have not earned the broad support of the TOUGH2-user community. PetraSim, a product of Thunderhead Engineering, makes use of the TOUGH2 codes much easier. Users can construct and run a TOUGH2-T2VOC simulation and view the results entirely within PetraSim. PetraSim allows development of complex three-dimensional grids, boundary conditions, and initial conditions. Construction and assignment of wells for fluid or heat injection and extraction is also simple. The complex array of multiphase-fluid and heat-transport parameters is arranged in a remarkably intuitive manner. Output can be visualized in PetraSim without importing the output text files into an external graphics program. This software will likely result in increased use of the TOUGH2-T2VOC codes. A free demo version of PetraSim is available for a limited time at www.thunderheadeng.com/ where numerous example problems are also provided. The most recent version must be purchased, and includes integrated TOUGH2 and T2VOC solvers at no extra cost. Prices range from $500 for a single, one-month license to $5,000 for unlimited use. An educational package is also available for a reduced price.

Visit www.mines.edu/igwmc and www.thunderheadeng.com

MAY 2003

May 1-2 University of Arizona Water Resources Research Center. **Local Approaches to Resolving Water Resource Issues: What's Working, What Hasn't Worked, and Building on Existing Efforts**. Prescott, AZ. *ag.arizona.edu/AZWATER*

May 7-9 Association of California Water Agencies. **Spring Conference: "Financing Our Water Future: An Issue of Dollars and Sense."** South Lake Tahoe, CA. *www.acwanet.com*

May 8-9 CLE International. **Law of the Colorado River.** Phoenix, AZ. *www.cle.com*

May 9 **ABSTRACTS DUE!** American Water Resources Association. **2003 Annual National Meeting**. Nov. 3-6, San Diego, CA. *www.awra.org/meetings/California2003/*

May 12-15 U.S. Committee on Irrigation and Drainage. **Water for a Sustainable World—Limited Supplies and Expanding Demand**. Phoenix, AZ. *www.uscid.org/03conf.html*.

May 12-16 Government Institutes/ABS Consulting. **The Environmental Compliance Bootcamp**. Phoenix, AZ. *www.govinst.com*

May 15-16 CLE International. **Endangered Species Act**. San Diego, CA. *www.cle.com*

May 17 Groundwater Resources Association of California. **Aerial Photography Interpretation Workshop**. Sacramento, CA. *www.grac.org*

May 20-22 Government Institutes/ABS Consulting. **Chemistry for Non-Chemists**. Phoenix, AZ. *www.govinst.com*

JUNE 2003

June 5-7 Arizona Hydrological Society and others. **11th Biennial Symposium on Groundwater Recharge**. Tempe, AZ. Contact Jenny Bush at (602) 294-9600 or email dbartlett@clearcreekassociates.com

June 14-18 American Geophysical Union. **Chapman Conference on Ecosystem Interactions with Land Use Change**. Santa Fe, NM. *www.agu.org/meetings/*

June 17-19 Government Institutes/ABS Consulting. **U.S. Environmental Laws and Regulations Basics**. Albuquerque, NM. *www.govinst.com*

June 26-27 CLE International. **Law of the Colorado River.** Phoenix, AZ. *www.cle.com*

JULY 2003

July 1 **ABSTRACTS DUE!** New Mexico Water Resources Research Institute. **New Mexico Symposium on Hydrologic Modeling**. Aug. 12, Socorro, NM. *wrri.nmsu.edu/*

July 17-18 Government Institutes/ABS Consulting. **How to Audit Your Environmental Management System**. Las Vegas, NV. *www.govinst.com*

July 21-25 Government Institutes/ABS Consulting. **Environmental Compliance Bootcamp**. Colorado Springs, CO. *www.govinst.com*

AUGUST 2003

August 4-8 Government Institutes/ABS Consulting. **Federal Facility Environmental Compliance Bootcamp**. Houston, TX. *www.govinst.com*

August 7-8 CLE International. **Arizona Water Law**. Phoenix, AZ. *www.cle.com*

August 12 New Mexico Water Resources Research Institute. **New Mexico Symposium on Hydrologic Modeling**. Socorro, NM. *wrri.nmsu.edu/*

August 18-19 CLE International. **New Mexico Water Law**. Santa Fe, NM. *www.cle.com*

August 19-21 Government Institutes/ABS Consulting. **U.S. Environmental Laws and Regulations Basics**. Denver, CO. *www.govinst.com*

August 19-22 National Ground Water Association. **Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Assessment, and Remediation Conference and Exposition**. Costa Mesa, CA. *www.ngwa.org/education/*

August 21-22 CLE International. **Environmental Law on the Reservation**. Phoenix, AZ. *www.cle.com*

August 28 **ABSTRACTS DUE!** American Geophysical Union. **Annual Meeting**. Dec. 8-12, San Francisco, CA. *www.agu.org*

SEPTEMBER 2003

September 17-19 International Ground Water Modeling Center. **MODFLOW and More 2003: Understanding through Modeling**. Golden, CO. *www.mines.edu/research/igwmc/events/modflow2003/*

September 17-20 Arizona Hydrological Society. **16th Annual Symposium**. Mesa (Phoenix area), AZ. *www.azhydrosoc.org*

September 22-23 CLE International. **Western Water Law**. Denver, CO. *www.cle.com*

September 29-Oct 3 National Ground Water Association. **Natural Attenuation, Risk Assessment, and Risk-Based Corrective Action**. San Diego, CA. *www.ngwa.org/education*

OCTOBER 2003

October 5-8 Inland Northwest Research Alliance. **2003 Subsurface Science Symposium: Advances in Understanding and Modeling Subsurface Processes**. Salt Lake City, UT. *www.b-there.com/breg/inra/*

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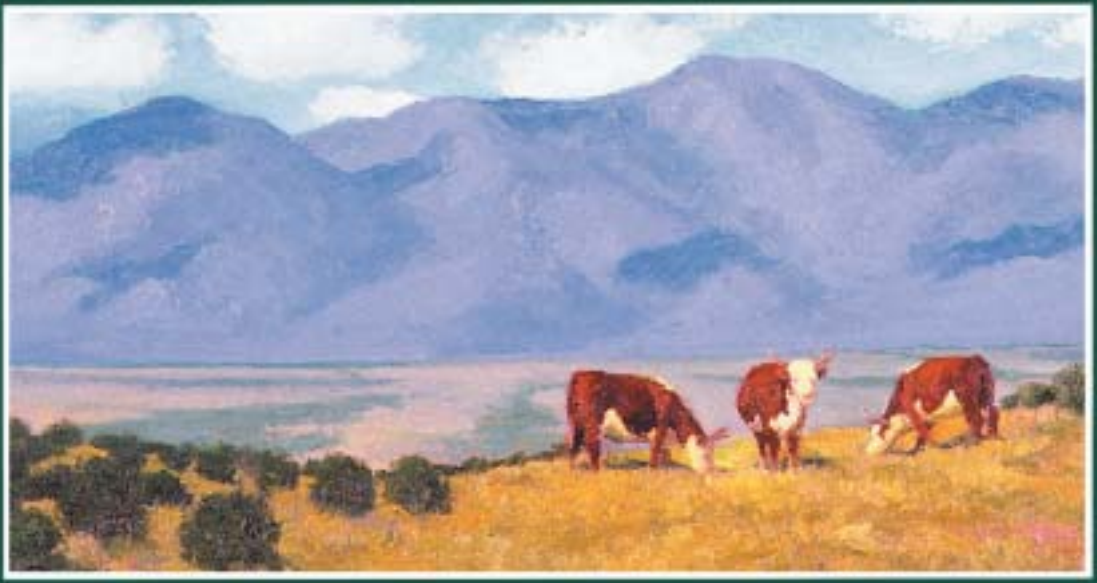

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