21st Century Irrigated Agriculture
The intention was always clear

We started out with a practical idea: to offer solutions in groundwater science based on our collective expertise — a blend of strong capabilities, project coordination skills, and extensive statewide experience; and to offer these solutions in an honest and straightforward manner — communicating, simply and clearly, with water purveyors, drilling contractors, laboratories, policymakers, regulators, water managers, lawyers and other stakeholders.

From there, we grew a company of professionals with multi-disciplinary expertise, and a reputation based on our track record and our way of doing business. And while we take this time to celebrate our first five years, and look forward to the challenges of the next five, our intention hasn’t aged one bit.
The USGS recently reported that agriculture accounts for 80 percent of the combined groundwater and surface water withdrawals in Arizona, California, Nevada, New Mexico, and Utah. In recognition of this substantial use, we look at trends and technologies in irrigated agriculture – covering about 14 million acres in these five states – to see how farmers are adapting to the pressures of drought, increased competition for water, concern for the environment, and urban growth. Farms provide us with a safe, domestic food supply and can act as a water supply buffer during droughts: points to consider as increasing amounts of farmland are converted to residential subdivisions.

The Southwest Hydrology Advisory Board recently celebrated its one-year anniversary and welcomed new members Mike Alter (Clear Creek Associates), David Bolin (Orange County Water District), Chuck Graf (Arizona Department of Water Quality), Karl Kohlhoff (HDR Engineering), Nabil Shafike (New Mexico Interstate Stream Commission), and Bob Turnbull (Roscoe Moss Company). Many thanks to departing members Peggy Barroll (New Mexico Engineering), Nabil Shafike (New Mexico Interstate Stream Commission), and Bob Turnbull (Arizona Water District), Chuck Graf (Arizona Department of Water Quality), Karl Kohlhoff (HDR Engineering), Nabil Shafike (New Mexico Interstate Stream Commission), and Mario Lluria (Salt River Project). All current members are listed at right.

If you’re looking for job or a new employee, be sure to visit the Jobs page on our Web site. It has become very active in recent months, and employers can directly post announcements of any length for no charge.

Finally, we thank all the contributors to this issue and the advertisers who sponsor it, and urge all of you to send us your news and ideas for future issues.

Betsy Woodhouse
Publisher
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21st Century Irrigated Agriculture

Agriculture accounts for the greatest single water use in the Southwest. Demands for water by growing urban areas, environmental and recreational interests, and industries, combined with many recent years of drought, create competition for water that is greater than ever. How are farmers coping? New technologies allow improved efficiency in irrigation and for moving water through irrigation districts, but salinity remains a growing problem. Higher-valued crops are being planted to offset increased water and monitoring costs. The ag-to-urban movement impacts not just our food supply, but also our water supply. Our feature articles discuss these and other aspects of agriculture in the 21st century.

Perspectives of a 21st Century Vegetable Farmer

Tom Ikeda

California’s rural San Luis Obispo County has seen many changes in 40 years. An area farmer describes the increased competition for water and land, technological advances in irrigation, crop changes, new environmental regulations, and how all these factors are impacting the region’s economy and lifestyle.

EBID: Water Management, Measurement, and Drought

Henry Magallanez and Valerie Beversdorf

Elephant Butte Irrigation District in New Mexico has continued to deliver irrigation water while coping with prolonged drought by adopting new technologies and management practices. Innovative methods measure flow and deliveries, with data tracked on the Internet.

Efficiency and Innovation at Westlands Water District

Russ Freeman

The total available water in the Westlands Water District of central California is less than the district requires. Area farmers and Westlands are working to improve water use efficiency by investing in improved irrigation systems and using new technologies to monitor ET and soil moisture.

Is Irrigated Agriculture Sustainable?
The Battle to Counteract Salinity

Clinton Williams

Irrigation-dependent farmers in the Southwest face considerable challenges, such as leaching excess salts without depleting water supplies, growing more salt-tolerant crops, and coping with lower-quality water from wastewater facilities and saltier water from drought-depleted reservoirs.

Controlled-Environment Agriculture: A Sustainable Option

Gene Giacomelli, Nadia Sabeh, Paula Costa, and Merle Jensen

Crop yields can be dramatically increased when crops are grown in greenhouses with tight controls on air and root temperatures, light, water, plant nutrition, and climate. Is this our farming future?

Solving Water Needs in the Pecos River Basin

R. King and E. Sims

The Pecos River Settlement Agreement calls for the New Mexico Interstate Stream Commission to purchase agricultural land and water rights in order to ensure sufficient flow into Texas. As a result, the market for farmland and water rights in the targeted irrigation districts has shifted.

Water, Growth, and the Future of Agriculture

Grady Gammage Jr.

What are the ultimate costs of converting central Arizona’s remaining agricultural land to residential and urban use? Farmland can mitigate the urban heat island and provide a water supply buffer in times of drought.
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Water-Quality Trends in the Upper Los Piños River Watershed

Winfield G. Wright – Southwest Hydro-Logic

The scenic upper Los Piños River watershed is located in the San Juan Mountains of southwestern Colorado, with headwaters in the Weminuche Wilderness of the San Juan National Forest (see map). Los Piños River and Vallecito Creek drain into the manmade Vallecito Reservoir, which supplies irrigation water to agricultural communities and the Southern Ute Reservation in the lower Los Piños River watershed. About 80 percent of the annual runoff is derived from snowmelt in May, June, and July. Although the headwater area may appear to be isolated from the effects of human activities, stressors on the watershed include atmospheric deposition, wildfires, naturally occurring constituents, and growth, such as vacation homes near the reservoir.

Since 1997, volunteers from the Vallecito Lake community have collected water-quality data in the reservoir and its tributaries. Water quality and quantity data have also been collected in the watershed by state and federal agencies since 1963. The Pine River Watershed Group was formed in 1999 to facilitate watershed activities and coordinate collection and compilation of water quality and quantity data. Recently the Colorado Watershed Protection Fund awarded the organization a grant to compile and interpret the available water-quality data in the upper Los Piños River watershed.

The U.S. Geological Survey collected water-quality samples from high-altitude lakes in the headwaters of Vallecito Creek from 1985 to 2002, and has collected water quality and quantity data in Vallecito Creek upstream from the reservoir since 1963 (Mast and Turk, 1999). Some water-quality parameters such as ammonia, chloride, iron, and gross beta radioactivity (possibly from atmospheric nuclear testing) show declining trends (see charts, next page). The causes of the declining trends are unknown; however, changes in sample collection and analytical methods cannot be ruled out. Nitrate and sulfate, typically used to detect atmospheric deposition from coal-fired power plants, did not show significant trends; however mercury concentrations in reservoir fish tissue have increased over the last decade, indicating a possible connection between such plants and water quality in the watershed. No mines exist in the watershed that would likely impact mercury concentrations.

In June and July 2002, the Missionary Ridge wildfire burned 70,485 acres in the forested and developed lands northeast of Durango, Colorado and about 8,000 acres in the upper Los Piños River watershed. In August 2003, the Bear Creek wildfire burned about 1,500 acres in the upper Vallecito Creek watershed. Such wildfires are a natural part of a forest ecosystem, but runoff from the burned areas affects...
water quality. Dissolved oxygen concentrations decreased in the reservoir since the wildfires occurred (see chart at right), resulting in a fish kill of thousands of Kokanee salmon during summer 2003, one year after the Missionary Ridge wildfire. Concentrations of iron, manganese, and nitrite plus nitrate have increased in water from the reservoir and in the Los Piños River downstream. Some of the impacts were not noticeable until normal runoff conditions returned after the drought.

The population of the area is estimated to be about 3,000 during the summer when visitation is highest. Fecal coliform counts were as high as 4,600 colonies per 100 milliliters (ml) in streams near public campgrounds and 93 colonies per 100 ml in water from domestic wells. Arsenic concentrations (likely from naturally occurring sources) were as high as 44 parts per billion (ppb) in water from domestic wells. Arsenic and fecal coliform in domestic wells did not exceed the respective water-quality standards of 50 ppb and 200 colonies per 100 ml.

Contact Winfield G. Wright at wwright@frontier.net or visit www.swhydrologic.com.

Reference
AWRA Dialogue Identifies Water Resource Policy Issues

Betsy Woodhouse, Ph.D. – Southwest Hydrology

The Second National Water Resources Policy Dialogue, convened Feb. 14-15 by the American Water Resources Association, brought together 250 experts from across the country to jointly identify the top water resources challenges facing the nation. The Tucson meeting was sponsored by nine federal agencies and numerous nonfederal agencies, organizations, and companies. The attendees came from a broad variety of employment sectors, but the sponsoring agencies of the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and the U.S. Geological Survey were especially well represented.

The dialogue was formatted so as to involve all participants in the process of identifying the major water resource issues that should be brought to the attention of decision makers. Three panels were convened, focusing on water resources supply and demand, infrastructure management, and environmental quality. After each panel presentation, the audience divided into groups of eight to ten individuals to identify the greatest needs and recommend actions for that topic. Each attendee contributed to the group’s conclusion, which then was presented to the entire audience. These ideas were recorded on ballots. Participants were given six votes that could all be cast for a single issue or divided up to reflect their opinions of the most important issues for each topic. Votes were coded by voter employment sector.

AWRA staff analyzed the voting results after the meeting and sent letters to President Bush, the speaker of the House, the majority leader of the Senate, key members of Congress, and all state governors identifying the top action items related to water resources and management as identified by the meeting participants:

- Address the nation’s water issues in an integrated manner, focusing not on single projects but on programs and watershed- and basin-level issues;
- Reconcile the myriad laws, executive orders, and congressional guidance that have created a disjointed, ad-hoc national water policy, and clearly define goals for the 21st century;
- More effectively coordinate the actions of federal, state, tribal, and
local governments in dealing with water, seeking collaboration instead of competition to provide better and more fiscally efficient use of scarce resources and to facilitate decisions on key water programs;

- Focus the nation’s strong scientific capabilities and cutting-edge information technologies to support more effective water-related decision making.

The letter also emphasized the need to educate public officials and the public about the extent and complexity of water challenges and the need for funding to support water resources infrastructure.

In addition to the three panel presentations and discussions, shorter concurrent sessions were convened to discuss policy issues related to the specific topics of science and water availability, oceans and climate, water and agriculture, eastern interstate water issues, and western water negotiations.

Former Assistant Secretary of the Interior Bennett Raley was one of several distinguished keynote speakers who presented his views on water resources management issues. The most important thing, he said, is to recognize the cold, hard reality of what is attainable with available funding and accept the resulting consequences. He believes federal funding will either continue to be static or decline for water supply infrastructure, and proposed that government agencies adopt new roles as partners, co-owners, and codevelopers of projects. Large, multi-agency programs such as CALFED may be the wave of the future, but for such programs to be successful, they will have to: 1) manage the science to focus limited dollars on the most effective areas, i.e., do relevant science; 2) manage expectations and not assume more funding will fall from the sky if a project runs short; and 3) avoid decision gridlock that can occur when consensus is the goal, and instead rely on leadership to move forward.

Robert Hirsch, chief hydrologist of the U.S. Geological Survey, presented a slightly more optimistic picture, saying that Raley’s “fatalism on lack of funding” may not be warranted. He offered the Federal Emergency Management Agency as an example of diverse groups uniting with a common goal and simple message and successfully obtaining sufficient funding. He suggested that developers should be included in the water resources conversation; knowing where and how much water exists is certainly in their interest. Hirsch also expressed the belief that pressuring federal agencies for money under the threat of environmental doom is pointless, and that projects are likely to be more successful if they can show matching economic benefits through ripple effects.

This meeting followed the First National Water Resources Policy Dialogue held in Washington, D.C., in September 2002. AWRA’s written summary noted that the Tucson meeting placed greater emphasis on western water issues, but that watchwords of the first dialogue—integrated management, building partnerships, and addressing problems in a comprehensive manner—were prevalent in the second meeting as well. One attendee observed, however, that in discussing the possibility of a national water resources policy or regulating agency, support appeared somewhat divided between East and West, with western support lukewarm.

Visit www.awra.org/meetings/Tucson2005/.
Basin States Can’t Reach Consensus; Feds Decide

The Upper and Lower Colorado River Basin states, tasked with working out a drought management plan—or at least an operations plan for this summer—failed to reach consensus by April 1, throwing the issue to the U.S. Department of Interior to decide. Throughout numerous meetings, the Upper Basin states of Colorado, New Mexico, Utah, and Wyoming maintained their position that a reduction in the amount of water released from Lake Powell to the Lower Basin this summer is justified because the unusually wet winter will increase flows into the Colorado River, particularly below Glen Canyon Dam. Lake Powell was depleted to about a third of its capacity during the previous five years of drought, and the Upper Basin states want it to refill as much as possible this year in case the drought intensifies in the near future. The Lower Basin states of Arizona, California, and Nevada argued that with the wet winter, enough water is available for the Upper Basin to continue to meet present obligations, thus no pressing emergency warrants a change in operations this year. Lake Mead was at about 62 percent capacity in early May.

The Colorado River Compact of 1922 stipulates that the Upper Basin must release 7.5 million acre-feet (maf) per year to the Lower Basin and maintain a total flow of 75 maf over 10 years at Lees Ferry, the dividing point between the basins. Under the Mexican Treaty of 1944, the United States must deliver 1.5 maf/year to Mexico; that amount has been split between the Upper and Lower basins. Since Glen Canyon Dam was built, the Upper Basin has always released a minimum of 8.23 maf/year, and more during wet years. Thus, the Upper Basin made the case that over the last ten years it has released well over 75 maf. Furthermore, the Upper Basin argued that tributary inflows into the Lower Basin, not included in Compact terms, should count toward the obligation to Mexico.

The San Diego Union-Tribune reported in May that U.S. Department of the Interior Secretary Gale Norton had decided in favor of the Lower Basin for this year, stating that no change in operations over the next five months was warranted on the grounds that reservoir storage during April was greater than predicted. However, she requested another review next April, reported the paper, declaring her authority over water management on the river. In the meantime, Norton instructed the states to continue trying to work out a long-term drought-sharing plan.


Perchlorate Reference Dose Set by EPA

In February, the U.S. Environmental Protection Agency announced it had established an official reference dose (RfD) of 0.0007 mg/kg/day of perchlorate, consistent with the recommended reference dose included in the National Academy of Science’s January 2005 report, and about 24 times higher than a preliminary dose set two years ago. A reference dose is a scientific estimate of a daily exposure level that is not expected to cause adverse health effects in humans.

The new RfD translates to a Drinking Water Equivalent Level (DWEL) of 24.5 parts per billion. A DWEL, which assumes that all of a contaminant comes from drinking water, is the concentration of a contaminant in drinking water that will have no adverse effect with a margin of safety. Because a margin of safety is built into the RfD and the DWEL, exposures above the DWEL are not necessarily considered unsafe.

EPA’s Superfund cleanup program plans to issue guidance based on the new RfD.

According to EPA, the RfD, which assumes total intake from both water and food sources, is appropriate and protective for all populations, including the most sensitive subgroups. The selected reference dose contains a full tenfold uncertainty factor to protect the most sensitive population, the fetuses of pregnant women who have hypothyroidism or iodide deficiency. This uncertainty factor also covers variability among other human life stages, gender, and individual sensitivities, protecting other sensitive subpopulations such as premature neonates, infants, and developing children, said the agency.

The perchlorate summary is available at www.epa.gov/perchlorate.

Nuclear Waste to be Moved from Banks of CO River

Federal and state agencies campaigned for weeks this spring to convince the U.S. Department of Energy (DOE) to remove a 12-million-ton pile of radioactive waste from the banks of the Colorado River near Moab, Utah. In April their efforts were partially rewarded, as DOE announced its recommendation to move the pile to

continued on page 14
THE CHALLENGE: The trend of multidisciplinary solutions to water resources problems is increasing. The increasingly complex solutions to these problems demand collaboration from a group of professionals from a variety of disciplines: there is no longer a single source for answers. As more people share our water resources with each other, issues of hydrology, agriculture, water quality, geology, geography, economics and other factors emerge that cannot be satisfactorily solved without input and involvement of many different branches of knowledge and practice. While water professionals now realize they need to communicate and work with other disciplines, they often don’t have the communication skills to work together.

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—Marian Norris, Hydrologist

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In November, DOE announced it was considering four options for dealing with the pile, one of which called for keeping it in place and capping it. The other three options involved moving and burying the waste at various sites located 17 to 85 miles away, at about twice the cost of capping it. Strong opposition to leaving the pile where it is came from the U.S. EPA, the USGS, Metropolitan Water District of Southern California, California Gov. Arnold Schwarzenegger, members of Congress from the affected states, state water agencies, and environmental groups.

Although DOE made a formal recommendation to move the pile, it must receive public comment and issue a final decision, which could come within several months. After that, congressional funding must be secured. The cleanup cost is expected to be around $450 million.


**ADEC Escapes Extinction**

The Arizona Department of Environmental Quality weathered a storm in the Arizona legislature this spring. ADEQ’s authorizing legislation has a sunset provision that allows lawmakers to periodically determine whether the agency should continue to exist; it was up for renewal this year.

The Arizona Senate first voted to disband the agency, citing dissatisfaction with the way the agency’s director, Steve Owens, has run the agency, particularly regarding interactions with certain business interests. But one day later, after much public outcry, the Senate reauthorized ADEQ for ten years, the typical period used for other agencies. Republican House Environment Committee Chairman Ray Barnes appeared to lead ADEQ’s opposition, according to articles in the *Arizona Republic.* In the House, Barnes’ committee initially voted to renew the agency for two years. Then renewal was approved for five years, but that was amended yet again to four years before it was passed.

Had ADEQ been disbanded, nearly all of the agency’s duties would have transferred to the U.S. EPA’s Region IX office in San Francisco. Business interests in the past have supported the existence of ADEQ because it is faster and less expensive to deal with a local agency. According to the *Republic,* many businesses and industries in the state continued to support ADEQ through the recent turmoil.


**No AMA Protection for Upper San Pedro**

In March, Arizona Department of Water Resources (ADWR) Director Herb Guenther determined that the Upper San Pedro Basin in southern Arizona will not be declared an Active Management Area (AMA). According to state law, the director may propose to designate an AMA if any of the following criteria are met: 1) active management practices are necessary to preserve the existing supply of groundwater for future needs; 2) land subsidence or fissuring is endangering property or potential groundwater storage capacity; or 3) use of groundwater is causing or threatening water quality degradation. The five existing AMAs in Arizona are in areas with high population or intensive agriculture.

Guenther based his decision on ADWR findings that sufficient groundwater supplies exist in the basin to meet future municipal, agricultural, and industrial needs. In addition, there is no evidence of land subsidence or fissuring, or that groundwater use is causing water quality degradation in the basin.

Supporters of the San Pedro Basin were dismayed by the decision, saying it ignored the interaction between groundwater and surface water, according to the *Arizona Republic.* Environmental groups have argued for years that growth in the city of Sierra Vista and Fort Huachuca has impacted the river’s ecosystem. In fact, said the report, several court
cases to protect the river have been won under the Endangered Species Act. The full ADWR report, consisting of two documents, can be obtained at www.adwr.state.az.us/adwr/Content/Publications/. Also visit www.azcentral.com.

**Court: Cost No Justification to Exceed Federal Standards**

In April, the California Supreme Court ruled that treatment costs cannot be used as a reason to exceed federal clean water standards for sewage treatment, according to the Associated Press, as reported in The [Palm Springs] Desert Sun. The ruling applied to the cities of Los Angeles and Burbank regarding effluent discharge that flows into the Los Angeles River from their three sewage treatment plants.

The court, quoted in the AP report, stated that decisions to issue wastewater discharge permits “may not consider economic factors to justify imposing pollutant restrictions that are less stringent than the applicable federal standards require.” However, cost can be considered if the standards to be applied are more stringent than federal standards.

The case was referred back to the lower court to determine if the standards under review did, in fact, go beyond federal restrictions. A Burbank city attorney told AP that the referral keeps alive the possibility for the cities to win their case.


**CO Kayakers Get Water Rights**

The Colorado Supreme Court determined that water rights can be claimed for boat courses, reported the Denver Post in March. According to the report, the court ruled unanimously that “the Colorado Water Conservation Board [CWCB] ignored state law and its own rules when it failed to evaluate an application for a water right submitted by course developers and recommended a lower flow instead.”

The development of boat courses is big recreational business in Colorado, with 13 courses already constructed and more in the works, said the article. This ruling does not mean a water permit is required for a course, but securing one provides insurance against future development that could divert water away from it. Apparently the CWCB had made its own determination of how much water a course on the Gunnison River would need, which was less than requested, effectively reducing a potential world-class course to a much tamer one, according to the Post.


**Mexico Reducing its Water Debt**

Recent rains and improved water-use efficiency in Mexico have allowed that country to reduce by more than half its long-standing water debt to the United States, reported U.S. Water News. Under the terms of a 1944 treaty, Mexico and the United States share water from the Rio Grande, but since the onset of drought in 1993, Mexico has failed to release its share of water from two reservoirs on the Rio Grande, said the article. The debt grew as large as 1.2 million acre-feet, but is now down to around 580,000 acre-feet, according to the report.

Texas farmers have been impacted the most by the shortage. While pleased to have the water for the upcoming growing season, the manager of the Harlingen Irrigation District told U.S. Water News that until a long-term plan for meeting the terms of the treaty is in place, Texans fear they may only receive water in wet years. However, Cristobal Jaime Jaquez, the general director of Mexico’s National Water Commission, told U.S. Water News that recently “his country has opened state water utilities to some private investment and is curbing excess demand and modernizing dams to use water more efficiently.”

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Back in the sixties when I was a child in San Luis Obispo County, California, the local economy lived and died with agriculture. Fifty years later, tourism and hospitality are the number one industries in the area while the open agricultural areas, vineyards, and wine industry provide direct and indirect benefits to the entire community. The population has increased dramatically in recent decades, and the water supply is now regulated by reservoir releases. Demands on the local watershed have changed as a result of three major factors: environmental concerns, a burgeoning metropolitan population, and agricultural changes. Population sprawl has increased the conversion of land from passive agriculture (dryland farming and grazing) to more intensive agriculture (vineyards, orchards, vegetables), with higher water requirements. This is because as land prices increase, farm returns must increase to justify the effort.

How has local agriculture adapted to these changes over time? Principally through increases in efficiency, such as improved irrigation techniques. However, although irrigation has become more efficient and land has been lost to urbanization, overall agricultural use of water has probably increased due to changes in crops made to offset the higher land values.

**Improved Irrigation Efficiency**
Advances in irrigation technology have allowed the evolution from furrow or flood irrigation to sprinkler systems, then to drip (on or below the ground) or micro-sprinkler irrigation (many, low-volume sprinklers close to the ground). Each method has its advantages and disadvantages:

- **Furrow or flood irrigation**
  **Advantages:** inexpensive and easy to set up, leaches salts from soil. Surge irrigation allows more uniform furrow/flood irrigation with less water through the use of wetting and drying cycles.
  **Disadvantages:** uneven application; moist environment can increase disease potential; uses a relatively high volume of water per acre.

- **Sprinklers**
  **Advantages:** good application uniformity; easy to control the amount of water; can leach salts from soil.
  **Disadvantages:** high initial capital costs; increased disease/rot potential; more water loss due to evaporation.

- **Micro-sprinkler/drip irrigation**
  **Advantages:** can irrigate uneven fields uniformly and cover many acres at once; puts water at the root zone where it is needed; improved efficiency of fertilizer and pesticide application; lowered humidity under plant canopy reduces disease pressure; can irrigate in any weather condition, including wind; general increase in production; flexibility of field operation since the whole field is not wet; can use less water.
  **Disadvantages:** salt build-up in soil; costly water filtration systems may be needed; high set-up costs; high maintenance costs.
Higher Value Crops Planted
Sprinkler and micro-sprinkler/drip irrigation have also allowed high-value crops to be raised on rolling hills. Crops such as grapes, citrus, avocados, and even vegetables and strawberries have changed the look of what was previously hillside grazing land. Technological advances in many areas (including irrigation) have allowed farmers to maintain or increase production while reducing the amount of prime agricultural ground farmed, and increasing production in marginal and existing cropland. Urbanization has claimed most of the lost farmland, but environmental mitigation efforts have also reclaimed a significant percentage of the lost land.

Environmental Regulations Require Attention
In recent years, environmental regulations and policies have had the greatest impact on agriculture and agricultural water use. A prime example is in the Klamath Basin in Northern California, where water has been withheld from farmers to protect endangered or threatened fish habitat.

New environmental regulations have also been enacted, such as the Irrigated Agricultural Conditional Discharge Waiver for storm runoff of irrigated agricultural lands. This program started out seven years ago as a water quality project initiated by local agricultural interests, but has been subsumed into a mandatory regional program through the Regional Water Quality Control Board. The program requires all irrigated agricultural producers to attend a 15-hour workshop, formulate a farm water management plan, and privately or cooperatively monitor water quality of all streams running onto and off farms.

Private testing can be very expensive, especially if multiple sites have to be monitored, as all streams entering and leaving the property must be analyzed on a schedule that requires monthly testing of nitrate, ammonia, orthophosphate, total dissolved solids, pH, temperature, turbidity, and flow; four times yearly testing for water toxicity; and annual testing for sediment toxicity and benthic invertebrate assessment. Therefore, the preferred method in the central coast region is cooperative monitoring, whereby monitoring locations are rotated among the participating farms.

What is the Future of Agriculture?
What all these changes have created, both in my community and hundreds of others, is a situation where growth, environmental regulators and requirements, and agricultural needs have put such high demand on the water supply that any increase in use from one interest takes water from the others. So where does that leave the future of agriculture? In an industry where prices had been stable for years, costs keep rising and regulations keep increasing, but returns are based on open market prices. Increased costs consequently cannot be passed on, and every extra cost is another nail in the coffin.

In other areas of the state and elsewhere, farmers have sold their water to metropolitan users. This seems to be a good deal at first, but what becomes of the agricultural support industries that rely on the purchase of seed, fertilizers, and chemicals? How will it affect those loyal employees who are no longer needed? What does the farmer do when his entire lifestyle has changed? In the Imperial Valley alone, water transfers cost the local economy an estimated $1 billion.

Agriculture in the West is now at a critical crossroads. Our resources are stretched thin, but supplying food for a growing population is essential. Food is cheap and readily available from a number of foreign as well as domestic sources. My feeling is that agriculture will lose out to other water interests unless we put a greater value on a safe domestic food supply.

Tom Ikeda is the president of the San Luis Obispo County Farm Bureau and vice president of Ikeda Bros., a 700-acre vegetable operation in Arroyo Grande. Contact him at 805-489-2526.
The Elephant Butte Irrigation District (EBID) is located in the Rio Grande Project of south-central New Mexico. Elephant Butte and Caballo reservoirs provide water storage for a combined capacity of about 2.3 million acre-feet for allocation to EBID, El Paso Water Improvement District No. 1 in Texas, and the Republic of Mexico. EBID’s allocated water is diverted at three dams into its irrigation system. This water is used on crops (mainly alfalfa, cotton, and pecans) grown by flood irrigation in the Rincon and Mesilla valleys.

EBID’s delivery system comprises 357 miles of canals and laterals. Water not consumed by crops is returned to the Rio Grande through a system of approximately 400 miles of drains and wasteways. Nearly all of the EBID irrigation system is unlined, consisting of open, earthen channels constructed during the early 1900s by the U.S. Bureau of Reclamation.

While this is generally thought to be wasteful, seepage from the irrigation system has actually maintained the health of the underlying aquifer. The aquifer provides reserve storage that has allowed agriculture to survive through extended droughts.

Water Monitoring and Data Management

Accurate measurement of flow is a critical factor in EBID’s successful provision of surface water to irrigate the 90,640 acres of water-righted land in the district. During the past decade, EBID has developed means to measure flow at all levels of operation, including river and canal flows, diversions, farm deliveries, and return flows. Several forms of water measurement structures have been installed, including weirs, broad-crest weirs, and submerged orifices. Each water measurement site is evaluated to determine which type of flume will be most hydrologically effective, while ensuring acceptable accuracy in flow measurement. Sedimentation, low availability of head, and construction cost have prompted the development of additional water measuring structures, such as the Samani Circular and Trapezoidal flumes and the Samani-Magallanez flume. Currently about 200 water measurement devices have been installed throughout the district.

The district has also made substantial progress in developing automated data acquisition systems. Hardware and software have been designed to facilitate monitoring and control of irrigation facilities, including river/canal gates and stilling wells. Additionally, about 150 radio telemetry units have been installed at certain checks, turnouts, well
Manual and automated methods are utilized to monitor the flow of water through gauging and radio telemetry stations in EBID. These provide data for efficient management within the system and accurate accounting for deliveries that allow farmers to benefit from conservation measures. Sixty test wells were drilled throughout the district to monitor the depth to groundwater; they are equipped with telemetry so that groundwater levels can be monitored in real-time. Water quality monitoring for temperature and specific conductance has been added to the data acquisition system, starting with surface water flows crossing the state line into Texas.

The Global Water Flow Probe, a commercially available propeller meter, is the primary device used to meter turnouts. This device measures the velocity of water through the turnout gate and the height of the water. Staff gauges are being installed, one upstream and one downstream of each turnout gate, to allow and publish a calibrated rating table of submerged orifice equations. Radio telemetry transmits real-time data to EBID headquarters for processing and archiving.

With the rapid growth of its flow measurement system, EBID had to develop a system for managing the glut of hydrologic and operations data. The radio telemetry system brings the data to a central polling computer at EBID headquarters. From there, the data are formatted and passed to a SQL server for database storage. The data, retrievable in graph or tabular form, are accessible on the Internet at www.ebid-nm.org.

**Management Practices Evolve**

Under drought conditions, more work is required to equitably distribute irrigation water, and with each drought, management practices change. For an unprecedented 24 years, from 1979 to 2002, EBID enjoyed full water supply allocations with annual surface water allotments to constituents of three acre-feet per acre (36 inches) (see chart, page 18). However, EBID could allot only eight acre-inches per acre—too little for crops—during the drought-affected 2003 and 2004 irrigation seasons. How would EBID ensure delivery of

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**Under drought conditions, more work is required to equitably distribute irrigation water, and with each drought, management practices change.**

Efficient measurement of water flow using a submerged orifice equation. In-stream metering is also used in on-farm ditches or supply laterals. EBID is working with New Mexico State University to refine...
the correct amount of water to which constituents were entitled? And how could they get more water? To address these concerns, EBID implemented permanent special procedures and policies to allow commingling of surface water and groundwater in EBID facilities, and to meter the delivery of irrigation water.

Historically, farmers have utilized groundwater to supplement surface water during periods of drought. In order to assist farmers in irrigating crops, EBID implemented a conjunctive management policy, allowing the conveyance of metered water pumped from private wells through EBID canals and laterals to supplement surface water deliveries.

**Water Ordering**

Crop patterns have changed significantly since the 1950s when cotton represented almost 80 percent of the district’s crops (see chart, page 19). The first modern irrigation wells were drilled during that decade’s drought, and higher-value, higher-investment crops such as pecans and vegetables were planted due to the reliability of supplemental groundwater. These changes in crop patterns required more flexible water management policies and procedures, leading to alterations in the water ordering process.

Formerly, charges for irrigation water were based on standard rates that reflected crop type and number of irrigated acres. Farmers irrigated without actually being metered. Now, water orders and charges are volumetrically based. Types of water orders include surface water, pumped groundwater, and commingled surface water and groundwater. Pump orders are required for well pumps discharging into EBID facilities. The amount of water released from Elephant Butte Reservoir is based on the water orders received from all EBID water users. The charge against the users’ annual allotments is determined by metering at all turnouts, ensuring that constituents get their correct amount, and at well discharge pipes where groundwater discharges into EBID facilities. Calculations are performed and a metering worksheet is completed in the field when water is delivered. The delivered acre-feet on the worksheet are entered into the database and deducted from the irrigator’s annual allotment.

A Farmer Services page is available on EBID’s Web site, where farmers can transfer water from one farm to another, obtain transaction histories, review their tax accounts and land records, and check current water allotment balance, pending orders, and available balances. In the near future, farmers will also be able to place water orders on the Web.

**Additional Efforts Benefit Region**

EBID’s primary mission is to equitably deliver irrigation water to its constituents, but the district continues to reach beyond traditional surface water uses to benefit the region. Nontraditional efforts include collaborating with government agencies and organizations on wetland restoration projects and development of hiking trails along EBID rights-of-way, and leveraging these resources and efforts with the infusion of grant funds.

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formed in 1952, Westlands Water District encompasses more than 600,000 acres of farmland in western Fresno and Kings counties in Central California. In contract with the U.S. Bureau of Reclamation, water is conveyed to Westlands through the Central Valley Project. It is pumped from the Sacramento-San Joaquin Delta, and delivered 70 miles through the Delta-Mendota Canal to San Luis Reservoir during the winter months when there is an abundance of water in the system. During spring and summer, the water is delivered to Westlands farmers through the San Luis and Coalinga canals. Once it leaves the federal project canals, water is delivered to farmers through 1,034 miles of underground pipe and more than 3,300 water meters.

Unlike water agencies with more abundant supplies, Westlands must ration water to its farmers, even in the wettest years. The district’s primary annual contract entitlements from the Central Valley Project total 1,150,000 acre-feet. The annual safe yield of the regional confined aquifer adds another 135,000 to 200,000 acre-feet. Thus, the total water available falls about 215,000 acre-feet (15 percent) short of the 1,500,000 acre-feet required to irrigate the entire district. Since 1991 when the district last received a water contract supply near 100 percent, the delivered water has decreased to about 65 or 70 percent of the contract amount. District farmers must cope with uncertainties of contract supply, groundwater, and short-term water transfers when they make their cropping decisions, while dealing with economic uncertainties of the farming economy. As a result, at least 10 percent of the district is put to fallow annually.

Efficient Irrigators

As a federal water user, the district must prepare a water management plan, and the guidelines suggest a goal of 85 percent efficiency. That is, 85 percent of the water applied to crops is used for evapotranspiration (ET) and other plant uses, with the balance lost to deep percolation. In fact, the average district-wide seasonal application efficiency has averaged about 84 percent over the past 25 years. Improved efficiency generally requires water users to invest in improved irrigation systems. Since 1985, adoption of drip/micro-irrigation systems has doubled every five years to a current total of over 120,000 acres or about 22 percent of irrigable acreage. Virtually all permanent crops are drip-irrigated, and more field crops are being irrigated with drip systems every year.

District irrigators have adopted new technologies as their benefits are demonstrated. Land leveling with laser equipment is now routinely utilized for surface irrigation. Since the district does not have any outflow, tailwater reuse is a must, and all water users must prevent tailwater from impacting their neighbors. Pre-irrigation of recently tilled lands before planting is routinely accomplished with hand-moved aluminum sprinklers rather than with the furrow system, which cannot control the depth of water applied.

With the availability of GPS satellite positioning, precision agriculture is rapidly taking hold. GPS-controlled tractors can have smaller engines, saving fuel. Ground preparation can occur 24 hours a day, requiring fewer tractors to be maintained. Precision tilling reliably permits beds to be...
Irrigated agriculture accounts for billions of dollars in the U.S. economy. According to 2002 data, agricultural production in ten counties exceeded $1 billion or more (see table, next page). All ten of these counties are in the western United States; nine are in California and the tenth is in north-central Colorado. All of the counties have annual evaporative demands greater than rainfall, which means that irrigation is required for optimum plant growth and survival. Thus the availability of water for irrigation is critical to meet the food and fiber needs of the United States.

In the semi-arid Southwest, virtually all agricultural production depends on irrigation. In central and western Arizona, much of the water used for irrigation comes from surface water sources including the Colorado, Salt, Verde, and Gila rivers. Over the past five to ten years these projects have struggled to supply adequate water due to decreasing water supplies and a persistent drought over much of the West. A compounding problem, faced not only by Arizona, is that as lake and reservoir levels fall, the salinity of the remaining water increases. Increased salinity in irrigation water increases the osmotic potential in the root zone and can lead to a reduction in yield because plants are unable to extract sufficient moisture from the soil to meet evaporative demands. Excess irrigation is then needed to leach the excess salts below the root zone. Thus increases in salinity result in increased water demand, placing a further strain on water supplies during periods of drought.

**For irrigated agriculture to be sustainable, ... water supplies must not merely meet the evaporative demands of the crops grown: up to twice that amount of water is required to prevent salt accumulation in the root zone.**

**Different Crops for Different Salts?**

The link between irrigation, salinity, and productivity has been recognized for nearly 150 years and a considerable research effort has been undertaken to prevent loss of productive irrigated lands to salinization. One effort that has helped maintain productivity while reducing the quantity of water needed for irrigation is determining crop response to salinity. The graph at right shows the response to salinity of three important irrigated crops grown in the arid Southwest: lettuce, alfalfa, and cotton. The graph shows the normalized potential yield response to increasing salinity and demonstrates that individual crops have a threshold for reduced yield due to salinity. For example, at the salinity level at which cotton just begins to exhibit yield reduction, lettuce yield has dropped to near zero. Thus, the selection of crop type is very important when managing the salinity of irrigation water.

Over the past ten years, the salinity of Salt River Project water delivered for irrigation in central Arizona has averaged 0.5 to 1.4 deciSiemens per meter (dS/m), depending on the time of year and source of the water being delivered. Colorado River water delivered to Nevada, Arizona, and California averaged 0.95 dS/m over the same time period. Agricultural production along the Colorado River near Yuma depends on a successful winter lettuce crop. Because lettuce has a salinity threshold value of 0.90 dS/m, if salinity levels rise significantly in the Colorado River, area crop yields will be significantly reduced. On the other hand, cotton has a salinity threshold of 5.1 dS/m and shows only a 25 percent reduction in yield at a salinity of 8.4 dS/m. If the increase in salinity seen in the Southwest continues, it may mean a shift in cropping patterns and potential economic impacts on agricultural production throughout the region.

**Use of Reclaimed Water for Irrigation**

Urban water needs put additional pressure on irrigated agriculture. Increasingly, urban water users are purchasing water from agriculture and replacing it with water of lesser quality. In the Phoenix metropolitan area, Buckeye Irrigation District uses reclaimed municipal sewage from a city sewer treatment plant for irrigation. Water passing through municipal treatment,
distribution, and reclamation facilities of the Phoenix metropolitan area can increase salinity by up to 50 percent. Salt loads in waste water increase both in concentration (due to evaporative processes) and total mass (due to importation of salts via processes such as water softeners). This increase in salt load to the waste water treatment plants places a greater strain on the organisms used for treatment and can potentially preclude the use of reclaimed water for the irrigation of salt-sensitive crops.

**Lessons from History**

The costs of not addressing the salinity issue will have far-reaching impacts. Throughout history, only the Nile River Valley in Egypt has sustained a civilization dependent on irrigation. Since irrigation first began along the Nile River, annual floods that inundate the land have not only provided fresh nutrients but also carried away the salts imported by irrigation water from the previous season. Other civilizations in both the old and new worlds that depended on irrigation ultimately collapsed due to salinization and the loss of arable lands caused by irrigation and inadequate leaching of salts from the root zone.

An example of the catastrophic effects of salinization due to irrigation without leaching can be seen in the archaeological record of the Hohokam people of central Arizona. Land that is now irrigated with water from the Salt River and Central Arizona projects was first irrigated by the Hohokam from 200 B.C. to 1450 A.D. using a network of small control structures and canals. Current thought is that the Hohokam finally faded as a culture due to salinization impacts and subsequent insufficient food production.

Present technologies such as micro-irrigation, crop selection, and plant breeding are providing a way for irrigated agricultural production to keep pace with needs while using less water, however there are theoretical limits to how much water can be saved using these techniques. Micro-irrigation is currently being used not to maintain salt balance in a field but to maintain the salt balance in the root zone of individual plants. This allows for much less water use but causes salts to accumulate in the soil, increasing the complexity of managing and irrigating the crop. In the San Joaquin Valley of California, efficient use of land and water is maximized by growing crops with varying salt tolerances in sequence and by maintaining all imported salts within the boundaries of individual farms. Plant breeders are also looking for ways to select for crops that can tolerate higher salinity levels without a significant loss in productivity or quality.

Lacking a natural resource that purges itself of salinity such as the mighty and reliably flooding Nile, we in the Southwest must remain determined to avoid the fate of the Hohokam and continue to seek ways to improve irrigation to secure a sustainable agricultural future.

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Controlled Environment Agriculture (CEA) is an agricultural production procedure providing high-valued fruits, vegetables, and flowers to world markets. The University of Arizona’s Controlled Environment Agriculture Center (CEAC) is pursuing research, education, and outreach programs aimed at further developing CEA as an economically, environmentally, and socially sustainable agricultural option.

CEA uses an integrated science and engineering approach to establish the most favorable conditions for plant productivity, while optimizing resources such as water, energy, space, capital, and labor. Regulating the aerial and root environment is a major concern in CEA systems; therefore crops are grown, often without soil, inside greenhouses designed to control air and root temperatures, light, water, plant nutrition, and climate.

Greenhouses are typically covered and have environmental control hardware to prevent wind, rain, extreme temperatures, excessive solar radiation, insects, and animals from damaging the crops. Evaporative cooling and natural ventilation cool crops during the day, and natural gas provides heat as required. Plant growth is further enhanced by using the natural gas exhaust from heaters to raise carbon dioxide levels in the greenhouse from the ambient 355 parts per million (ppm) to a target range of 800-1,000 ppm.

**What Is Being Grown?**

CEA can grow virtually any crop, including root crops, although the method may not be economically viable for some, such as tree crops. The best choices are high-valued, high-productivity crops, such as tomatoes, cucumbers, sweet peppers, and flowers, for which there are economic rewards for year-round availability and high quality. Peaches, avocados, papayas, pineapples, and grapes do not appear to be economically feasible options, but strawberries, raspberries, and other berries may prove to be.

**Optimal CEA Locations**

The ideal climate for CEA has clear, sunny skies, low humidity for effective evaporative cooling, and temperature ranges typical of those in the semi-arid Southwest at elevations of 4,000 to 6,000 feet above sea level. Sites should also have low risk of such natural disasters as heavy snow, hurricanes, violent thunderstorms, and hail that could damage greenhouses. In addition, a reliable, high-quality water supply is critical.

**CEA can produce crop yields that exceed field production as much as tenfold, with greater consistency and quality.**

CEA vegetable production is developing rapidly in semi-arid regions of Mexico and the southwestern United States. Arizona is the largest greenhouse vegetable producer in the country, with about 250 acres under cultivation. The United States has about 1,460 acres of CEA vegetable production of an estimated 29,500 acres of total greenhouse production that includes nursery, floriculture, seeds, mushrooms, and sod (USDA, 2002). Mexico traditionally has about 1.65 million acres of vegetables in field production, but the greenhouse vegetable industry grew from about 1,100 acres in 1999 to more than 2,350 acres in 2003 (Benavides and Ramirez, 2003).

**Hydroponics Well-Suited to CEA**

Greenhouse food production usually includes hydroponics, a nurturing procedure without soil. The hydroponic solution consists of water and elemental salts. In addition to standard fertilizer components (nitrogen, phosphorous, and potassium), calcium and magnesium are added to the solution in lieu of applying lime to soil. Fourteen minor elements normally found in soil, including iron, manganese, and zinc, are added to the hydroponic solution as soluble compounds. Solution pH is monitored continuously to maintain a range of 6.2 to 6.5, and electrical conductivity is monitored to keep total dissolved solids between 2.5 and 3 milliSiemens per centimeter. Lab analyses of the 19 elements typically are run twice per month.

Hydroponic systems are of two basic types: open systems that discharge a portion of the hydroponic solution, and closed recycling systems. The trend is toward the more efficient closed systems, despite their greater requirements in terms of capital...
costs and expertise requirements. Note that even in “closed” systems, built-up salts must be periodically discharged, and in “open” systems, some discharged water and nutrients may be captured and re-used.

While greenhouses and hydroponic systems employ cutting-edge technology and are capital-intensive, most employees need only basic agricultural skills. Supported by the control technology, growers match plant varieties, production age, and market demands to current and projected climate conditions to obtain optimal marketable yields.

**High Water-Use Efficiency**

Hydroponic greenhouse systems consume much less water for a given crop yield than traditional cultivation. On average, the tomato hydroponic system has a system water use efficiency of about 288 gallons of water per pound of tomato yield, compared to around 1,670 gallons of water per pound with traditional field production. This savings is attributed to precise application of water, appropriately timed irrigation scheduling, less demand from wind-induced evapotranspiration, greater plant yields, year-round production, and generally healthier plants with controlled conditions. Recirculating hydroponic systems save even more water.

**Other Advantages**

**High Production Rates**: CEA can produce crop yields that exceed field production as much as tenfold, with greater consistency and quality. Compared to seasonal field production, CEA has been shown to increase annual production of cucumbers, tomatoes, and sweet peppers from 2 to 16, 1 to 12, and 1 to 6 pounds per square foot, respectively.

**Salinity Issues Minimized**: A great benefit of environmental control in greenhouses is that increased soil salinity, an issue in field production because of its negative effect on marketable yield and quality, is minimized. These benefits are achieved through daily management of root zone salinity and atmospheric humidity to modulate plant transpiration. As a result, CEA that employs a recirculating hydroponic system not only ensures total reuse of water and nutrients, but also improves fruit quality while saving water and decreasing nutrient emissions.

**Pest Control**: By keeping out most harmful insects and keeping in those that are beneficial, greenhouses provide an environment conducive to chemical-free, integrated pest management. Thus, CEA can generate higher yields of improved-quality, pesticide-free crops, using less land than traditional field agriculture.

**Looking Ahead**

Today, CEA research focuses on improving fruit quality, taste, and nutrition. Efforts are also underway to improve water use efficiency with respect to both plant evapotranspiration and evaporative cooling. One research goal is to replace light and infrared sensors that were originally developed for environmental monitoring of field crops with sensors inserted directly into the plants to monitor photosynthesis and other plant processes.

The future of CEA lies beyond standard food production, to such areas as production of “nutriceuticals,” plants grown for their healthy byproducts, such as high-lycopene tomatoes (believed to help prevent cancer) and antioxidant-rich watermelons. “Farmaceuticals,” plants that are genetically modified so as to produce vaccines, may be well suited for CEA because they would not be grown in open fields where cross-pollination could occur. Phytoremediation, a procedure to harness plant bioprocesses to extract soil or water contaminants and provide for their disposal, may also benefit from CEA techniques. For example, contaminated land could be made suitable for soil-grown crops by erecting a greenhouse over it and extracting soil contaminants. It may also be feasible to pump water from a contaminated river or aquifer into a greenhouse hydroponic system that then cleans the water before returning it to the environment.

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**References**


The Pecos River Basin is located in southeastern New Mexico (see map). Water use in the basin is divided into several categories including agriculture, municipalities, industry, and interstate compact deliveries. Both ground- and surface water sources with rights of varying priority dates are utilized.

In 1948, New Mexico and Texas entered into the Pecos River Compact. In 1988, as a result of a lawsuit filed by Texas against New Mexico, the U.S. Supreme Court entered an amended decree, which appointed a federal river master and established an accounting methodology to verify state line water deliveries. Since 1988, New Mexico has struggled to maintain compliance with the compact and decree, which enjoin the state from defaulting on its annual obligation to deliver Pecos River water to Texas. New Mexico’s failure to comply with the terms of the compact and decree could ultimately result in federal intervention, whereby the state would lose its ability to manage its water on the Pecos River.

Since 1992, New Mexico has had to aggressively lease water to meet its Pecos River Compact delivery obligations. However, leasing is an expensive, uncertain, and temporary solution. New Mexico continues to maintain a minimal state line credit but is in considerable danger of a net shortfall in the next few years due to the impact a wet year (such as 2004) has on a prolonged drought within the context of the compact accounting. Remedying a net shortfall has the potential to cause catastrophic economic and social hardship to the Pecos River Basin and the state through reduced economic activity (Whittlesey et al., 1993).

Consensus Building and the Settlement

In the summer of 2001, New Mexico was dangerously close to a possible net shortfall and feared that the only way to remedy the situation was through priority administration. Under priority administration, water rights holders have their water usage involuntarily curtailed until compact delivery requirements are met, from the most junior to most senior water right holder. Water curtailment is restored in reverse order once the delivery requirements are met.

The New Mexico Interstate Stream Commission (NMISC), the state agency charged with meeting interstate compact obligations, responded to this situation by creating an ad hoc committee of major stakeholders in the lower Pecos River Basin, including representatives from agriculture, ranching, industry, municipalities, and counties. The committee was charged with devising both short- and long-term consensus solutions to the Pecos River Compact delivery problem.

Despite complex and in some cases long-standing adversarial relations between some basin representatives, a consensus was reached on both interim and permanent solutions to the compact delivery problem. The committee presented its plan and a $68 million funding request to the New Mexico Legislature.

The 2002 Legislature drafted legislation (NMSA 72-1-2.4) largely based upon the committee’s plan and authorized the NMISC to use $36.4 million to implement the statute, which ultimately provides long-term solutions to New Mexico’s Pecos River Compact delivery obligations. Key components of the statute are: 1) achieving long-term compliance with the compact; 2) purchasing farmland and appurtenant water rights of varying amounts in the Carlsbad, Roswell, and Fort Sumner areas; 3) settling a 50-year old lawsuit, known as the Lewis Adjudication, between the Carlsbad Irrigation District (CID) and Pecos Valley Artesian Conservancy District (PVACD), prior to any purchases; with contractual agreement between all parties; and 4) establishing priority of purchases. Elements from the statute were later incorporated into a settlement agreement.
In January 2003, the U.S. Department of the Interior, State of New Mexico, NMISC, CID, and PVACD entered into the Carlsbad Project Settlement Agreement (NMOSE, 2005). The settlement settles the project phase of the Lewis Adjudication, guarantees an annual water allotment of 3,697 acre-feet per acre to CID members, and establishes a schedule for delivery of water to the state line. Implementation of the settlement requires completion of conditions precedent (see diagram above), which include: entry into a partial final decree (PFD); implementation of the consensus plan, including land and water rights acquisition and developing an augmentation well field; and completion of federal National Environmental Policy Act (NEPA) requirements.

Hydrologic evaluations of the settlement indicate that its implementation would achieve long-term compact compliance by increasing water in both the Pecos River and the adjacent artesian aquifer, thus re-establishing hydrologic equilibrium. Long-term compliance with the compact would foster economic stability in the basin as well.

**Implementation of the Settlement**

**PFD:** Five formal protests to the PFD were filed with the District Court in conjunction with the settlement. Ultimately, three of the protests were resolved and the court ordered dismissal of the remaining two. The court’s decision has been appealed.

**Consensus Plan Purchase Program:**

In December 2002, the NMISC issued a request for bids, seeking offers from landowners interested in selling their agricultural land and water rights to the NMISC. Sufficient offers were received to meet the minimum settlement requirements.

Per statutory requirement, the NMISC developed a purchase price range based upon the offer prices and the specific characteristics of the land and water rights being offered within each area. These price ranges were much higher than originally projected in the financial request to the legislature, in part because of the legislative requirement to purchase the land in addition to appurtenant water rights but also because the state of New Mexico’s entry into the market resulted in a significant shift in both the Roswell and Carlsbad areas to a market that favors sellers.

To date, the NMISC has negotiated purchase agreements totaling 3,080 acres in CID and 6,500 acres in the PVACD. At the time of the drafting of this article, a total of 673 acres in CID and 1,412 acres in PVACD have been purchased. The NMISC will continue to close on agreements upon completion of due diligence for each transaction. Negotiations continue for additional purchase agreements, which will be contingent upon obtaining additional funding.

A land maintenance program is being developed for the purchased lands, which will include establishment and maintenance of existing vegetative cover to minimize wind erosion and weed encroachment to maintain the land in accordance with applicable state and federal laws. Funding for this program was not contemplated in the original proposal to the legislature.

**Consensus Plan Augmentation Well Fields:** The NMISC has begun developing primary and complementary augmentation well fields. Drilling at the primary well field, located in the southern Roswell Artesian Basin (RAB), commenced in July/August 2005.
Arizona farmers have never matched the idyllic Jeffersonian model of self-reliant individuals whose flinty independence formed the backbone of American democracy. Because we rely on elaborate irrigation systems to make agriculture possible, our farms have always been large, often corporate, and dependent on contractual obligations. Also, Arizona agriculture has historically focused not on food crops, but fiber. Perhaps these are some of the reasons that as farming began to disappear in central Arizona, we never heard an outcry, as in the Willamette Valley or in the northeastern United States, about the need to create agricultural preservation zones so as to preserve a “special lifestyle” while saving open space.

In Arizona, the survival of agriculture has never been about a shortage of land. Land we have in abundance—the question always is water: Is it available? Where? And at what cost?

When I was first elected to the Central Arizona Project (CAP) Board more than twelve years ago, I took my seat with the expectation that I was essentially the representative of urban interests, since I made my living representing real estate developers. I have always lived in urban Arizona and had no particular affinity for agricultural uses. As a basic believer in the free market, I viewed agriculture as kind of a holding zone: what you did with property until it was ripe for subdividing.

Interestingly, in Arizona even most farmers hold a similar view. Part of the reason why Arizona has so successfully represented its water interests in the larger western context is that, in comparison to states such as California, farmers and city dwellers in central Arizona get along relatively well because they grow both crops and houses in the same area. In California, urbanization takes place on the coast and developers must grab water from farmers in the central valleys. But here, we tend to convert farmland to urban land at the same time that we convert agricultural water to urban water.

A section of housing requires on average no more and often less water than the same section of land used to grow crops. So as we convert land to residential use, we use less water, and we explain this to citizens to calm their fears.

Yet agricultural water and urban water are not the same commodity. An essential component of water is its reliability as a resource. Domestic urban water must be especially reliable; it is very difficult to take water away from homes. Agricultural uses, especially for non-food crops, lie at the opposite end of the dependence/demand scale and therefore, logically, at the opposite end of the price scale. It took me a while on the CAP Board to understand why we would sell water to farmers below the cost of getting it here but there is logic to that idea: doing so preserves and protects our water supply from others who would claim it. It has therefore been in the interest of cities to subsidize the price of water to farmers.

Part of the reason why the Phoenix area has weathered the western drought with far fewer water restrictions than ... other cities in the Southwest is that agricultural water has been available to move to urban uses in our time of shortage.

We are now beginning to face the question of what happens as we convert the remaining agricultural land in central Arizona to urban uses. Left to the free market, agriculture will ultimately disappear as the urban population grows and water flows toward higher-value uses. Toward the end of my tenure on the CAP Board, I came to the conclusion that there is great value in retaining agriculture as part of the mix of land and water use in central Arizona. There are at least three reasons for doing this.
First, agriculture is the only real reason we are here at all. Despite abundant land and sunshine, the Hohokam were able to create a civilization here only because water could be moved and applied to the land. Some living remnant of why we are here would be instructive to our grandchildren. Our civilization “rose from their ashes.”

More concretely, the urban heat island is increasing at an alarming rate. In the last fifty years in central Arizona, average nighttime summer temperatures have increased 11 degrees and now hover in the mid 90s. If the temperature increases another 11 degrees in the next fifty years, it is unlikely that people will continue to move here. Studies by researchers at Arizona State University show that irrigated agriculture fields actually cool off more at night than the native desert. The continued presence of agriculture has a mitigating effect on the heat island.

Third, and most importantly, agricultural water use is a buffer. In times of shortage, it is relatively simple to tell farmers they cannot plant their crops. It is relatively simple to let their water migrate to the higher priced and less interruptible urban uses. Part of the reason why the Phoenix area has weathered the western drought with far fewer water restrictions than Denver, Las Vegas, San Diego, or other cities in the Southwest is that agricultural water has been available to move to urban uses in our time of shortage. If our urban population increases to where it requires the entire available water supply, we lose that safety valve.

In 1999 in Phoenix in Perspective, I suggested that we permanently set aside a block of 500,000 acre-feet of water for agriculture, and model urban growth based on that assumption. It is now six years later; in that time we went deeper into drought and may only now be starting to climb back out. We still have not seriously debated the relationships between long-term agricultural use, urban growth, and the ultimate sustainable size for our city. I still think it is a good idea.
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located over buried drip-irrigation systems. Automated yield monitoring during harvesting is becoming common. Variable-rate application of soil amendments, fertilizers, and other inputs makes possible tighter management and control.

Even a uniform irrigation system with good control over the depth of water applied will not perform to its capabilities without good management. The Water Conservation Program at Westlands has worked for over 25 years to provide information to its water users that allows them to manage their allocations as efficiently as possible.

**ET Data Help Determine Irrigation Volume**
Real-time crop ET data specific to Westlands has been mailed weekly to all water users since 1978. Now the data obtained from the district’s weather stations are faxed, e-mailed, and posted on the district’s Web site daily. Originally, ET information was primarily used to facilitate irrigation scheduling, which had to be planned well in advance so the cumbersome irrigation equipment could be moved into place. But as drip systems were adopted and irrigation events became more frequent and easier to initiate, water scheduling has increasingly emphasized applying the proper amount of water rather than scheduling the date for the next irrigation.

In the 1980s, Westlands staff used neutron probe soil moisture monitoring data to develop specific crop coefficients for determining ET rates. However, satellite imagery is now available that provides a large amount of ET data at a minimal cost compared to earlier methods. Thus district staff today are utilizing 2003 and 2004 satellite imagery to develop and update crop coefficients in order to produce real-time ET rates. Farmers can determine how much water to apply to a particular crop on a particular day by using the ET measurements to calculate water lost from the root zone since the last irrigation, when the soil was presumably saturated. This water balance approach helps prevent water loss to deep percolation while ensuring the crops receive sufficient moisture.

**Satellite Imagery Used**
Lack of uniformity in the irrigation system has always been compensated for by applying additional water so that drier parts of a field receive enough. Since 2003, however, Westlands has provided water users with satellite imagery on its Web site that can be used to identify areas of uneven distribution. The Normalized Difference Vegetative Index (NDVI) imagery provides a sensitive measure of the vegetative mass and water status of a crop and is usually available within three or four days from the date of overflight. With this information and investment in improved technology, issues of nonuniform distribution can be addressed.

District water users have found other uses for satellite imagery. Consider the tomato farmer in his field who receives a cellular telephone call from the cannery, saying that he must stretch out his deliveries. However, tomatoes spoil from water stress if not harvested in time. The farmer can log on to the district’s Web site and look at the imagery for his field – which may be only a week old – and proceed to harvest first the parts of the field that are not expected to hold well.

Variable-rate application services for various agricultural inputs are being routinely offered by suppliers to water users in the district. Satellite imagery and yield monitoring are now being used to develop maps that guide variable application rates of soil amendments, fertilizer, growth regulators, and defoliants.

New technology is continually being developed to improve water-use efficiency in agriculture and elsewhere. Westlands provides information and data to its water users to help them take advantage of that technology.

The district acknowledges grant assistance from the U.S. Bureau of Reclamation and the California Department of Water Resources, which have provided partial funding for the efforts described here. Contact Russ Freeman at rfreeman@westlandswater.org.

**References**
- Pecos River, continued from page 27 mid-April. The NMISC is finalizing details for the design of a complementary well field located in the middle RAB. Some water rights purchased will be transferred to the well fields.

**NEPA:** Two environmental impact statements (EIS) are being completed by the NMISC as a joint-lead agency with the Bureau of Reclamation. The Carlsbad Operations and Conservation EIS that proposes to re-operate Summer Dam for the benefit of the Pecos bluntnose shiner fish will be completed in June 2006. The Long-Term Miscellaneous Purposes Contract EIS proposes to change Carlsbad Project water from irrigation to other uses (in this case, state line delivery) and should be completed in March 2006.

**Conclusion**
As a result of signing the Carlsbad Project Settlement, adjudication costs have been drastically reduced and the adjudication process has been expedited. However, the settlement has not yet been fully implemented. Currently, it is estimated that an additional $63.6 million will be required for full implementation. The settlement may ultimately fail if the funding to support the acquisition program is not provided. This may leave strict priority administration as the only means to remedy a net delivery shortfall. Priority administration will be costly, difficult, and highly contentious. It will require significant expenditures for administration, enforcement, and litigation with unpredictable and potentially disastrous results for Pecos River water users and the state of New Mexico.

Any opinions or positions expressed in this article are the authors’ and do not necessarily represent the opinions or positions of the New Mexico Interstate Stream Commission or the state of New Mexico. Contact Rebecca King at rking@ose.state.nm.us or Elisa Sims at esims@ose.state.nm.us.
Farmland, Water Rights Sold to Developer in AZ

Vidler Water Company, a subsidiary of Pico Holdings Inc., has agreed to sell 15,470 acres of Arizona farmland and an associated 42,000 acre-feet of groundwater rights for around $95.3 million, according to the Wall Street Journal.

The land is in the Harquahala Valley Irrigation District in west-central Arizona. The Wall Street Journal was unable to identify the buyer, a real-estate developer.

The sale was expected to close on June 30, 2005. According to the Pico Holdings Web site, the sale agreement covers all of Vidler’s water rights in Arizona, and the Vidler Arizona Recharge Facility water storage site would be Vidler’s sole remaining asset in Arizona if the sale is completed.


CA Cheese Company Above the Law...for a While

In December, the Sacramento Bee exposed the fact that for 16 years, according to the newspaper, the Hilmar Cheese Company in Merced County, the world’s largest cheese factory, released wastewater daily at a volume and salinity levels exceeding California’s Water Quality Control Board regulations for groundwater protection, while enforcers apparently looked the other way.

According to the Bee, the company released an average 700,000 gallons of waste daily onto nearby land leased from the company’s owners and supplying dairies. The newspaper’s investigation of state records showed that in the previous four years alone, the water board recorded at least 4,000 violations of drinking water laws by Hilmar, yet the agency never levied a single fine or injunction. Instead, the Bee found, the water board accommodated the company’s four requests over eight years to raise the limit on wastewater volume as production expanded. The Bee said that on Dec. 2, after its reporters had spent three months investigating the case, the water board finally issued a “cleanup and abatement” order.

What was going on? For one thing, the Bee found that Hilmar had close ties to the governor’s office. In 2003, the company donated $21,200 (the maximum allowed by a corporation) to Arnold Schwarzenegger’s gubernatorial campaign, and three months after taking office the governor selected the company’s founding partner and part-owner, Chuck Ahlem, as California’s undersecretary of agriculture. And from 1996 through 2000, the Bee said, Ahlem had served under Gov. Pete Wilson on the nine-member Central Valley Regional Water Quality Control Board, the agency that quietly allowed Hilmar Cheese to ignore its wastewater rules.

In recent years, various entities had begun to take notice of Hilmar’s activities. In 2001, new engineers and geologists with the water board filed the harshest inspection reports to date, according to the Bee, but further action was stilled. More recently, a state attorney general’s investigation was launched in response to neighbors’ complaints about odors, swarms of flies, and polluted tap water, said the newspaper. Hilmar’s public response over the years, as reported by the Bee, has been to maintain they are diligently working to improve their conditions, to “be a great neighbor,” and to comply with environmental standards. Ahlem has consistently maintained that he never sought special treatment for his company.

In late January, the Bee reported that Ahlem resigned from his position in the governor’s office on the eve of a state hearing on why the dumping went on for so long. He said he would return to the private sector and complete a wastewater treatment operation that will address his company’s environmental compliance problems.

The same day that Ahlem announced his resignation, the Bee learned, the California Environmental Protection Agency levied a $4 million fine against Hilmar Cheese Company for 1,039 days of pollution violations since January 2002. Additional enforcement actions may be forthcoming.

In March, the Central Valley Regional Water Quality Control Board acknowledged to the Bee that its investigation of the case had revealed a lack of state leadership in setting and maintaining enforcement priorities as well as a need for more inspectors. The Bee said that board directors learned at a hearing that each of the state’s nine water boards enters and tracks pollution enforcement data differently, and that, according to Kelly Briggs, enforcement coordinator for the Central Valley region, the Central Valley Board lacked a coherent system for prioritizing cases. Consequently, certain staff members have been assigned to work only on enforcement issues and top managers at the offices in Sacramento, Redding, and Fresno will begin to set priorities together, the Bee reported.

Visit www.sacbee.com

SRP and Phelps Dodge Reach Water Agreement

In February, Salt River Project (SRP) and Phelps Dodge Corp. signed a water agreement as part of the Gila River Indian Water Rights Settlement recently approved by the Arizona Water Settlement Act. The agreement settles water-rights issues and allows for the transfer of Blue Ridge Reservoir from Phelps Dodge to SRP.

The agreement is part of a long history of water agreements between the two parties. Their first joint effort was the construction of Horseshoe Dam, funded by Phelps Dodge and built by SRP between 1944 and 1946. In return, Phelps Dodge received water credits through an exchange agreement with SRP for use at Phelps Dodge’s Morenci...
copper mine. Horseshoe Dam provides additional water-supply security in the Salt River Valley. In order to meet its need for additional water, Phelps Dodge built Show Low Lake in 1952 and Blue Ridge Reservoir in 1965. Phelps Dodge and SRP entered a second water-exchange agreement in 1962 to cover diversions and exchanges of water from these facilities.

This latest agreement confirms each party’s respective water rights in the watersheds of the Salt, Verde, and Gila rivers. In addition, it provides SRP the opportunity to acquire Blue Ridge Reservoir and its water production facilities – fulfilling Phelps Dodge’s obligations under the 1962 agreement to offer the reservoir to SRP. Phelps Dodge and SRP have agreed that if SRP acquires the reservoir, a portion of the water will be delivered to the Gila River Indian Community as part of the Comprehensive Gila River Settlement. Blue Ridge Reservoir, with a storage capacity of 15,000 acre-feet, is about 25 miles north of Payson in Coconino County.

SRP is the largest provider of water and power in the Salt River Valley (including Phoenix), delivering about 1 million acre-feet of water to a 248,000-acre area. Phelps Dodge is the world’s second largest copper producer, with about 4,800 employees at its mines and other operations in Arizona.


**Bohannan Huston Opens Denver Office**

Bohannan Huston Inc., an engineering, spatial data, and advanced technologies firm based in Albuquerque, has opened a regional office in the Denver area. The company was recently awarded two large contracts by the Colorado Department of Transportation to provide CADD (Computer Aided Design and Drafting) migration and custom training services.

Melvin Dahlberg has been named to head Colorado operations. Dahlberg has 26 years of engineering experience managing multidisciplinary civil, highway, and street design projects for public agencies.

Visit www.bhinc.com

**Carollo Wins Desal Projects**

Article originally appeared in Water Tech Online, Feb. 4, 2005

Carollo Engineers will be working to drive two desalination and concentrate (brine) management and disposal research projects to benefit Arizona’s public water, according to a Feb. 2 Carollo news release.

The first of the awards is from the American Water Works Association Research Foundation (AwwaRF) and will focus on desalination recovery enhancement and the minimization of concentrate volume, the company reported.

The second project, awarded by the Joint Water Reuse & Desalination Task Force (WateReuse Foundation, AwwaRF, Water Environment Research Foundation and the U.S. Bureau of Reclamation), will develop a method to help water utilities evaluate their brine disposal options, the release said.

Visit www.watertechonline.com

**Black & Veatch, San Antonio Collaborate**

Article originally appeared in Water Tech Online, Feb. 4, 2005

Working to meet its future water supply demands, the San Antonio Water System (SAWS) will be collaborating with water engineering consulting firm Black & Veatch on a program management contract, according to a Feb. 3 company news release.

Black & Veatch has entered the design phase of the project to help provide a greater amount of water by way of the Gonzales County Carrizo Aquifer Program, the release said. The program will include the development of wells, pumping stations, approximately 100 miles of transmission main, water treatment plant modifications, high-service pumping stations, and integration facilities, the company reported.

The new facilities are expected to be designed, constructed, and operational by January 2008. The program budget is approximately $300 million dollars for phase-one facilities, the release said.

Visit www.watertechonline.com and www.gccap.info/
Errol L. Montgomery & Associates, Inc., is seeking a hydrologist with advanced groundwater flow and solute transport modeling skills. The candidate should have an MS in Hydrology, Geology, or Soil/Water Science, and 3 to 6 years of experience. The preferred candidate would have skills in unsaturated/vadose zone modeling, hydrochemical modeling, and inverse modeling methods. Experience in supervision of well drilling and testing, preparation of lithologic logs, use of pressure transducers and data loggers, and water quality sampling is also preferred. Technical writing skills will be emphasized. The position is for our Tucson, Arizona office. Information about our company can be found at www.elmontgomery.com.

Please submit resumes to Hale Barter at hbarter@elmontgomery.com.
Nevada Water Group Holds Annual Meeting

The Nevada Water Resources Association held its 2005 annual meeting in Reno Feb. 1-3, with the theme “Growth, Water, and the Quality of Life in Nevada.” The keynote speaker was Nevada’s new state climatologist, Jeff Underwood. Panel discussions focused on the meeting’s theme, and concurrent sessions covered water quality topics such as nitrate and perchlorate contamination and EPA’s National Pollutant Discharge Elimination System stormwater permit requirements.

Mike Turnipseed, former Nevada state engineer and director of the Department of Conservation and Natural Resources, was awarded NWRA’s Lifetime Achievement Award. Christine Thiel, who retired from her position as deputy state engineer of Nevada last year, was also recognized. Diana Lefler was presented with an award of appreciation for her leadership in NWRA’s scholarship programs. Project of the Year was awarded to the city of Sparks for its effluent reuse program.


First AGWSE Ground Water Summit a Success

Nearly 400 people convened in San Antonio, Texas, in April to attend the first Ground Water Summit hosted by the Association of Ground Water Scientists and Engineers, a division of the National Ground Water Association. The four-day meeting included technical courses, field trips, keynote and guest lectures, a forum discussion, concurrent sessions, posters, exhibitors, and a student mentoring session.

While close to 30 percent of the attendees came from Texas, the remainder came from across the United States and nine other countries. Attendees represented federal agencies, academia, consulting, state and local agencies, and supporting products and services.

Technical sessions covered the topics of bioremediation, emerging contaminants, geophysical applications, integrated surface water and groundwater management, water resources in arid environments, groundwater education, groundwater in developing countries, water quality monitoring and data management, pathogens, groundwater law, and remediation technologies.

Of note were presentations by several distinguished speakers. Among these, T. Boone Pickens described his philosophy and attempts to export large amounts of groundwater from rural northern Texas to the urban centers of the state. Douglas Solomon, NGWA’s 2005 Darcy Lecturer, spoke about inert gas tracers in groundwater. William Woessner, the Geological Society of America’s 2005 Birdsall-Dreiss Lecturer, spoke about viruses and pharmaceuticals in groundwater impacted by septic system effluent.

Allen Moench, of the USGS, was presented with the John Hem Excellence in Science and Engineering Award for his work on the hydraulics of water-table aquifers and their interaction with surface water.

A Darcy Forum was held in which the future of the groundwater profession was discussed at length. No consensus was reached, but several strong themes emerged: the future of hydrogeology will be more interdisciplinary than ever; some hydrogeology problems are simply too complex to be solved; hydrogeology itself may be relatively mature, but its research future lies in expanding and meshing with other disciplines; and as scale and sample density improve (through such technologies as geophysics and remote sensing), they may open up new areas of understanding for hydrogeologists, much the way x-rays expanded the understanding of human health.

The 2006 Ground Water Summit is already being planned for next April, again in San Antonio.

Scientists’ E-mails Add to Yucca Mountain Woes

Yucca Mountain, the U.S. Department of Energy’s (DOE) targeted site for the nation’s high-level radioactive waste dump, has been the subject of controversy and scrutiny for more than a decade. Recently disclosed e-mails indicate research results may have been compromised, adding fuel to the controversy. DOE is tasked with demonstrating that waste buried in the repository will not reach the accessible environment – where anyone could be affected by it – for at least 10,000 years. This means they have to demonstrate that the geologic setting, in combination with the design of the waste containers, will isolate the radioactive waste, also taking into account any possible climate change that could occur in that time period. The opposition, led by the state of Nevada, is skeptical that such demonstrations can be made.

To carry out the complex investigations necessary in a way that would stand up to the considerable scrutiny of all involved, DOE implemented quality assurance/quality control (QA/QC) procedures designed to provide detailed documentation for all work performed.

U.S. Geological Survey scientists have performed much of the research on Yucca Mountain. In March, e-mails were uncovered by U.S. Department of Interior officials that proved that certain QA/QC procedures had not been consistently followed. Three USGS scientists’ communications obtained from 1998 to 2000 revealed, for example, that the date a computer code was installed was faked when a QA/QC audit requested the information and the modeler did not have it. Nevada officials pointed out that while that infraction might not be terribly serious, the revelation of that type of deception made them question everything else.

The e-mails concerned infiltration and climate models the scientists were developing. Infiltration is a key aspect of the Yucca Mountain demonstration: if too much water were to leak into the repository, the containers could rust and leak and contamination could seep out of the repository. And while the climate at Yucca Mountain is currently arid, under certain climate change scenarios it could be wetter, at which point knowing the hydrologic properties of the material above the repository would become even more essential.

The e-mails reflected an atmosphere of high pressure for the scientists to get accurate predictions as quickly as possible with minimal budget and support staff. They also indicated the researchers understood that their resulting numbers were extremely critical to the project, and that they were working long hours, often on their own time, to produce results. Finally, in the e-
mails the scientists indicated extreme frustration with QA/QC requirements, and acknowledged that they were not always following DOE procedures. Comments such as “delete this memo after you’ve read it” were sprinkled throughout.

The e-mails were released on the Web site of the House Government Reform Subcommittee on the Federal Work Force and Agency Organization. All names and some other details have been blacked out. The House subcommittee, chaired by Nevada Rep. Jon Porter, has been leading the investigation and conducting hearings. Porter has hired a full-time investigator to focus on Yucca Mountain.

In June, the Las Vegas Review-Journal reported that DOE had tentatively concluded that the scientific results were technically sound in spite of the QA/QC issues, but that the House subcommittee had made little progress.

Visit reform.house.gov/FWAO/.

Impacts of Recreation on Lake Powell’s Water Quality Studied

A recently released U.S. Geological Survey report describes levels of organic and inorganic constituents in water and sediment from two side canyons of Lake Powell during 2001 and 2002. The study evaluated the effects of visitor use on the water quality of the three canyons when visitation was low (winter) and high (summer). Volatile organic compounds, including benzene, toluene, ethylbenzene, xylene, and a fuel additive, MTBE, were present in water samples from Forgotten and Moqui canyons, where visitor use was greatest. Trace amounts of 33 organic wastewater compounds, including cholesterol, estriol, coprostanol, DEET, and EDTA also were present. Nearly all organic and inorganic constituent concentrations were orders of magnitude below U.S. EPA Maximum Contaminant Levels, however one sample from Moqui Canyon contained 3.1 microgram per liter (μg/L) of benzene, only slightly below the MCL of 5 μg/L. Bacterial samples were collected in areas where visitors congregated for recreational boating and camping. E. coli counts in some samples from Moqui Canyon beach areas exceeded the EPA-recommended limit. Organic and inorganic constituents in beach sediments generally were below detection levels. Concentrations of selenium, uranium, and arsenic, which are not associated with visitor use, were higher in Forgotten and Moqui canyons than in most fresh waters in the United States, averaging 1.5 μg/L, 4.7 μg/L, and 1.4 μg/L, respectively.

A third side canyon, Knowles, was used as a control canyon and was closed to boat traffic for the duration of the study. Except for minor concentrations of some volatile organic compounds and cholesterol, contamination from visitor use in Knowles Canyon was not detected.

Side canyons of Lake Powell, of which there are over 90, are the most popular recreation areas of the Glen Canyon National Recreation Area in Arizona and Utah. Millions of people visit Lake Powell each year for fishing, boating, camping, and day-use activities. Emissions from houseboats, personal watercraft, and speedboats, plus nonboating

see R&D, page 39
Underwood New CEO, GM of Metropolitan

from the Metropolitan Water District of Southern California

In April, Dennis B. Underwood, former commissioner of the U.S. Bureau of Reclamation, was named chief executive officer and general manager of the Metropolitan Water District of Southern California, the region’s major water importer and wholesaler. Underwood, who had been Metropolitan’s vice president of Colorado River resources, is the 12th general manager in the agency’s 77-year history. He fills the vacancy left by Ronald R. Gastelum, who retired at the end of 2004.

As a Metropolitan vice president, Underwood managed the district’s Colorado River matters and played a principal role in California’s development of a plan to bring the state’s water use in compliance with its legal apportionment for Colorado River supplies. He also helped forge a first-of-its-kind long-term program that would pay farmers in the Palo Verde Valley near Blythe to annually set aside a portion of their land, rotate their crops, and transfer saved water to urban Southern California. Most recently, Underwood helped negotiate one of the nation’s largest habitat conservation programs, covering 27 species along more than 450 miles of the lower Colorado River.

As CEO and general manager of Metropolitan, Underwood is responsible for implementing the policies of the 37-member board. He is Metropolitan’s chief spokesman and works with federal, state, and local officials, both elected and appointed, to carry out the district’s mission.


Phoenix Fires City Water Director

In February, the Arizona Republic reported that the City of Phoenix fired its water services director, Mike Gritzuk, who had been in the position for 17 years. This action came approximately a month after a “boil water” advisory was issued to the city’s 1.4 million water users. The boil water advisory was issued due to the detection of high turbidity entering the water supply at one of the city’s water treatment plants. The turbidity was attributed to increased mud, sludge, and other particulates in the runoff from recent heavy storms. At that time, only two of the city’s five water treatment plants were in service. The advisory lasted two days, and ultimately it was determined that no standards other than particulates were exceeded and public health was never endangered. However, news releases on the city’s Web site indicated the city’s leaders were unhappy with the timing and amount of information that was conveyed to them during the scare.

The Republic was unable to obtain specific reasons for why Gritzuk was fired; City Manager Frank Fairbanks told the paper simply that “his services were no longer needed.”

Gritzuk told the Republic that the firing came as a complete surprise to him, and that he planned to sue to recoup the severe damage to his reputation that the city’s reaction to his handling of the water scare caused. Gritzuk is involved in water issues on a national level. He holds offices in the national WateReuse Association, the American Water Works Association, and the Arizona Pollution Control Association, and is a member of EPA’s National Drinking Water Advisory Council.

Danny Murphy is currently the acting water services director. In April, the Business Journal of Phoenix reported that the water services director is one of seven top positions in the City of Phoenix’s 26 departments that remain open. Fairbanks told the Business Journal that permanent directors would not be decided upon until this fall at the earliest.


Sorooshian Wins NASA Award

Soroosh Sorooshian, a professor in the Civil and Environmental Engineering and Earth System Science Departments at the University of California, Irvine,
Hansen Named Arizona’s Engineer of the Year

A panel representing Arizona’s engineering community, the Engineers Week Committee, selected Lawrence Hansen of AMEC’s Earth & Environmental office in Tempe as Arizona’s Outstanding Engineer of the Year in February. The committee cited Hansen’s 30-year career in geotechnical engineering and his recent work to protect the public in rapidly growing areas of Maricopa County from potentially unsafe earthen flood-control dams.

Hansen’s work relative to earthen dams with severe embankment cracks and other problems resulting from subsidence-induced earth fissures has included investigation, analysis, design, and construction management of McMicken Dam, Vineyard Flood Retarding Structure, and Buckeye Flood Retarding Structure No. 1.

Hansen also was the principal engineer during a response to a significant failure of a mine tailings dam in central Arizona that threatened Phoenix’s drinking water supply and impacted public lands. He directed the development of designs to stabilize the site, ensuring that no further damage to public land occurred.

R&D, continued from page 37

activities introduce contaminants to the lake and to beach areas.


Kennecott to Begin Massive Utah Water Cleanup

What may be the biggest water cleanup project in the nation’s history began this spring when Kennecott Utah Copper Corporation handed out the first construction contract. The project is expected to turn an environmental mess into billions of gallons of clean drinking water for four Salt Lake Valley cities, according to a news release from Kennecott.

The contamination came from 100 years of mining activity in Bingham Canyon of the Oquirrh Mountains. Two huge plumes of salt- and sulfate-contaminated groundwater are moving slowly far below 50 square miles of the Salt Lake Valley. Much of the problem predates Kennecott. But at a meeting of the Jordan Valley Water Conservancy District (JVWCD), Kennecott acknowledged the root cause of the pollution. Said Louis Cononelos of Kennecott, “Many times, as well-intentioned as past generations of miners were, the controls they put in place simply were not adequate by today’s standards.”

Kennecott has already spent hundreds of million of dollars controlling the pollution, and will pay most of the cost of the groundwater cleanup. The Salt Lake Tribune reported that the company paid $37 million into a natural resources damage trust fund in 1995, now worth $62 million. The JVWCD will pay for “normal water development and treatment costs” during the remediation, according to the Tribune.

Richard Bay of the water district noted that “Kennecott shoulders the burden of the cleanup, and the district and the public share only the burden of conventional water treatment.

[It’s a] very good deal for the public.”

A contract was awarded to drill the first four of numerous wells that will tap the deep aquifer. A network of pipelines will carry the contaminated water to two reverse-osmosis treatment plants that will filter out most of the salts and sulfates. Together the plants are expected to convert 80 percent of the contaminated water to drinking-quality water that will be delivered to the cities of Herriman, Riverton, West Jordan, and South Jordan.

The original plan was to dump the waste from the filtration process right into the Jordan River. That idea met with so much criticism that the project was derailed for several years. The latest plan spares the Jordan River and puts the waste in Kennecott’s tailings impoundment. Later, it may be dumped directly into the Great Salt Lake, a possibility that could lead to future battles.

Kennecott expects the treatment project to take about four years to get fully underway.


Finding NEMO: Integrated Watershed Management and Educational Outreach

Kristine Uhlman, R.G., NEMO Program Coordinator, and D. Phillip Guertin, Ph.D. – University of Arizona

Rural Arizona communities and watershed partnerships are finding mapping support, hydrologic watershed modeling, and land-use planning resources through the Nonpoint Education for Municipal Officials (NEMO) Program of the University of Arizona’s Cooperative Extension.

Nonpoint-source water pollution—pollution that originates from a broad or diffuse area—results from a variety of human land uses, such as increased urbanization, agricultural practices, abandoned mine sites, forestry activities, home septic system failure, and construction site activities. These pollution sources cannot always be controlled at a single location and can only be curbed by implementing land management practices at multiple levels. Arizona NEMO integrates watershed management and planning with research-based, professional education in order to engage stakeholders and foster better land-use decisions. Emphasis is on the linkages between water supply and quality. In addition, NEMO supports the use of geographical information systems (GIS) to simulate and predict the impact of land-use changes.

Educational outreach is an important aspect of the NEMO program. Arizona NEMO organizes stakeholder-group workshops, publishes watershed-based planning documents on its Web site, and is developing a toolbox of Arid Region Best Management Practices. Arizona NEMO partners with and is funded by the Arizona Department of Environmental Quality (ADEQ).

Watershed-based plans include the identification of subwatershed areas susceptible to water quality problems and pollution, nonpoint-source pollution to control, and management measures needed to protect or improve water quality. In Arizona, excessive sediment is the principal nonpoint-source pollutant in 36 percent of the 409 stream miles classified as impaired. The impact of nonpoint-source sediment pollution is over three times greater than impairment caused by the next leading constituent, dissolved and particulate metals from abandoned mine sites. To identify subwatershed areas within the Bill Williams, Verde, and upper Gila watersheds that are at elevated risk of nonpoint-source sediment and abandoned mine-site related pollutants, NEMO applied GIS mapping and modeling tools to identify locations where implementation of management measures would optimize water quality improvement.

For example, for the Upper Gila Watershed Partnership, a NEMO project included hydrologic modeling to prioritize the location of stream restoration projects. The Automated Geospatial Watershed Assessment–Soil Water Assessment Tool (AGWA-SWAT) was used to illustrate the effects of land-use change on runoff and erosion across the Upper Gila watershed from the New Mexico border, and identified several subwatershed areas vulnerable to water quality degradation due to nonpoint-source sediment. Projects were identified within areas of concern and the partnership received two competitive grant funds totaling $182,600 from ADEQ’s Water Quality Improvement Grant Program. Another NEMO project included extending and improving road drainage culverts and stream bank protection structures to preserve, protect, and improve water quality by reducing sediment discharge and excess organic input to the San Francisco River. The Central Detention Dam Rehabilitation Project focused on debris and sediment clearing and invasive vegetation removal.

The arid climate and unique stormwater hydrology of Arizona, coupled with increased urbanization and development, will only exacerbate nonpoint-source water pollution. To ensure the sustainability of water resources, careful water management practices and wise land-use decisions are critical. Arizona NEMO is becoming an important partner for land-use decision makers, resource managers, and watershed groups across the state.

Visit Arizona NEMO at www.srnr.arizona.edu/nemo/ and the national program at www.nemo.uconn.edu. Contact Kristine Uhlman at kuhlman@ag.arizona.edu or 520-621-5951.
Review of MODFLOW-2000 and Packages

Eileen Poeter, Ph.D. – Colorado School of Mines, IGWMC

MODFLOW2000 (MF2K) is the most recent version of the U.S. Geological Survey’s public domain MODFLOW software for simulating flow in saturated porous media in three dimensions with a finite difference grid.

A Geraghty and Miller survey of more than 5,000 groundwater modelers conducted in 1993 indicated MODFLOW was the most widely used groundwater model in the world. More than 23,000 copies of MODFLOW were downloaded from the main USGS web site from 1990 to 2000. Its popularity has continued, in part due to the modularity of the program and the resulting ability of USGS and others to add capabilities.

MF2K includes observation, sensitivity and parameter-estimation options with a convenient “Parameter” approach that facilitates model setup. A wide range of conditions can be represented using “Packages,” including many recently released ones: The Hydrogeologic-Unit Flow (HUF) Package facilitates connection with hydrogeologic framework models such as EarthVision by populating the model grid with hydraulic parameters using defined hydrogeologic units. The Multi-Node Well (MNW) Package distributes flow in wells that intersect multiple model layers (for horizontal or angled wells, multiple nodes) and accounts for reduced pumpage caused by drawdown at the pumping well. The Geometric Multi-Grid (GMG) Package is efficient for solving large problems and is the first part of MODFLOW to be written in C rather than FORTRAN. The StreamFlow-Routing (SFR, replaces STR) Package routes surface water to streams and lakes, adjusting the river stage as stream discharge changes, such that flux to and from the groundwater system adjusts to the changing stage. The Subsidence and Aquifer-System Compaction (SUB3) Package simulates elastic compaction and expansion, and inelastic compaction of compressible fine-grained beds within the aquifer. Unsaturated flow packages are due out soon.

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SOFTWARE REVIEW

Review of MODFLOW-2000

Eileen Poeter, Ph.D. – Colorado School of Mines, IGWMC

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### THE CALENDAR

#### JULY 2005

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#### AUGUST 2005

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<tr>
<td>August 10-12</td>
<td>Interstate Technology and Regulatory Council and GRAC. MTBE &amp; TBA: Comprehensive Site Assessment and Successful Groundwater Remediation</td>
<td>San Francisco, CA</td>
<td><a href="http://www.grac.org/">www.grac.org</a></td>
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<td>August 16</td>
<td>New Mexico Water Resources Research Institute. 2005 New Mexico Water Research Symposium: Advances in Hydrology - Methods and Instruments</td>
<td>Socorro, NM</td>
<td><a href="http://www.nmsu.edu/conf/tc05/symposium.html">www.nmsu.edu/conf/tc05/symposium.html</a></td>
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<td>August 17</td>
<td>National Ground Water Association. Ground Water Data Management</td>
<td>Costa Mesa, CA</td>
<td><a href="http://info.ngwa.org/servicecenter/Meetings/index.cfm">info.ngwa.org/servicecenter/Meetings/index.cfm</a></td>
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<td>August 17</td>
<td>National Ground Water Association. Microbiology and Chemistry Enviro Active Well Sites</td>
<td>Costa Mesa, CA</td>
<td><a href="http://info.ngwa.org/servicecenter/Meetings/index.cfm">info.ngwa.org/servicecenter/Meetings/index.cfm</a></td>
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#### SEPTEMBER 2005

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#### OCTOBER 2005

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<tr>
<td>October 4-7</td>
<td>National Ground Water Association. Fundamentals of Groundwater Geochemistry (Oct. 4-5) and Applications of Groundwater Geochemistry (Oct. 6-7)</td>
<td>Orange, CA</td>
<td><a href="http://info.ngwa.org/servicecenter/Meetings/index.cfm">info.ngwa.org/servicecenter/Meetings/index.cfm</a></td>
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<tr>
<td>October 17-19</td>
<td>National Ground Water Association. An Introduction to Ground Water</td>
<td>Albuquerque, NM</td>
<td><a href="http://www.ngwa.org/pdf/e/course/133oct05.pdf">www.ngwa.org/pdf/e/course/133oct05.pdf</a></td>
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<tr>
<td>October 18-20</td>
<td>New Mexico Water Resources Research Institute. 50th Annual New Mexico Water Conference: New Mexico Water: Past, Present, and Future, or Guns, Lawyers, and Money</td>
<td>Las Cruces, NM</td>
<td><a href="http://www.nmsu.edu/conf/conf05/conf.html">www.nmsu.edu/conf/conf05/conf.html</a></td>
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#### NOVEMBER 2005

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<tr>
<td>November 3-5</td>
<td>California Groundwater Association. 57th Annual Convention and Trade Show</td>
<td>Sparks, NV</td>
<td><a href="http://www.groundh2o.org/events/events.html">www.groundh2o.org/events/events.html</a></td>
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<tr>
<td>November 7-10</td>
<td>Northern Arizona University. 8th Biennial Conference of Research on the Colorado Plateau</td>
<td>Flagstaff, AZ</td>
<td><a href="http://www.usgs.nau.edu/cond205/index.htm">www.usgs.nau.edu/cond205/index.htm</a></td>
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## Standalone Graphics Output in dwg Format
Drill&Log creates log graphics in AutoCAD dwg format without having AutoCAD installed. AutoCAD dwg versions 14 to 2006 are supported.

### AutoCAD Plug-in
For additional flexibility, Drill&Log includes an AutoCAD Plug-in that enables you to create profile sections, fence diagrams, paginated output, etc.

### LAS, Excel, ASCII support
Easily import data from various file formats into your database. LAS 2.0, Excel and ASCII formats are supported.

### 2D & 3D Log Graphics
Drill&Log provides 2D as well as georeferenced 3D log graphics — all in standard dwg format. This is a sound basis for the creation of solid models, fence diagrams, etc.

<table>
<thead>
<tr>
<th>Item No.</th>
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<tr>
<td>CN01670</td>
<td>Drill&amp;Log Standard Academic</td>
<td>$399</td>
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<tr>
<td>CN01669</td>
<td>Drill&amp;Log Pro Academic</td>
<td>$599</td>
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<td>CN01667</td>
<td>Drill&amp;Log Standard Commercial</td>
<td>$999</td>
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<tr>
<td>CN01668</td>
<td>Drill&amp;Log Pro Commercial</td>
<td>$1499</td>
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## Database Driven Log Archive
All your data is stored in a central database that can easily handle thousands of logs (both drillings and pile driving). The integrated project management facility helps you to create a structured log archive.

### Multi User, Network Enabled
Access your data from any number of workstations in your network at the same time — even edit data for the same log at the same time.

### Document Management
Host any external data files such as base maps, core photos, lab reports, etc. directly within the Drill&Log Database. Data can be accessed from inside Drill&Log as well as from any log graphics via hyperlinks.

### 2D log graphics: Fully customized log graphics offer an enormous amount of flexibility. Create your own log templates and create log graphics in dwg, dxf or dwf format without having AutoCAD installed.

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http://www.rockware.com/training.html

## TectoniCAD
AutoCAD program for visualization and analysis of geological structure data in 2D and 3D.

### Areas of Application
Sophisticated 3D presentation options enable the communication of complex geological situations.

TectoniCAD is used in all fields, where efficient communication of structural data is a must, e.g. in tunnelling, road construction, slope stability problems and various other engineering geology tasks.

In didactics TectoniCAD assures hands-on-experience concerning the principles of stereo projection:
- ASCII data import and export
- High quality rendering: material mapping, transparencies
- Extraction of profile sections
- Georeferenced 3D output
- Full model editing in AutoCAD

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<th>Item No.</th>
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<tr>
<td>CN01672</td>
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<tr>
<td>CN01671</td>
<td>Standard</td>
<td>$499</td>
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## LogPlot
An easy-to-use boring log plotting program with almost unlimited flexibility in log layout.
- Plot a single page log for shallow borings, or a multiple page/continuous well log for deep wells.

### Creating a Logplot Is Simple
1. Select Log Design
2. Enter/Import Your Data
3. Compile & Display Your Graphic Log

<table>
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<tr>
<td>CN01679</td>
<td>Single User, Commercial</td>
<td>$599</td>
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</tbody>
</table>

LogPlot has been widely used in the environmental, petroleum, mining and geotechnical industries since 1983.

## Over 200 Environmental & GIS Software Solutions at RockWare.com
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