



COLORADO WATER

Newsletter of the Water Center of Colorado State University

December 2006

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EDITORIAL

Recycling, Reusing and Reclaiming Our Water

Reagan M. Waskom, Colorado Water Resources Research Institute, Director

Samuel Taylor Coleridge's epic poem *The Rime of the Ancient Mariner*, written in 1799, spins the tale of a sailor whose ship was becalmed after he foolishly killed an albatross. As his shipmates perished one-by-one from thirst, the accursed mariner spoke the famous words:

*Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink.*

The Ancient Mariner's realistic, though dated view of saltwater and the madness it caused men thirsting for fresh water is a cautionary tale worth revisiting when you have a free evening. Our situation is a bit different, but Colorado and much of the World has issues of water quality and supply that may be an albatross about our necks if we don't solve the problems confronting us.

Interestingly, I've been involved in several conferences recently on issues related to water reuse and desalination. The Water Reuse Foundation held an outstanding conference in October on the subject of recycled wastewater and the American Society of Agronomy just held a symposium in November on the use of impaired waters. This past summer's Colorado Water Congress meeting featured discussion of reuse and desalination in the Middle East and the recent S. Platte Forum included a keynote by Dave Stewart on the treatment and use of produced water here in Colorado.

As we contemplate the increasing need and use of recycled water, you might ask if there is any water that is not reused. Are we currently drinking and bathing in recycled water? Absolutely! Although perhaps not as directly as some municipalities envision for us in the near future. Through the natural water cycle driven by our sun, planet Earth has recycled and reused water for millions of years. Water recycling, though, generally refers to projects that use technology to speed up these natural processes. Water recycling might be better thought of as "unplanned" or "planned." A common example of unplanned water recycling occurs when cities draw their water supplies from rivers that receive wastewater discharges upstream from those cities. In the South Platte basin we pride ourselves in stating that the water from the river has been used and reused six or seven times before it reaches Nebraska.

Only a small fraction (less than one percent) of the earth's fresh water is readily available for our use and it is estimated by the United Nations that the World's population is expected to be 7.8 billion by 2025. Furthermore, it is estimated that 30% of our accessible fresh water is currently used by humans and projections for the year 2020 estimate that we may be using 70% of the accessible fresh water by that time. Climate variability aside, this puts us perilously close to the limits of freshwater supply. Similarities in water and energy sustainability are often observed, however, unlike energy (many alternative sources are known) there is no known alternative to water. It is interesting to note that, like the Ancient Mariner, scarcity may also be imposed on us by limitations in water quantity.

While the above projections may be debatable, few will argue that much of our water goes to irrigation and that irrigation has been essential in increasing the world's food production in the past decades. Sustaining our irrigated lands while population grows will require conservation, as well as development of additional water sources. How do we as scientists and leaders in the stewardship of water resources address these growing needs amid a static resource base?

California has recently made a commitment to obtain 20% of the state's water from reclaimed wastewater and desalination by 2020. Other states and nations have similar goals for the use of these waters. One thing I've learned from the recent conferences I've attended is that the use and reuse of impaired waters is not an "if" scenario. Rather, it is a matter of how and when and can we do this without creating new problems for ourselves? In some cases such as California and Florida, the impetus for recycling wastewater comes not necessarily from a water supply need, but from a need to eliminate or decrease wastewater discharge to the ocean, an estuary, or a stream in order to meet water quality standards. Additionally, the ability to capture and reuse water is often limited by state water quantity laws and downstream compacts.

Agricultural fields are in many cases the best place to recycle impaired water and to gain some economic benefit in the process. However, due to the salts that are concentrated in recycled water, leaching is often required to sustain productivity. This creates its own water quality problems and may negate some of the water conservation benefits

as additional fresh water is often needed to leach the salts and maintain yields. The recent problem with E. coli on fresh spinach has also led to problems of public perception surrounding the use of recycled water.

Perhaps there is a need for us to engage more public dialog on the treatment, disinfection, and level of safety of recycled water for use on croplands, landscapes and parks. Additionally, many research questions currently exist. For example, we need sound scientific guidelines for irrigation water quality criteria/regulation, best management practices to sustain cropping systems receiving impaired waters, treatment guidelines on what level of water quality specific crops/soil systems need

to be sustainable, groundwater impacts from recycled water drainage and leaching, not to mention more information on the economic, social and policy implications of recycled water use.

The bottom line is that new thinking is needed to address the predicted fresh water shortages that will certainly occur in localized areas across the globe. The good news is that the science and technology needed to treat, disinfect and put impaired water to beneficial use is rapidly developing and will soon be in place to help conserve our water resources and help meet some of our future needs.

MEETING BRIEFS

Taking the Plunge: Colorado Water Basins Explored Research, Data Tools for Regional Water Decisions*

by Bridget Julian
Colorado Institute of Public Policy

The Colorado's Future 2006 conference on Oct. 6 brought together nearly 100 water stakeholders from around the state. Approximately half of the attendees were elected members of their local Colorado water basins; other participants included ranchers, engineers, municipal water providers, watershed representatives, researchers, and federal agencies.

Water researchers predict that Colorado's population growth and the concentration of that growth along the Front Range corridor means that more water diversions from agricultural use, and from Colorado's Western Slope, are likely. Water community members needed a place to discuss their common ground, as well as their differences, and decide how to manage changes in water allocations.

Recognizing this need, in 2005 the Colorado Legislature passed legislation known as "The Colorado Water for the 21st Century



Conference organizer and CIPP Director Lyn Kathlene shares a thought with Metro Roundtable member Bernie Zimmer.

Act" that created nine geographically defined state water basins, and mandated that specific interests, such as agriculture and recreation, be represented at each basin roundtable.

The Act also created an Interbasin Compact Committee to address statewide water issues. As the Interbasin Compact Process Overview explains, the act is intended to "change the dialogue on water throughout Colorado, broaden the range of stakeholders that will actively participate in the

state's water decisions, and create a locally driven process where the decision-making power is in the hands of those living throughout the state's river basins."

Additional funding gives these water basins the opportunity to conduct their own basin needs assessments. The results of these needs assessments will frame discussions about future water diversions and allocations within Colorado. The needs

assessment must address both water needs and availability issues, including:

- Consumptive and nonconsumptive water needs
- Available and unappropriated waters in the basin
- Projects or non-structural methods for meeting water supply needs

“A meeting was the natural next step to help water basin members prepare for the needs assessment,” says Lyn Kathlene. Dr. Kathlene is the director of the Colorado Institute of Public Policy at Colorado State University. “Our basin survey results, published in our 2006 report on water in Colorado, indicated that basin members had an array of values and perspectives that would define their needs assessment priorities. We decided that the 2006 Colorado’s Future conference would provide a useful first venue for a cross-basin dialog.”

The Oct. 6 conference focused on the next step of the Colorado Interbasin Compact Process, the upcoming basin needs assessments, and what kinds of research might answer questions raised by water providers and users. The needs assessments will be conducted by CDM and begin in 2007.

The meeting was produced by the Colorado Institute of Public Policy at Colorado State University, the Colorado Department of Natural Resources, and the Center for Policy Studies at the University of Colorado, Colorado Springs. Additional conference sponsors included the Colorado Water Resources Research Institute, Parker Water & Sanitation, Aqua Engineering, Aurora Water, Colorado Water Conservancy District, The Nature Conservancy, Northern Colorado Water Conservancy District, Pueblo Board of Water Works, and the Rocky Mountain Farmers Union.

Conference speakers included Eric Kuhn, Colorado River Water Conservation District; Dr. Dan Smith, Colorado State University; Tom Iseman, The Nature Conservancy; and



CU researcher Chris Goemans explains his work to Eric Wilkinson and Dave Merritt.

Jim Westkott, Colorado Demography Office.

The conference featured key basin assessment participants, including Eric Hecox, the manager of the Office of Interbasin Compact Negotiations, and Susan Morea, a vice president of CDM and the contractor selected by the Colorado Department of Natural Resources to conduct the basin needs assessments.

As basin members discussed their preparations and research efforts, it became

clear that every basin in Colorado is geographically and demographically unique, and each has its own perspective on how to approach a water needs assessment.

For some basins, pending federal decisions about endangered species protection and minimum water flows may greatly affect the use of basin water, and therefore possible water availability. Other basins, particularly those on the western slope of Colorado, face increased demand from non-consumptive uses such as recreation and tourism but lack a consistent framework for the incorporation of these water interests.

The eastern plains basins face their own challenges. Their agricultural water comes in part from well water. Wells are a junior right in Colorado water law, which means that they only receive their allotted water if all senior water rights are met. Colorado’s losses in recent court cases has resulted in sending more water downstream and this, combined with a recent drought cycle, has shut off wells in the plains.

All of the basins, however, have an overriding common interest: how to predict and meet the needs of all their various water stakeholders, including agricultural, municipal, industrial, environmental, and recreational users.

As basins struggle with questions of how to predict basin needs and meet



Members of the afternoon panel discuss Roundtable information needs with the audience.

anticipated water shortfalls, consumer behavior becomes an important factor.

Dr. Christopher Goemans from the Western Water Assessment presented results of a study of water demand and conservation done by Bobbie Klein and Christina Alvord of Western Water Assessment.

Their data highlight the complexities facing municipal water managers as they try to make predictions. For example, low-water landscaping reduces water usage. But precisely because the water demand is always lower, increasing the number of low-water landscapes reduces the amount of water that managers can count on saving when lawn-watering restrictions go into effect. And sometimes, consumer behavior is less predictable: given a gauge to ascertain exact household water usage, consumers in one Colorado area were careful not to consume enough water to put them into a higher fee bracket—but they consumed their full amount of water at the lower fee, which resulted in an overall increase in household



CSU Professor Dan Smith and Colorado River District Manager Eric Kuhn take a break.

water use. As these examples suggest, while policy and information can create or reinforce changes in consumer behavior, it is far from a simple, linear relationship.

Conference participants agreed that more conversations and information-sharing among water basins would be necessary as they prioritized their water concerns, and several participants offered to share research materials and templates with other basins. Regular basin meetings, sponsored by the Colorado

Department of Natural Resources, will be one means of facilitating this effort to address statewide water needs collaboratively.

The majority of the materials used at this conference, as well as conference proceedings, can be found at the Colorado Institute of Public Policy website, at <http://www.cipp.colostate.edu/conf/2006/index.htm>

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Related Web sites

Colorado Institute of Public Policy: <http://www.cipp.colostate.edu/>

Colorado Office of Interbasin Compact Negotiations: <http://dnr.state.co.us/Home/ColoradoWaterforthe21stCentury/IbccHome.htm>

Colorado Water Resources Research Institute: <http://cwri.colostate.edu/>

Natural Resources Law Center: <http://www.colorado.edu/Law/centers/nrlc/>

Western Water Assessment project: <http://wwa.colorado.edu/IbccHome.htm>

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Natural Resources Law Center: <http://www.colorado.edu/Law/centers/nrlc/>

Western Water Assessment project: <http://wwa.colorado.edu/>

MEETING BRIEFS

Conference Stresses Collaborative Watershed Efforts

by Cynthia Peterson, Colorado NPS Connection Editor

For the first time, four organizations that work to protect water resources in Colorado sponsored a joint meeting to highlight collaborative watershed initiatives.

The Colorado Watershed Assembly, Colorado Watershed Network, Colorado Riparian Association and Central Rockies Chapter of the Society for Ecological Restoration last month (CeRSER) hosted the “Sustaining Colorado Watersheds Conference: Science and Restoration through Collaboration.”

Speakers at the conference in Breckenridge underscored the theme by focusing on successful partnerships and collaborative efforts.

Russell George, Executive Director of the Colorado Department of Natural Resources, noting that water is “one of the toughest subjects people can get into,” discussed the state’s role in addressing water supply. He emphasized the collaborative approach taken by the nine basin roundtables, created by House Bill 05-1177, to address local water supply issues.

Rick Brown discussed the Statewide Water Supply Initiative (SWSI). Brown, manager of intrastate water management and development for the Colorado Water Conservation Board, reported on the progress of the technical roundtables formed under Phase II of SWSI. They attempt to break down geographic barriers and explore options related to future water management in Colorado.

Doug Kemper, Executive Director of the Colorado Water Congress (CWC), spoke about opportunities for “cooperation with limits” in the water arena. While noting that collaboration is often more difficult to sustain than develop, he discussed the CWC’s willingness to explore collaborative water management initiatives. He also said that additional

data and strong leadership will be important in creating successful collaborative programs.

John Carney, Executive Director of the nonprofit Colorado Water Trust, discussed the organization’s mission to acquire water rights to be used for conservation benefits. He said the Trust, established in 2001, is the only organization of its kind in the state. In addition to purchasing senior water rights to augment the Colorado Water Conservation Board’s instream-flow program, the Trust provides technical assistance to local governments and water-based conservation efforts. He said that the Trust’s partnerships, local expertise and funding are key elements of success.

The banquet keynote speaker was Robert Glennon. He is the Morris K. Udall Professor of Law and Public Policy at the University of Arizona College of Law and author of “Water Follies: Groundwater Pumping and the Fate of America’s Fresh Waters.” Glennon highlighted ecological changes to riparian systems caused by groundwater pumping. He outlined the various forces leading to over-reliance on groundwater sources and suggested innovative approaches to address the resulting complex problems.

Breakout sessions were offered on two tracks. The Collaboration in Watershed Planning and Health track included water quality assessments and data management tools. The Restoration Planning and Science track highlighted case studies and community-based restoration efforts.

In addition, a capacity-building workshop was offered to conference attendees, as were two field trips: one to mining remediation sites and another to view best management practices for reducing sedimentation from roads.



MEETING BRIEFS

17th Annual South Platte Forum Convenes: Honors Robert Ward's Contributions

From the Gold Rush to the Urban Crush: The Past, Present and Future of the South Platte River Basin" was the theme of the 17th Annual South Platte Forum held Oct. 25 and 26, 2006 in Longmont, Colorado. More than 200 people participated in sessions on the history of the basin and water supply issues including talks by State Demographer Elizabeth Garner on population growth, Division Engineer Jim Hall on management issues, State Climatologist Nolan Doeskin on climate, consulting engineer Dave Stewart on recycling water produced during oil and gas extraction, and many others. Highlights included a spirited discussion on the issues surrounding well augmentation and well shut downs in the basin and a keynote address by historian Tom Noel describing the early history of settlement and development in the basin. Former Division Engineer and amateur historian Dick Stenzel provided an outstanding overview of well development and regulation in the S. Platte basin, which has been summarized in the article beginning on the following page. For a copy of the program/proceedings, go to <http://cwri.colostate.edu>

Robert Ward was honored with the Friends of the South Platte Award at this meeting in recognition of his contributions to the organization over many years. The award includes a framed copy of the photo "South Platte Sunset," generously provided by John Fielder.

The 2007 South Platte Forum will be held in late October 2007. Watch www.southplatteforum.org for details.



Robert Ward receives the "Friend of the South Platte" Award from Organizing Committee Chair Don Kennedy.



Robert Ward receives congratulations from Andy Pineda, Nolan Doeskin and Don Kennedy.



Dr. Tom Noel talks South Platte history with conference participants.



Tom Cech and Chuck Howe discuss the South Platte well issue.

Wells: The Final Frontier

by Dick Stenzel

Presented at the 17th Annual Platte Forum

Water development within the South Platte River Basin initially occurred in the upstream portions of the basin near Denver and along its Front Range tributaries to meet agricultural and urban development needs. The return flows from irrigation recharged the alluvial aquifers, and caused a rise in base flow conditions in the lower reaches of the South Platte River began to flow year round.

As the flows in the lower river increased and reservoirs were constructed, additional development of the basins' water resources occurred. With an estimated storage capacity of nearly nine million acre feet, the South Platte aquifer represents a water resource many times larger than all the surface water storage that have been developed in the basin. This source of water became the next logical place that irrigators looked at to meet their irrigation needs.

The construction of the first high capacity irrigation wells in Colorado date back to over one hundred years ago. The first irrigation well of which there is any record was excavated by E.F. Hurdle, in 1886, in the Lone Tree Creek alluvium, located east of the town of Eaton. Hurdle not only constructed the first well, but also dug two others, at that time, in the same vicinity. Centrifugal pumps were installed which were operated by steam engines. This first irrigation well furnished water to eighty acres of land.

One of the earliest cases concerning tributary groundwater was also associated with the Hurdle well in the case of McClellon v. Hurdle which occurred in 1893. McClellon was the owner of 400 acres of land in Weld County. In 1886 he had filed the necessary papers to secure a water right and constructed diversion works to irrigate his land from Lone Tree Creek. E.F. Hurdle dug the well I discussed previously that same year and later McClellon believed he was injured by the well pumping. The court held that Hurdle had not invaded the rights of the prior appropriator but also held that it is an invasion of the rights of a prior appropriator to divert water from a stream—surface or subterranean—by means of dams, wells, or pumps, whereby the flow of a senior surface water right is diminished and results in injury. However, in this case the court felt that the evidence was vague and indefinite and did not approve the claim for damages.

Between the period of time from Hurdles' first irrigation well and 1930 approximately 300 high capacity irrigation type wells were constructed. With the advent of the electric pump and electric networks which extended power lines into the rural areas of Colorado, additional groundwater development

ensued. The groundwater supplies were not subject to drought and thus were more reliable. The increase in the number of high capacity irrigation wells was another 1400 wells.

The drought of the 1950's saw even more development of irrigation wells and by 1960 approximately 1200 new irrigation wells had been constructed. Prior to 1957, a permit was not required to construct a well and ground water was not managed or allocated by the State. The Colorado Ground Water Law of 1957 required a permit from the State Engineer as a prerequisite to drilling a new well and obtaining a new ground water right. The law also made provisions for the registration of existing wells.

Even though there were a few early water court decisions regarding the wells and surface water rights dating back to the Hurdle case in 1893, the connection between ground water and surface water was not well understood. Some of the earliest State Engineers expressed concerns about the impact alluvial wells might have on surface water rights. Many people believed that ground water was separate from surface water and that the pumping of ground water could not affect surface streams. Consequently, ground water was generally considered to be outside the priority system, and wells were not adjudicated or regulated in Colorado for many years.

By the 1960s, thousands of irrigation wells had been drilled along the South Platte, and surface diverters began to assert that ground water pumping affected the surface flow. The legislature responded by passing the Groundwater Management Act of 1965. It affirmed the prior appropriation system also applied to tributary ground water and directed the State Engineer to administer the distribution of tributary ground water in accordance with the priority system. The 1965 Act also required a well permit be obtained from the State Engineer for the construction of any new well.

Even after passage of the 1965 Act, there remained the problem of bringing wells into the priority system. In some cases, unadjudicated wells had been allowed to operate for many years and the well owners believed that their rights to ground water had been vested.

The General Assembly had given the State Engineer the difficult task of curtailing junior wells for the benefit of senior surface water rights. The problem of administration was aggravated by the fact that there is often a lag time between pumping and the effect on the stream. This meant that the curtailment of a well would not immediately make more water

available for a senior surface diverter.

In 1968 the Colorado Legislature authorized a study by consultants to determine the impact of junior wells constructed in the 1940's and later. The study found that wells were reducing stream flows. The Water Right Determination and Administration Act of 1969 was designed to integrate tributary ground water and surface water use and provide maximum utilization of the water resource by allowing for flexible "plans for augmentation." As an incentive for the well owners to adjudicate their wells and join the priority system, the 1969 Act provided that water court applications to adjudicate wells filed before July 1, 1972, would not be subject to the postponement doctrine and the wells would be given a priority relating back to the original appropriation date.

Furthermore, the act stated the State Engineer could promulgate rules to assist in the administration of wells. State Engineer Kuiper began rule making in 1970 to curtail wells on graduated basis unless wells were operating in accordance with a court approved augmentation plan or a substitute supply plan approved by the State Engineer under CRS 37-80-120. The rules were challenged by a well owner organization and a 4 week trial took place in 1974. The trial was recessed and the parties stipulated to a decree incorporating the rules as proposed. The passage of Rules and Regulations of South Platte River, in 1974, required all existing and new high capacity non exempt type wells to replace their depletions to the affected stream systems of the South Platte.

Well owners were encouraged to form associations or conservancy districts to develop plans to replace well depletions that occurred when there was a call on the South Platte River, which in the 1970's up through the 1990's was usually during the months of July and August.

The Groundwater Appropriators of the South Platte (GASP) was established in 1972 to augment 3,000 wells and the Central Colorado Water Conservancy District's Ground Water Management Subdistrict was formed in 1973 to cover 1,000 wells. Some well owners like those under the Fort Morgan and Reservoir Company, Bijou Irrigation Company and the Poudre River Well users sought and obtained water court decreed plans for augmentation.

The GASP and CCWCD organizations operated under annual replacement plans, or substitute water supply plans ("SWSP") approved by the State Engineer. Both plans relied on the fact that the period for senior calls was very limited due to good runoff conditions and the fact that there was a Gentleman's agreement during the winter to not place reservoir calls.

The South Platte Rules and Regulations as approved in 1975 required that a replacement amount equal to 5% of the projected annual volume of ground water diversions be made available to the Division Engineer. The Division Engineer was to use

the water at a rate of flow sufficient to compensate for any adverse affect on lawful water requirement as evidenced by a valid senior water right call, but a rate not to exceed 5% of the capacity of the calling diversion structure.

Later on, the Division One Office required replacement of out of priority depletions as calculated by using the SDF method. Since most of the irrigation wells did not have meters, the amount pumped was determined by first calculating the potential consumptive use of crops grown by the member wells and then determining how much supplemental ground water was needed after the surface water supplies were utilized.

More detailed accounting of the replacement activities by both GASP and Central of the replacement sources and deliveries was begun in 2000 to assure adequate replacement was being made in a timely manner. Spreadsheets were developed maintained in the Division One Office to track river calls, depletions and replacements. The depletion amounts were based on model runs of well depletions that were provided by GASP and Central. The replacements were from various surface water ditches; reservoirs, augmentation wells and recharge projects, and leased municipal reusable effluent. The detailed accounting assured that replacements were made day to day whenever a river call existed. There was a coordinated effort on the part of both entities to trade any excess augmentation supplies available in a given reach of the river in order to maximize their replacement supplies.

The Empire Lodge decision in 2000 ruled that the legislature did not give the State Engineer authority to approve SWSP's. This decision was upheld in the Supreme Court. The water court decision had a direct impact on the annual approval of SWSP's in the South Platte River basin since the State Engineer no longer had the authority to approve SWSP's.

In 2002, the Legislature passed HB 02-1414 which allowed the State Engineer to approve an SWSP if an application for a plan for augmentation was pending in Water Court. This bill also required notice to interested parties and allowed a plan to be appealed to the Water Court.

The State Engineer filed new well use rules in May of 2002 that were nearly identical to the rules promulgated in the Arkansas River basin in 1996. These rules would have allowed the State Engineer to annually approve SWSP's that met the much more stringent standards than existed with the 1974 Rules and Regulations.

These rules were challenged as unconstitutional by some objectors in 2002. The Judge Klein ruled and the Colorado Supreme Court later agreed in 2003 that annual approvals of replacement plans were not allowed by statute.

The Legislature approved SB 03-73 in March of 2003 giving well organizations in the South Platte River basin up to three

years to file a plan for augmentation with the Water Court and allowed the State Engineer to annually approve a SWSP after conducting a hearing.

River calls in 2003 occurred nearly the entire year. There were several reasons for the extended periods of call occurring. As the need for recharge credits increased, the downstream reservoirs could not take a chance that they might not fill. The gentlemen's agreement that had existed for so many was discontinued. Further the pressure on well owners to reduce their depletions to the river resulted in many ditches starting the ditch operations earlier than had occurred when wells were being used to provide the first irrigation water.

Many GASP well owners who had developed augmentation sources prior to 2002 withdrew from GASP and decided to proceed with the development of their augmentation plans or decided to rely upon or improve their decreed plans for augmentations which had been approved in the past.

Excess augmentation credits that historically were shared by those well owners mentioned above had historically been used in the GASP plan for the remaining well owners in GASP who had not developed their own augmentation supplies. GASP also leased additional sources of augmentation water to cover these well owners' depletions who had not developed augmentation sources. The drought saw many of the municipal augmentation sources that were historically leased by GASP were significantly reduced and the cost of leasing the water increased to the point where GASP could not justify acquiring the water.

In 2003, GASP filed for approval of a SWSP under SB 03-73 and the plan was approved to allow for replacement of ongoing stream depletions that resulted from past pumping, but no pumping was allowed. All of these actions resulted in GASP deciding to go out of business. GASP finished its sale of water assets in 2006.

The South Platte Well Users who were former GASP members filed two augmentation plans with the Water Court in May of 2003 and sought approval of a SWSP for 380 wells. The plan was approved in June of 2003. In 2004, CCWCD established the Well Augmentation Subdistrict (WAS) which included the above 380 wells and 61 additional wells.

In GASP's stead, other groups were formed. These groups were mainly associated either with areas such as a part of a County or ditches. The groups filed augmentation plans in water court. All of the largest ones except the Lower South Platte Water Conservancy District in District 64 and WAS have been decreed.

In conclusion, due to the increased demands on the South Platte River over time, additional water was imported into the South Platte River Basin through trans-basin diversions, primarily from the Colorado River Basin. The South Platte Rivers annual flow at the Henderson Gage is greater under current

conditions when compared to the historic flows. The same is true at the Colorado - Nebraska State Line. The increased flow is partially a result of wastewater discharge, lawn irrigation return flows from trans-basin diversions and not nontributary and nontributary ground water pumping. In addition, urban development in the South Platte River basin has changed the surface runoff characteristics. The increased impervious surfaces and the storm runoff from these surfaces have increased the surface flows.

Today, as municipalities seek to capture and reuse their imported water supplies we can expect to see less water being available to farmers. I believe this will result in river calls becoming more frequent and also more senior than we have seen in the last 20 to 30 years.

We are also seeing the length of calls increasing from what occurred in the period from the 1970's to 2000. This is in part due to farmers reducing their use of wells in order to reduce their augmentation requirements and the reduced stream flows that are the result of lower than normal precipitation in the years since 2002. Even when precipitation increases in the future, the anticipated reduction in reusable supplies from upstream municipalities and the reduction in the use of wells to meet irrigation needs will continue to increase the period of time that we see river calls in the basin during the summer.

The historic lack of river calls from November through March will probably cease to exist since reservoirs need to place calls to assure that they can fill their reservoirs and not have compete for the water that otherwise will be diverted by junior recharge water rights. The calls may also be necessary due to less reusable water supplies being available during the summer that resulted return flows during the winter.

The number of center pivot systems that exist today and that are still being installed in the South Platte River basin will also further impact future stream flows. This is because the center pivots increase the irrigation efficiencies, while at the same time reducing recharge to the groundwater alluvial system. It makes one wonder what the call regime will look like in the coming years.

Wells do improve agricultural productivity in the South Platte Basin by increasing the farmer's flexibility. Wells are also an effective buffer from a drought. However, wells must also have adequate augmentation plans to protect senior water rights from any injury associated with the lagged depletions from well pumping.

This presentation (along with others from the 17th Annual South Platte Forum) is available at:
www.southplatteforum.org



Colorado Groundwater: Learning from the Past

by Patricia J. Rettig

Head Archivist, Water Resources Archive, Colorado State University Libraries

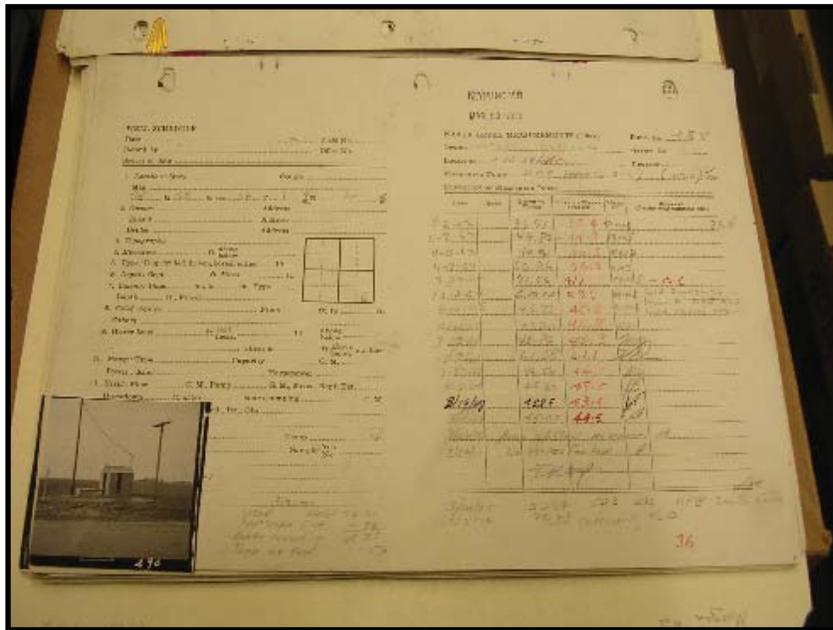
It is cliché to say that the more things change, the more they stay the same. But then, clichés are usually all too true.

Formulation of legislation which will allow and encourage the integrated management, administration and use of surface water and groundwater, without infringement of present vested rights, will require considerable ingenuity on the part of the attorneys and legislators involved.

Though this statement could very well apply today, it was written nearly forty years ago. Morton W. Bittinger and Kenneth R. Wright made the statement in the cover letter submitted with their August 1968 “Report on Engineering Water Code Studies for the South Platte River.” Authorized by the Colorado General Assembly, the study by the engineering contractors was intended to lead “to recommendations for legislation which would provide for the integrated use of ground and surface water and to a fuller utilization of the waters of the State” (p.1).

How well the attorneys and legislators succeeded is still a contentious issue in the state today. The study ultimately led to the Water Rights Determination and Administration Act of 1969, which required surface water and tributary groundwater rights to be administered together. Adjudication of tributary

wells and augmentation plans became part of the state’s water law, as did the water court system. Other legal changes have taken place in subsequent years, but the Bittinger-Wright report is often identified as a significant turning point for the state, in part paving the way for the recent closure of wells on the eastern plains.



Just one of the thousands of pages of well data in the Groundwater Data Collection.

The Bittinger-Wright report can be found in the Groundwater Data Collection, one of numerous rich resources in the Water Resources Archive. While many significant subjects are documented in the Archive, groundwater is one of the more prominent. In addition to the Groundwater Data Collection, other collections holding related information include the Bittinger Papers, the Delph Carpenter Papers, the Robert Glover Papers, and the recently donated GASP Records.

The Groundwater Data Collection

In addition to various reports about groundwater in the state, the Groundwater Data Collection also holds box after box of data. Of special significance is the data collected by William E. Code, the “father of Colorado groundwater studies.” His sixty field books in the collection contain meticulously handwritten notes dating from the 1920s through the 1950s. Other data in the collection includes thousands of pages of observation

well data, primarily from the 1950s and 1960s. The data was collected by CSU personnel for a long-term Agricultural Experiment Station project; related reports are also in the files.

Also documented in this collection are groundwater studies CSU personnel conducted in various Colorado locations, including in the Arkansas and San Luis valleys, but those in the South Platte Valley are the most extensive. Projects there included the Kiowa Creek natural recharge study and the Prospect Valley and South Platte Ditch artificial recharge studies. In addition to the data, reports, and correspondence associated with these studies, there are over 300 related maps, charts, and drawings.

The Papers of Morton W. Bittinger

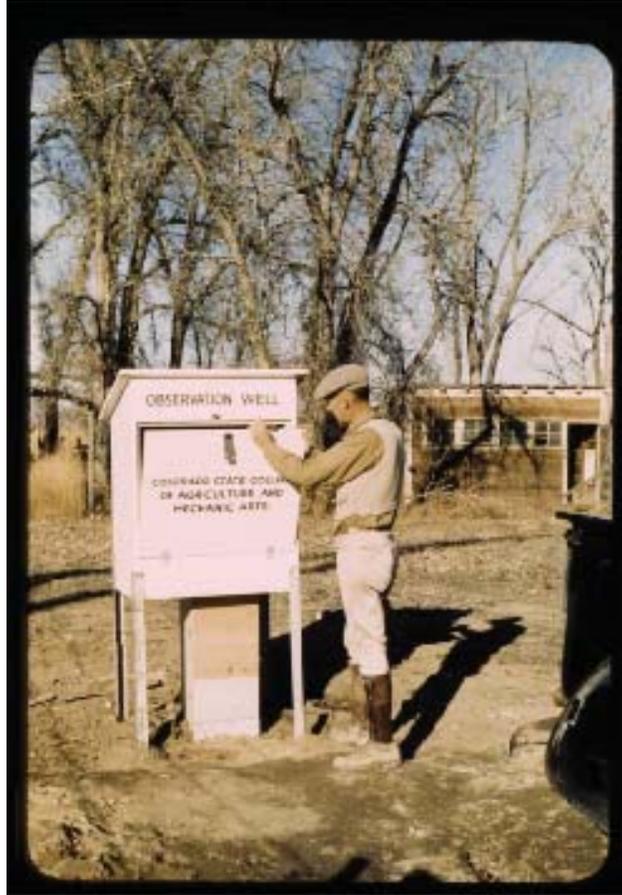
Mort Bittinger began his own consulting firm after leaving Colorado State University. As a CSU professor of civil engineering from 1957 to 1967, he was in charge of groundwater research. Among his many contributions was the application of computer technology to solving groundwater problems. Though the collection of his materials in the Archive is small, it is significant. The Bittinger Papers solely contains documents written by him. Though not comprehensive, it does gather significant pieces of his work in a single location.

The Papers of Delph E. Carpenter and Family

Though Delph Carpenter is mainly known for his interstate compact idea, some research he conducted turns out to be very relevant to today's groundwater issues. In preparing for a lawsuit over the South Platte in 1918, Carpenter interviewed some "old timers" about the river. Nearly ninety years later, these sworn statements give early testimony that the river once ran dry in certain places at certain times of the year. The collection also contains some relevant reports written by other people, including those on seepage measurements and return by R. G. Hosea.

The Papers of Robert E. Glover

A Bureau of Reclamation engineer for over thirty years, Robert Glover studied hydraulics, the trial-load method, and the



A Colorado A&M observation well, 1942. From the Groundwater Data Collection, Water Resources Archive.

thermal properties of concrete in addition to groundwater issues. Among his extensive body of work, he developed a number of equations that have helped others solve groundwater problems. He also later taught at CSU in the 1960s and 1970s, developing a course on groundwater. His collection of materials—still in process at the Water Resources Archive—contains voluminous files of documentation of his studies, the development of his equations, the notes for the courses he taught, publications by others on topics of interest, and much more, including numerous photographs, slides, and maps.

The Records of GASP

Established in 1972, GASP (Groundwater Appropriators of the South Platte) has been a major player in the basin's water supply planning and utilization. Recently shut down, the organization has begun cleaning out its offices and donating its records to the Water Resources Archive. Not

yet fully inventoried, the collection is known to contain annual membership lists from its beginning through the 1990s along with various well and contract information. The collection will also eventually contain meeting minutes and other kinds of documentation.

Learn From the Past

Taken together, these collections as well as other holdings in the Archives and Special Collections Department of the CSU Libraries contain significant facts, documentation, and data that the public can use to tell the story of groundwater studies, law, and policy in Colorado. This is a significant story, continuing to effect people's lives. Knowing how the state got to the present situation can be very instructional, even leading to increasing understanding of how to solve ongoing problems. The "considerable ingenuity" needed forty years ago is still required today and can be bolstered by learning more about the history of Colorado's groundwater.

For more information about any of the materials described here or other holdings of the Water Resources Archive, visit the website [<http://lib.colostate.edu/archives/water/>] or contact the author (970-491-1939 or Patricia.Rettig@ColoState.edu).



Update on the Construction of the Weighing Lysimeter in the Arkansas Valley

by Mike Bartolo, Dale Straw, and Bret Schafer

In 2004, plans were implemented to construct a large weighing lysimeter in the Arkansas Valley. Ultimately, the lysimeter will address the longstanding issues raised in Kansas v. Colorado over crop water use. More specifically, the lysimeter will be used to validate the Penman-Monteith method for assessing crop evapotranspiration and develop crop coefficients for various crops grown in the Valley.

To insure that the lysimeter was successfully designed, constructed and put into use, the Colorado Division of Water Resources, Colorado State University, and USDA-ARS formed a multi-person team to bring the project to fruition. Dr. Thomas Marek, Texas A&M University, designed the lysimeter based on others that were operating in Texas.

The actual design and construction of the lysimeter involved a number of activities, most notably, the hard work and dedication of many individuals. This report is intended to highlight a few of the steps in the construction process.

One of the first tasks of the lysimeter project was to choose a site that was representative of the Arkansas Valley. A logical choice was CSU's Arkansas Valley Research Center, centrally located one mile east of Rocky Ford. At the Research Center location, a large enough field was needed (10 acres minimum) to adequately allow for a crop border around the lysimeter. Once the field and site location were determined, a thorough evaluation of the soil structure and depth to ground water was conducted (Figure 1).



Figure 1

One of the more critical phases of the entire project was the design and construction of the metal housing components (inner and outer tanks) of the lysimeter. Fabrication of the large metal structures was primarily done at the USDA-ARS shop in Fort Collins. Once completed, the components were transported to Rocky Ford for further assembly and installation.

The acquisition of the monolith (filling the inner tank with soil) was a major step that involved first, securing anchors to the bedrock and second, pushing the tank into the soil via heavy duty hydraulic jacks (Figure 2). This technique was employed to maintain the integrity of the existing soil structure.



Figure 2



Figure 3



Figure 4

Notably, the acquisition site was located several hundred feet from the final lysimeter site to avoid excessive soil compaction.

Once the monolith was acquired, pipes were bored beneath the inner tank (Figure 3) to hold the soil in place and secure the tank for lifting. The inner tank, now weighing 45 tons, was then lifted and inverted (Figure 4) so that a drainage system could be installed (Figure 5).



Figure 5



Figure 6

At the actual site of the lysimeter, the foundation that would seat the outer tank was secured and poured (Figure 6). Once in place, the outer tank was fitted and secured to the foundation and the scale (Figure 7) and other interior components installed.



Figure 7



Figure 8

Next, using heavy duty cranes, the monolith was re-inverted, transported to the lysimeter site, and carefully placed inside the outer tank (Figure 8). Other fitted metal components, collectively termed the "top hat", were welded in place



Figure 9

to complete the tank structure and make it watertight (Figure 9).

Electricity and communication lines were run to the site and inside the lysimeter.

Then, electrical

outlets, phone lines and data loggers (Figure 10) were installed. After additional groundwork, the load cell on the lysimeter scale was calibrated (Figure 11) using a series of weights. As of November of 2006, the lysimeter was recording data.

During the upcoming fall and winter, additional ground preparation will take place. In spring 2007, the lysimeter and surrounding field will be planted with alfalfa. The current plan is to maintain the alfalfa for three to four years during which time a second smaller "reference" lysimeter will be constructed and planted to a reference crop (alfalfa). Thereafter, other crops will be grown on the main lysimeter and their respective crop coefficients determined.



Figure 10



Figure 11



Figure 12



Understanding the Behavior of the Colorado River System Under Uncertain Streamflows

by Julia A. Keedy, Jose D. Salas, Darrell G. Fontane
Colorado State University

David H. Merritt
Colorado River Water Conservation District

Problem

The Colorado River is one of the most important rivers in United States. The water supply provided by the Colorado is critical for a wide range of water users in seven western states. Over 25 million people in the western states depend upon the Colorado River. However, Colorado water resources are under great stress due to the increasing population growth and climate variability. Understanding the variability of the river flows and its effects is important to water planners and managers of the system. The historical streamflow records of the Colorado are useful because they document the flow variability that has occurred in the past. But, the historical record is only one snapshot of an infinite number of streamflow sequences that could occur in the future. The full picture is not revealed in that one sequence. In fact, it is very unlikely that an identical sequence will ever occur again in the future. This study evaluates two alternative approaches which improve the understanding of the behavior of the Colorado River system beyond that provided by the historical record. Recently, the inability of the Colorado River's historical record to capture the system's variability has become apparent. The four-year period from 2000 to 2003 has been the driest of the 98-year historical record. Prior to 2003, this drought was not included in long term planning analyses because it had not yet occurred. This drought reemphasized that the historical record is not robust enough to simulate the possible range of future conditions.

Approach

This lack of robustness is a perpetual problem. However, further insight to possible future flows can be obtained using alternative approaches that are trained by the historical record. One approach is to use tree-ring reconstructed streamflows. Tree-ring indices can be used from the present back to the end of the 15th century in order to reconstruct flows in the Colorado River system. This process creates a record that is more than five times as long as the historical record. Another approach is to generate synthetic streamflow using a statistical model based on the historical streamflows. Once a model is developed, any number of synthetic streamflow traces of any length can be created. These two approaches are compared to

the historical records by running the traces through a computer model that simulates Colorado River physical processes and operational procedures. The outputs of the model, in the form of reservoir releases and reservoir levels, are analyzed for comparison.

Streamflows

Three different streamflow datasets are compared, the historical streamflow, the tree-ring reconstructed streamflow, and the synthetically generated streamflow. The historical records are naturalized streamflows at 29 stations throughout the Colorado River basin (Fig.1). The naturalized dataset spans the period 1906-2003 on a monthly timescale and was developed by the U.S. Bureau of Reclamation (Reclamation) and Colorado State University (CSU).

Tree ring indices were obtained from the Paleoclimatology Branch of NOAA, Boulder, Colorado. The tree-ring reconstructed streamflows were developed by CSU in collaboration with Reclamation. Appropriate tree ring indices from a collection of trees sampled in and around the river basin were used to reconstruct streamflows back to 1490 at four stations: the Colorado River above Imperial Dam, AZ; the Colorado River at Lees Ferry, AZ (Lees Ferry); the Green River at Green River, UT; and the Colorado River above Cisco, UT. Then, spatial disaggregation models were used to obtain the reconstructed streamflows at other sites for the entire basin. Finally, the stations were grouped and temporally disaggregated to create monthly streamflows for each station.

The synthetic streamflows were generated using a stochastic model implemented in the statistical software package SAMS developed by CSU. A bivariate autoregressive order-1 model was fit to the historical annual streamflows of two key stations: Lees Ferry and an index station comprising the sum of the intervening flows in the Lower Basin and the Paria River at Lees Ferry, AZ. These two stations were chosen because Lees Ferry streamflows are important for policy decisions involving lakes Powell and Mead, and the Lower Basin and Paria River streamflows contain the remainder of the system inflows. The model scheme included the



disaggregation of the key stations into their upstream stations. Two spatial disaggregation steps were used to disaggregate the flows at the Lees Ferry station into 20 upstream intervening stations, and one disaggregation model was used to split the Lower Basin sum into the corresponding 9 intervening stations. Finally, the stations were placed into appropriate groups in order to disaggregate the annual streamflows into monthly streamflows. After the complete model was defined, 100 traces, each 71 years long, were simulated resulting in 7,100 years of synthetic flow records for each of the 29 stations.



Figure 1. Colorado River system showing the location of 29 sites. Site 20 corresponds to the Lees Ferry station, Lake Powell is near site 20, and Lake Mead is near site 25.

A comparison of these three sets of streamflow was made in order to determine their statistical characteristics. The analysis is based on the flow at Lees Ferry because the station comprises the majority of flow in the system and is commonly used for reference and comparison. Determining the basic statistics of each approach gives a basis for comparison. Figure 2 illustrates the historical and tree-ring reconstructed streamflows at Lees Ferry. The thin line is the annual streamflow volume, and the thick line is the five-year running average of the annual volume. The tree-ring reconstructed streamflow has the same general pattern as the historical streamflows, only with several more extreme single-year and five-year streamflow sequences.

The historical annual streamflow averages just over 15 million acre-feet (MAF) and covers a range of 5.4 to 25.4 MAF with a standard deviation of 4.4 MAF. The tree-ring reconstructed annual streamflow averages just under 15 MAF and the standard deviation is about 4.5 MAF, very similar to those of the historical record. As expected with a longer period of record, the tree-ring streamflows cover a wider range than the

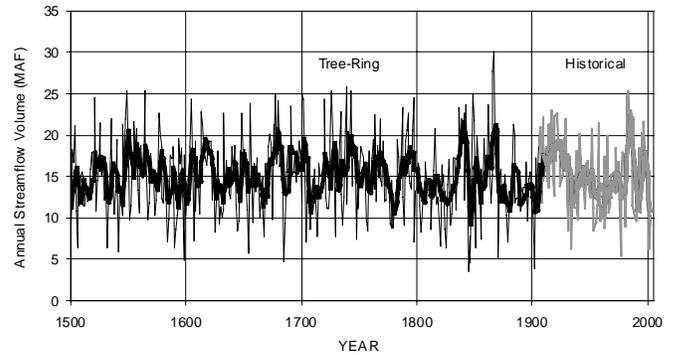


Figure 2. Annual historical (1906-2003) and tree-ring reconstructed (1490-1905) streamflow at Lee's Ferry

historical streamflows, i.e. 3.5 MAF to 30.1 MAF. The stochastic generated streamflow's annual average is nearly the same as the historical average and the standard deviation is within about 2% of the historical value and about the same as the standard deviation of the reconstructed streamflows. This is expected since the stochastic model is built to reproduce the historical annual average and standard deviation. The stochastic streamflow covers an even broader range than the tree-ring streamflow, 3.3 to 37.9 MAF. This is consistent because the stochastic streamflow simulates 7,100 years of streamflow, a considerably longer sequence than the tree-ring and historical records. Table 1 summarizes

these statistics and shows that the mean and standard deviation for the three streamflows are similar. However, the table also shows that their extremes are quite different. It is these extremes that are of greatest concern to policy makers because the high and low flows are the most difficult and most important to consider for planning purposes.

	Historical	Tree	Stochastic
Average	15,076,151	14,972,483	15,069,342
Minimum	5,407,262	3,464,657	3,304,391
Maximum	25,397,639	30,107,969	37,865,046
Standard Deviation	4,444,186	4,540,639	4,551,642
Number of Years	985	14	7,100

Table 1. Lees Ferry Annual Streamflow Basic Statistics (acre-ft)

River Simulation

The index sequential method (ISM) was utilized to generate synthetic flow traces based on the historical and reconstructed streamflow data. The ISM is a simple method that has been used in some practical cases for generating synthetic flows. The ISM generates the flows by sequentially block resampling the historical (or reconstructed) series. This method extracts every possible trace directly from the period of record. For the historical streamflow dataset, trace 1 consists of the streamflow from 1906 to 1976, the first 71 years of record. Trace 2 is offset one year from trace 1, so that it consists of the streamflow from 1907 to 1977. This one year of offsetting is continued until the end of the record is reached at which time the beginning of the record is wrapped around so that the offsetting may continue. The last trace, trace 98, consists of 2003 streamflow followed by 1906 to 1975 streamflow. Using this method places every year of streamflow in every year of the simulation model across all the traces. This simulation method has been the standard method used for long term river planning and management of the Colorado. The ISM was also used for simulating synthetic flow traces based on the tree-ring reconstructed streamflows. However, since there are 514 years of reconstructed streamflows, there are 514 different overlapping traces. Finally, the stochastically generated synthetic streamflows are the 100 traces, 71 years in length as referred to above.

The river basin model in which the simulated streamflows are input is the Colorado River Simulation System (CRSS), which has been implemented in RIVERWARE, software developed at the University of Colorado. CRSS was developed by Reclamation and is used for the long term planning and management of Lakes Powell and Mead. The model operates on a monthly timestep and includes 12 major reservoirs and 8 major tributaries to the Colorado River. River objects simulate the physical processes while a comprehensive rule set simulates the reservoir operations. The model is run with three key inputs, initial reservoir conditions, projected water demands, and river inflows. The initial conditions were set to December 2004 reservoir levels because this study began in 2005. The model's projected water demands were unchanged in each run. Reclamation obtained these projections from each state within the basin and then implemented them in the model. The Upper Basin's normal annual depletion increases from 4,445,000 AF in 2005 to 5,429,000 AF in 2060. The Lower Basin's normal annual depletion remains constant at 7,500,003 AF as does Mexico's at 1,515,000 AF since these are the maximum normal depletions set by the Compact. These demands dictated the model study horizon. Seventy-one years (2005-2075) was chosen because the projected demands level off in 2060 and running the model out to 2075 gives an indication of steady state conditions. Finally, the river inflows, which were explained previously, were input to make three different modeling scenarios.

Analysis of Results

CRSS was run under each streamflow scenario, producing three different sets of output that could be compared. Of the entire model output, two key indicators, Lake Powell release volumes and Lake Mead storage volumes are analyzed.

Lake Powell's release volume was analyzed in terms of the ability to satisfy the minimum objective release amount of 8.23 MAF per year. CRSS allows for a minimum objective release deficit because Powell's pool level is never allowed to drop below the minimum power pool elevation of 3,489.96 feet. This is not necessarily how the reservoir will be operated in the future, but it indicates the critical state of the system. The percentage of runs in which the minimum objective release was not met for any given year of simulation was computed in order to give an estimate of the probability that a deficit could occur at some point in the future. Then, among the deficits, the basic statistics were calculated for each year. These two results are plotted for each of the streamflow scenarios in Figures 3 through 5.

The results are consistent with the previous streamflow analysis. The ISM (historical) streamflow produced the smallest possible deficit volume of approximately 3.5 MAF while the stochastic streamflow produced the largest possible deficit volume of 6 MAF. Furthermore, the ISM (historical) streamflow resulted in a 0 to 1 percent chance of a release deficit occurring past 2020, while the ISM (reconstructed) streamflow resulted in a 0.4 to just under 4 percent chance of occurring past 2020, and the stochastic streamflow resulted in a 2 to 12 percent chance of occurring past 2020. These results are expected since the stochastic streamflow has the most extreme hydrology compared to the ISM (historical) or ISM (reconstructed). A distinct pattern of the annual deficit volume and deficit probability may be observed for the runs based on ISM. Both the ISM (historical) and the ISM (reconstructed) streamflows result in high probabilities of deficit and large maximum deficit volumes in the first few years. This behavior occurs because the streamflows generated based on the ISM (for both historical and reconstructed) can place critical droughts back to back. In effect, entire severe drought streamflow sequences are placed just after the 2000 to 2005 severe drought, which corresponds to the initial conditions of the system, e.g. very low reservoir levels at Powell and Mead. Once the initial reservoir conditions are overcome, the probability of a deficit decreases down to zero for the ISM (historical) and to one for the ISM (reconstructed). Another similarity between the outputs based on ISM (historical) and ISM (reconstructed) flow scenarios is the increase and then leveling off of the deficit probability at the end of the simulation time period. This increase is due to the increase in Upper Basin demands, and the evenness is due to the nature of the index sequential method. Thus, because of the way in which the ISM creates synthetic flow traces, it appears that the time series patterns of deficits becomes distorted, creating a



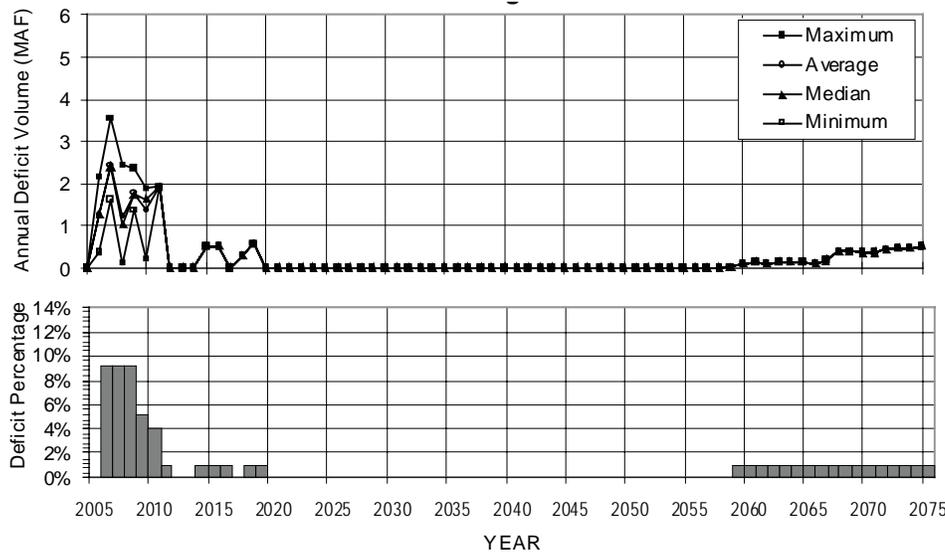


Figure 3. Minimum objective release deficit volume and percentage of occurrence for Lake Powell-ISM (Historical)

trend in the deficit statistics through time. The most disturbing result is that the deficit probability obtained from the ISM (historical) becomes zero in 45 out of 71 years and remains zero continuously for the period 2020 to 2058 thereby giving the impression of zero risk through a good part of the study period. The results obtained from the ISM (reconstructed) are similar in that the deficit probability remains near 1 percent or less during the same time period.

On the other hand, the results based on the stochastic flow scenario do not exhibit the same patterns as those based on the other two flow scenarios. The random behavior of the stochastic simulation's output occurs because each streamflow trace is entirely different and equally likely to occur, as it should be. This independence of traces is not maintained in the flow scenarios obtained from ISM. The independent nature of the stochastic simulation flow traces results in a random output pattern in all statistical metrics as shown in Fig. 5. An increase in the probability of deficit at the end of the simulation period is still present due to the increase in demands as cited above. In order to obtain the steady state probability, especially under increasing demands a simulation period much longer than the 71 years used in this study is required. Nevertheless, the

probability obtained towards the end of the simulation period may give an indication of such a deficit probability. The probability of a minimum objective release deficit is an important statistic to compare because water managers must plan river operations with an idea of this probability in mind as well as the probability that is acceptable to water users. The ISM (historical) scenario gave a deficit probability of 1 percent in the last 15 years of the study period, the ISM (reconstructed) flow scenario gave a probability just under 4 percent for the final 10 years of the study period, while the stochastic flow scenario gave a probability varying around 9 percent in the final 8 years. Clearly, the results based on the stochastic flow scenario give a more comprehensive and realistic picture of

possible and expected future conditions and behavior of the Colorado River system.

Other simulation outputs may be of interest to water managers of the system, such as the time series of annual reservoir volumes and frequency of reservoir volumes reaching specified thresholds (e.g. top live storage, bottom active storage, etc.) Lake Mead live storage volumes obtained based on the different streamflow scenarios were compared. Lake Mead's live storage volume is an important

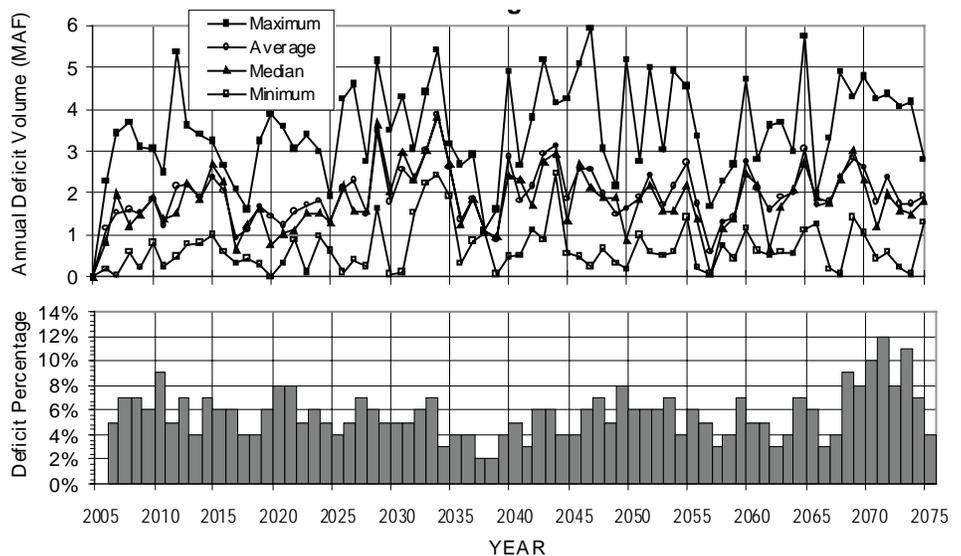
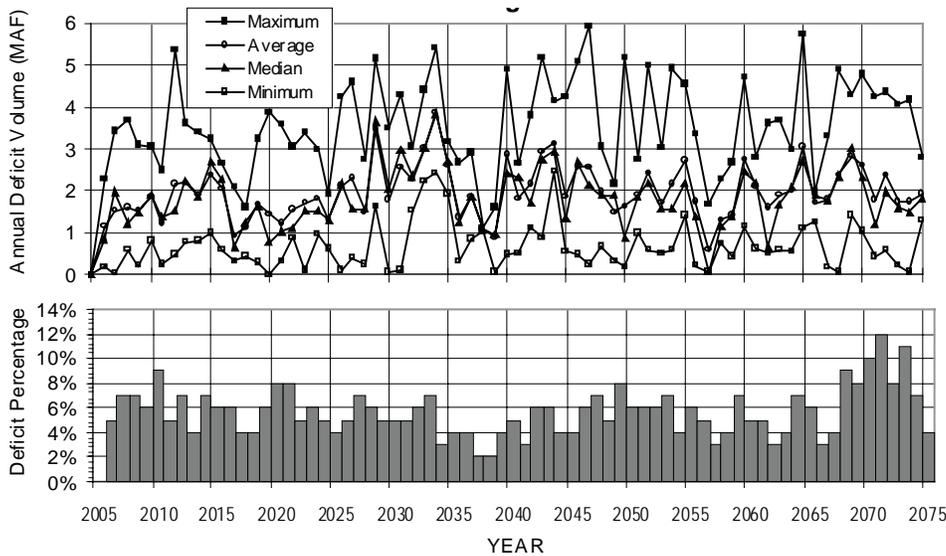


Figure 4. Minimum objective release deficit volume and percentage of occurrence for Lake Powell-ISM (reconstructed)



a decline and then leveling off of the medium June storage level as the Upper Basin demands increase and then level off. This behavior is expected because Mead receives nearly all of its water from the Upper Basin. Interestingly, the June median for the ISM (historical) scenario is slightly lower than for the other two. Another important feature to note is that the possible future minimum storage levels are significantly lower for the ISM (reconstructed) and stochastic flow scenarios than for the ISM (historical) flow scenario. In this case, the ISM (reconstructed) and stochastic streamflow scenarios give a more comprehensive picture of possible future conditions in the Colorado River system than the ISM (historical) streamflow scenario.

Figure 5. Minimum objective release deficit volume and percentage of occurrence for Lake Powell Stochastic

indicator of the system because there is not an absolute protect condition imposed upon it. The storage level reflects the state of the system without any lower boundaries. Lake Mead does have an upper boundary of 25.88 MAF of live storage. However, there is still 1.5 MAF of flood control storage on top of the live storage, but water is never allowed to remain in the flood control storage for an extended period of time. Critical low pool elevations are 1,050 feet and 1,000 feet. The upper Southern Nevada Water Authority (SNWA) diversion intake is located at the 1,050 foot elevation. This is also the estimated minimum power pool elevation. The lower SNWA diversion intake is located at the 1,000 foot elevation. If Lake Mead were to fall below this level, an alternative plan would need to be implemented in order for SNWA to actually make a diversion. It may be possible for the water to be pumped up to the intakes, or another lower intake could be added in anticipation.

Figures 6 through 8 illustrate Lake Mead's live storage volume possibilities and their relation to the critical levels in terms of annual maximum, June median, and annual minimum for each of the streamflow scenarios. These plots were developed by calculating the indicated statistics across all traces for each timestep in order to give an estimated range of possible future pool levels. All of the scenarios demonstrate

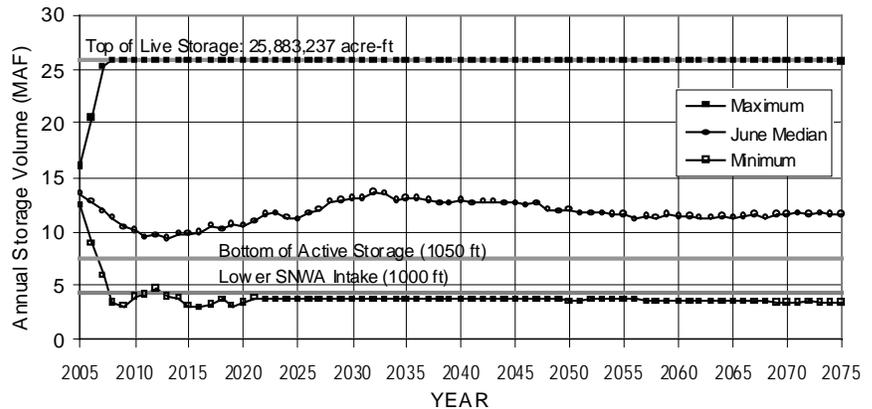


Figure 6. Lake Mead annual storage statistics – ISM (Historical)

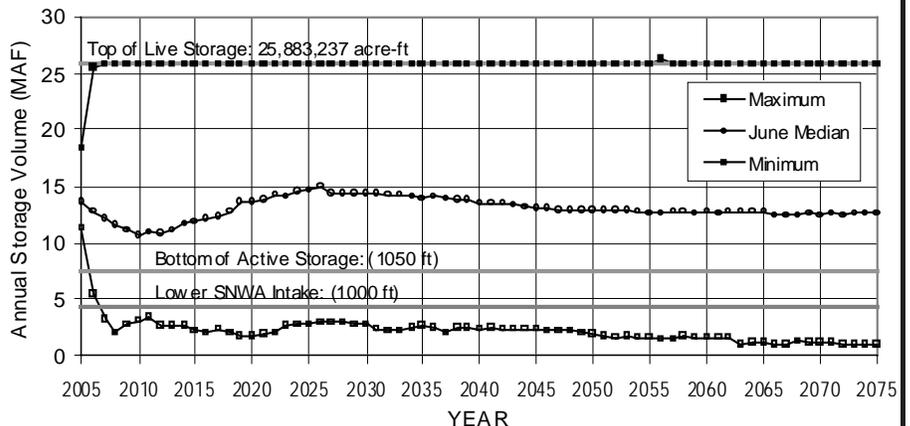


Figure 7. Lake Mead annual storage statistics – ISM (reconstructed)

Conclusions

In order to assess the expected future behavior of the Colorado River system one must test it under possible and likely streamflow scenarios that may occur in the system in the study period. This paper applied three streamflow simulation techniques, namely, the ISM (historical), ISM (reconstructed), and stochastic. This study has shown (and confirmed previous findings) that the ISM produces flow traces limited to the range of flows utilized in the method, i.e. the ISM (historical) will not produce flows beyond the maximum or minimum observed in the historical record. This would still be the case even if a longer record is utilized, e.g. reconstructed flows obtained from tree ring indices. This limitation will underestimate particularly the magnitude of short term droughts, e.g. one or two-year droughts. In the case of the Colorado River study ISM produces unrealistic patterns (trends) of deficits volumes and probability of deficits and underestimates their values, e.g. zero deficit for a 40-yr time span during the study period. On the other hand, the stochastic flow scenario does not produce such distortions

and instead gives a random pattern of deficits and probabilities through the study period, which is realistically expected to occur in the future. In addition, Lake Powell release volumes and Lake Mead storage volumes exhibited a wider range of possible occurrences in the ISM (reconstructed) and stochastic flow scenarios than in the ISM (historical) flow scenario. By simulating these more extreme river system scenarios water managers can better prepare for whatever the future may have in store.

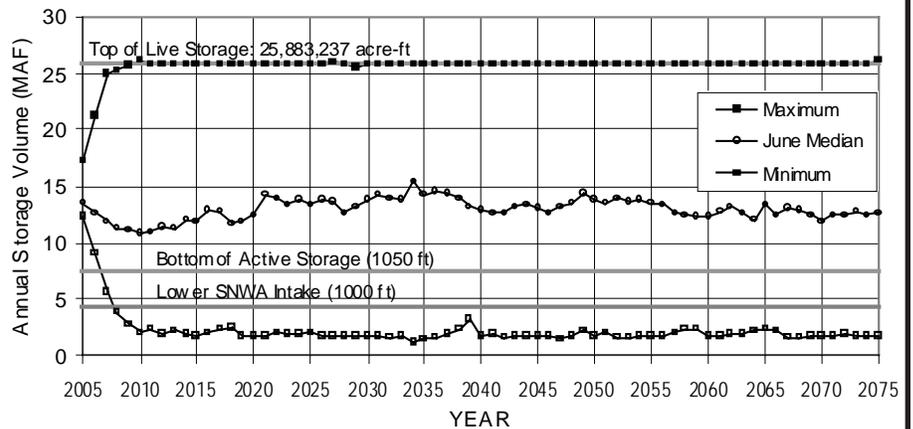


Figure 8. Lake Mead annual storage statistics - Stochastic

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Northeastern Colorado Contingent Tours Southeastern Australia for a Bird's Eye View of Canal Modernization

by Don Magnuson, Manager New Cache La Poudre Irrigating Company
 Stephen Smith, Chair Aqua Engineering
 MaryLou Smith, VP Aqua Engineering

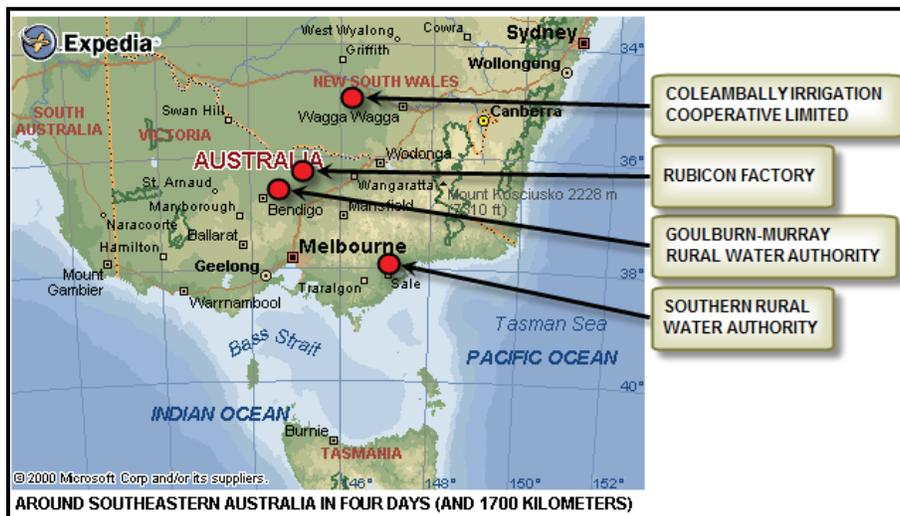
Northeastern Colorado's New Cache La Poudre Irrigating Company (New Cache) in recent years has installed remotely controlled computer-actuated gates on its Greeley #2 canal. Interested in the potential for further expansion of this technology in the future, New Cache manager Don Magnuson and Aqua Engineering's irrigation engineer Stephen Smith recently toured irrigation districts in southeastern Australia, each of which is employing cutting edge canal modernization to include full canal control.

Three Irrigation Districts...and a Factory
 Coleambally Irrigation Cooperative Limited (CICL) in New South Wales is a cooperatively-owned entity which operates much like our own mutual irrigation companies. Goulburn Murray Water and Southern Rural Water, both in Victoria, are self liquidating entities whose assets are state-owned. All three entities are implementing a level of canal control which is integrated with water orders, to allow for an overall level of automation that may be unprecedented.

In all three cases, the need to increase irrigation efficiencies was the impetus for significant financial outlay resulting in

infrastructure automation extending to on-farm deliveries. Under this level of automation, farmers can place their water orders over the internet and expect deliveries in as little as two hours. This allows farmers to more quickly react to changing circumstances given they do not have to forecast their water needs so far in advance.

Farmers place their orders by telephone keypad or over the internet. On-farm gates can be programmed to open automatically in the middle of the night so that the first irrigation set may be completed early in the morning before the farmer rises. Deliveries can be made reactively and for short



Kookaburra at feeding time at Lorne, along the Great Ocean Road east of Melbourne.



Remotely actuated gates of the Coleambally Irrigation Cooperative in New South Wales. This site is solar powered.

durations. The operating scheme on the canal can tolerate the changes through computer interactions to move the water around between canal reaches or to change the diversion at the head of the canal.



A sharp-crested weir flow condition allows these remotely actuated gates to be used for accurate flow measurements. The gates will automatically move to maintain a water surface level or to maintain a preset flow.

helpful as New Cache considers expanding its system.

From the Dethridge Wheel to High Tech

Irrigation districts and farmers in Australia, for almost 100 years, have used a measuring device called the Dethridge wheel to manage their on-farm deliveries. The wheels, used in a manner similar to the way we use Parshall flumes for on-farm deliveries, worked well for their time, but idiosyncracies in the way they are installed and operated can lead to inequities. For instance, changing upstream and downstream water surface levels can cause the flows to vary and sometimes water surface levels are manipulated by irrigators to increase on-farm deliveries. The picturesque wheels are gradually being replaced by the districts with remotely actuated and controlled aluminum gates. Large variations in the water surface elevation of the canal can be overcome by these gates which are programmed to raise and lower to deliver a consistent flow to the farm headgate. Flow measurement accuracy is on the order of +/- 2 percent.

Australia is currently experiencing prolonged drought, not unlike what we are seeing in Colorado. Though farmers are enjoying the increased efficiencies in operating the canal, it is hard for them to truly appreciate the gains given that their allotments are drought-reduced, masking the true benefit.

Visiting the Rubicon plant where these gates are manufactured was a highlight of the trip. Rubicon provided the gates and software being used on the Greeley #2, and the company has worked closely with New Cache and Aqua Engineering to ensure that the ditch company's needs are met. Rubicon recently chose Fort Collins as its base of operations in the U.S. as they expand their operations in this country. Hearing straight from the districts about Rubicon's customer response to issues with new products was especially



Gates are inventoried at the Rubicon factory in Shepparton, for installations pending at some of the districts.

Planners and Bailiffs

The deliveries and water surface elevations for the canal, which can be tens of miles away, are monitored through a computer operator at the district, called a "planner." Still, there is a need for real people out on the ditch. What we call the "ditchrider" in Colorado (and "mayordomo" in northern New Mexico) is called a "bailiff" in southeastern Australia.



Don Magnuson, touring the Rubicon factory in Shepparton, checks out the gate drive mechanism which uses 12 volt DC power.

Touring these Australian irrigation districts in October, which in Australia is spring, Don and Jeanette Magnuson and Stephen and MaryLou Smith viewed a variety of surface-irrigated crops under the canals including apricots, wheat, wine grapes, canola, and surprisingly, rice. Dairy and beef cattle and sheep production were seen to be significant in the agricultural economy as well.

Driving 1700 kilometers (1050 miles) in just four days, the group saw a great many emus and a few kangaroos. But the most memorable specimen of the animal kingdom encountered was the kookaburra most of us remember from the grade school song—"Kookaburra sits on the old (Australian red) gum tree, merry, merry king of the (Australian) bush is he!"



Forest Restoration in Ponderosa Pine on Colorado's Front Range Helps Lower Fire Danger and Protect Watersheds

by Chuck Dennis, Colorado State Forest Service

In contemporary ponderosa pine forests throughout Colorado, the need to thin dense stands to reduce the risk of catastrophic fires has become evident. Numerous thinning prescriptions have been implemented; many focus solely on lowering fire risk by removing ladder fuels and reducing crown connectivity, while others explicitly aim to alter forest structure and function. Restoration treatments can lower fire danger, protect watersheds and increase the overall biological diversity and long-term health of treatment areas.

Restoration Treatments v. Fuel Treatments

Mechanical fuels treatments remove excess trees and ladder fuels to reduce the likelihood that a surface fire will become a crown fire. They also reduce the connectivity of tree crowns, which makes it more difficult for a crown fire to spread throughout the canopy. This typically is accomplished by using mechanical devices.

Restoration treatments also remove ladder fuels and reduce crown connectivity; indeed, fuels treatments can be an important step toward restoration. But restoration treatments are focused on long-term rather than short-term ecosystem

health. Rather than focusing only on altering forest structure, restoration treatments also aim to alter forest function. For that reason, restoration treatments have the potential to provide a long-term solution to the current wildfire problem, which is really only a symptom of a larger problem—namely, an unhealthy ecosystem.

Treatments that combine thinning with prescribed fire and that focus attention on a wide range of post-treatment conditions (including herbaceous vegetation, wildlife habitat, watershed benefits and recreation) do the best job of reducing fire danger and improving forest health in the long-term.



These before (above) and after (below) photos of treatment on the Upper South Platte show the effects of thinning to achieve forest restoration goals.

Restoration treatments that focus on healthy forest structure allow low-severity fire to easily and inexpensively shape forest conditions in the future—and this, in turn, reduces the need for future maintenance thinning.

Restoration treatments, in other words, provide fire protection and additional benefits. Fuels treatments reduce fire danger, but only temporarily, and they do not emphasize these other benefits.



Restoration Treatments Must Be Informed by Reference Conditions

“Reference conditions” are conditions that existed before forest structure and function were altered by Euro-American settlers. They were not unchanging, but they sustained themselves. Colorado’s ponderosa pine ecosystems were subject to frequent fires of varying severities. Some fires no doubt were ignited by indigenous peoples, but most likely were caused by lightning. Both types of fires had the same effect: they sustained forest structure by removing tree seedlings and cycling nutrients to plants.

After Euro-American settlement, that sustainable cycle was broken by livestock grazing, unregulated timber harvest and

active fire suppression. Grazing removed the fine fuels that carry fire, while timber harvesting removed larger trees and made way for dense stands of younger trees. Fire suppression created fuel accumulations and increases in fire intensity. Forests have grown much denser and understory productivity has declined. Today, ecosystem conditions in many places are unsustainable.

Reference conditions are useful tools because they show what a site's potential can be under self-sustaining conditions. They are determined by locating trees or tree remains that were present before Euro-American settlement, which generally include living pines or snags with yellow bark, as well as large downed logs, stumps and stump holes. Tree-ring records help document past forest structure and fire history, as can historic photographs, land survey records, USDA Forest Service records and other written records. Relatively undisturbed sites nearby also can aid in understanding what reference conditions may have existed on a site to be treated, although it's important to consider the great differences in stand density and structure that can even exist on adjacent sites.

Reference conditions are not necessarily the same as restoration goals. Social, economic or other management considerations may make it undesirable—or impossible—to attempt to fully recreate reference conditions. But knowing how a site once looked is an important tool in deciding management goals and strategies. Incorporating the major characteristics of historic forests into treatment prescriptions can move land managers toward implementing more effective and sustainable treatments, from both an ecosystem health and cost standpoint.

Because landscape histories, site conditions, and political and social realities differ, there is no one-size-fits-all recommendation for mechanical thinning or prescribed fire across the entire range of ponderosa pine in Colorado. Fire behavior is variable enough that it is impossible to precisely predict future fire behavior from a given stand density and structure. In addition, ponderosa pine landscapes across Colorado are naturally highly variable. Restoration treatments vary with location, funding and management goals, but some general points are important and usually share the following qualities.

Saving the Elders

Logging in Colorado forests traditionally emphasized cutting large trees and has resulted in a scarcity of old, yellow-barked ponderosa pines. These trees tend to be resistant to fire and often provide valuable wildlife habitat and aesthetic benefits. However, many of the oldest trees that remain are in declining health due to increased competition with younger trees. Restoration treatments preserve old, yellow-barked pines by cutting mostly younger pines, lowering competitive pressures around old trees and protecting these trees from fire.

When thinning, most trees that pre-date grazing—those that are approximately 150-200 years or more in age—are retained. Most trees of species other than ponderosa pine are retained for diversity, except shade-tolerant trees that create ladder fuels.

Reducing Stocking Levels

Thinning both canopy and ladder fuels generally is necessary to reduce crown fire potential. Though it can be expensive, thinning does not carry the risks associated with using prescribed fire alone, and can be done throughout much of the year.

The goal of reducing stocking levels is to reduce tree densities to numbers that more closely resemble pre-1870 conditions by thinning from below most post-settlement trees, except those needed to emulate or ultimately develop pre-settlement densities and diameter distributions. Trees-per-acre prior to European settlement are estimated at 25 to 50 or more.

Distributing Trees in Groups

Ponderosa pines frequently grow in small clumps, often with interlocking crowns, and provide habitat for species that utilize tree trunks and crowns. The size, density, number and location of such clumps profoundly affect wildlife habitat, future risk of crown fire and, thus, watershed health. Finding a balance between wildlife habitat considerations, individual tree health and future fire risk is a vital part of planning restoration treatments.

Because they are based on averages across an area, basal area measurements often are not useful in quantifying the extent to which forested areas are comprised of clumps and openings. Standing trees left after thinning operations are clumped in a fashion that more closely resembles pre-1870 stand structures. Even spacing of trees is not desirable. It is desirable to vary density throughout forest stands from open pockets with no or few trees to dense pockets of trees with the equivalent of up to 150 trees per acre. Within forest stands or project areas, it is important, over time, to develop irregular stand structure and spatial arrangement. Historical stand structure appears to have been comprised of even-aged groups of trees that varied widely in size and shape. Often two, three and sometimes more age and size groups were represented in a stand.

Keeping Standing Dead Trees (Snag Retention)

In areas of general treatment, land managers strive to save most standing snags, particularly those larger than 10 inches in diameter. Retention of snags within fuelbreaks, defensible spaces, along trail and road corridors and within recreation areas are evaluated on an individual basis.

Creating Openings

Openings are areas with no to very few trees and a crown closure of 10 percent or less. Soils analysis has shown that some grassy openings in ponderosa pine forests were

apparently in place for very long periods before young pines encroached on them in the twentieth century. Research also has revealed that historic stands were extremely open and more than 90 percent of the landscape had crown closures of 30 percent or less. Openings of up to 40 acres or more were widely distributed across the landscape. However, most openings were small, in the two- to five-acre range, and only a few of the very large openings were present. Recreating such openings provides habitat for many wildlife species, and can greatly reduce the risk of crown fires.

Monitoring Natural Regeneration

Research also has shown that openings in pre-settlement forests were persistent and long lasting. Land managers must decide early in the decision process which openings are to be maintained over time, as that will dictate maintenance needs. Generally, regeneration of other areas occurs by natural seeding. If regeneration is lacking, planting can be used to achieve the desired density. If too many young trees in an area survive prescribed fire, some can be removed to achieve specified density levels.

Packing Out Heavy Fuels

New growth follows thinning or prescribed fire and puts a time limit on the effectiveness of these treatments. By itself, prescribed burning can be effective in reducing wildfire severity for up to 10 years. If management goals include reducing fire danger, treatments that leave heavy fuels behind in the form of slash or living trees don't work—they waste resources and force managers to implement more treatments in coming years. Only treatments that allow for the possibility of future low-severity fires to manage fuels represent a long-term solution to the problem of unnatural wildfire intensity.

Prescribed Burning

It is well documented that fires played a primary role in maintaining the structure of Colorado ponderosa pine forests before fire regimes were interrupted by Euro-American livestock grazing and fire suppression. However, to reduce catastrophic fire risk and return fire safely to its historical role in the ecosystem, it is often necessary to reduce existing fuel loads prior to burning. Burning in combination with thinning may be the most successful fuels treatment combination. Once forests are thinned, fire is crucial to maintaining forest structure and more closely emulates natural fire regimes than

thinning alone. Without fire, thinned forests will quickly become dense again.

Prescribed burning should be used, where appropriate, to reduce fuel loads, expose mineral soil, provide a nutrient flush for vegetation, reduce competition and stimulate production of grasses and forbs that may have evolved under periodic fire cycles. Forest restoration focuses on reintroducing more frequent, primarily low-intensity fires, which provide these and other benefits.

Though initial fires after thinning often are hot and/or smoky, due to the large quantities of needles and woody fuel on the ground, future fires should burn mainly herbaceous vegetation and tree saplings, producing less heat and less smoke.

Prescribed burning for maintenance purposes is typically cheaper than conducting additional mechanical thinning. Maintenance burns likely will be necessary within three to 10 years of the initial prescribed burn to reintroduce a periodic fire regime to sites where such a regime previously existed. Future fires, whether prescribed or lightning-ignited, should be part of the restoration planning process.



This aerial photo of the Buffalo Creek Fire shows the impacts of stand-replacing crown fires. Restoration treatments that combine thinning and prescribed fire effectively reduce fire danger and improve forest health.

Understory Restoration

Grasses, forbs, shrubs and other plants of the herbaceous understory comprise most of the diversity in ponderosa pine forests, and are important for aesthetics, and wildlife food and cover. In addition, the understory provides fuel for the frequent low-intensity fires that are necessary to maintain forest structure. For these reasons, restoration treatments emphasize restoring the diversity and productivity of these plants. In some cases, this may require reseeding with native species or removal of

invasive species.

Considering Size and Landscape Patterns

Larger treated areas more effectively reduce fire behavior than smaller areas. Landscape-scale planning techniques such as those developed by Mark Finney, Thomas D. Sisk and others can help assess where treatments should be concentrated to achieve the greatest degree of fire risk reduction and other corollary benefits, while meeting forest restoration needs. Software tools and GIS technology can help assess where

treatments are most beneficial and where resources should be concentrated.

Monitoring Programs and Adaptive Management Practices

Restoration is a new science, and land managers have much to learn about it. Reducing fuel loads is both a science and an art. Fire behavior and forest ecology are complex, and some effects of restoration treatments inevitably will deviate from the predicted outcome.

For that reason, monitoring of treatments and their effects is urgently needed to improve treatment planning and

implementation, modify future treatments, and communicate progress to practitioners and stakeholders. With careful monitoring, the lessons learned from current treatments will improve restoration practices and overall management of ponderosa pine forests—and both are essential for lowering fire danger and protecting watersheds.

Note: This article was composed from information found in the 2004 Forest Health Report compiled by the Colorado State Forest Service and the Forest Restoration Institute at Northern Arizona University. Materials used with permission.



Educational Program Targets Arkansas & Colorado Basin Roundtables

Irrigation water is an important risk management tool in limiting drought impacts and boosting crop yields. Additionally, rural communities are directly dependent on the availability of water and the sustained tax revenue base of irrigated agriculture. It is expected that 428,000 acres of irrigated farmland will dry up to meet future municipal and industrial uses (Colorado Water Conservation Board, 2004).

Colorado State University will offer an educational program to the Arkansas and Colorado Basin Roundtables on the impacts of reduced water availability to Colorado Agriculture. The proposed three-hour educational program is designed to help roundtable members better understand the potential consequences associated with water movements from agriculture to non-agricultural uses.

The educational program schedule and agenda is as follows:

Arkansas Basin Roundtable

March 14, 2007

9:00 a.m. – 12:00 p.m.

Colorado Basin Roundtable

March 26, 2007

9:30 a.m. – 12:30 p.m.



Program Agenda:

Tax consequences of lost property value due to shift of land from irrigated to non-irrigated use.

Demonstration of decision tool to compare alternatives for limited irrigation cropping.

Impact and implementation costs of alternative irrigation technologies.

Financial impacts of selling water rights versus continuing irrigated agriculture.

Risk management simulation game for agriculture and drought to help gain a better understanding of risk, personal risk preferences, and risk management strategies.

Speakers include

Rod Sharp, Jeff Tranel, and James Pritchett – Agricultural and Business Management Economists with Colorado State University. Sharp (located in Grand Junction) and Tranel (located in Pueblo) are currently serving as CSU's liaisons with the Colorado and Arkansas Basin Roundtables. They have joint appointments with Cooperative Extension and the Department of Agricultural and Resource Economics. Pritchett is an Assistant Professor in the Department of Agricultural and Resource Economics in Fort Collins.



USDA Water Management Group Builds On Long History With New Research Leader and Research Director

The USDA-ARS Water Management Research Unit (WMRU) of Fort Collins, CO is embarking on a new direction in water management research and has a new research leader, Thomas Trout, to lead that research.

USDA water management research has a nearly 100 year history in Fort Collins and has always been closely allied with Colorado State University. Its roots began in 1911 when USDA established the Irrigation Investigations Unit on CSU campus. In 1912, David Cone and Ralph Parshall built the hydraulics laboratory that was located south of the current Lory Student Center for many years. These two engineers formed the nucleus of what would become a continuous chain of USDA scientists at CSU. Through the years this group of scientists and engineers has made major contributions to the field of water management. Some of the best known work has been feasibility studies for the Colorado Big Thompson project, irrigation scheduling and crop evapotranspiration equations (Jensen-Haise equation for daily ET), water flow measurement devices (Parshall flume), and soil water movement models (Brooks-Cory equations).

Although the name and location of the USDA irrigation research group has changed several times, it has always maintained close ties with CSU and water issues in Colorado agriculture. In the last quarter of the twentieth century, the lab was located at the Agricultural Engineering Research Center (AERC) under the research leadership of Dr. Dale Heermann. The unit directed its research to irrigation scheduling and energy management and other water management issues in center pivot irrigation systems. Well known products of this focus has been the Colorado weather station network CoAgMet (with CSU), center pivot monitoring and control systems, and the software CPED for evaluation of uniformity of center pivot systems. After reorganization in 1991, the unit included weed scientists in the program.

In the last research cycle, the unit continued to focus on water management but took on the resource-crop-pests-irrigation-management systems of precision agriculture under center

pivot irrigated systems. The research was carried out by a multidisciplinary team that included CSU agricultural and engineering scientists.

With the beginning of another ARS research cycle and the arrival of a new research leader, the unit held a series of focus group sessions in early 2006 to help them plan future research directions. Focus group participants including producers, consultants, representatives of ag. industry, local, state, and federal government agencies and university teachers, researchers, and extension staff detailed their concerns about the critical water and agricultural issues for Colorado and the central plains. The economic viability and sustainability of irrigated agriculture in Colorado and the Great Plains with declining water supplies was the major issue expressed by many participants. The recent drought and state actions due to legal decisions regarding interstate compacts and instate water rights have brought the problem of limited water resources to the forefront. Reduced water availability is also driven by declines in regional ground water resources (e.g. Ogallala and Denver aquifers), changes in land use, re-direction of water resources to growing population centers along the front range and environmental restoration of rivers.



Dr. Walter Bausch



Dr. Gerald Buchleiter

The WMRU scientists have backgrounds in crop water use, real-time remote sensing of crop water and nutrient status, irrigation technology, scheduling and instrumentation, weed ecology under irrigated systems and herbicide behavior in the plant and soils. They assessed their expertise, interests, and resources and choose to direct the new research cycle toward irrigation water and weed management under limited water supply conditions.

The research mission of the WMRU will be to develop water and weed management technologies and practices for irrigated agriculture in water deficit areas that use water efficiently, improve agricultural productivity and sustainability, and reduce negative environmental impacts.

WMRU's specific research focus for the next 5 years will be to measure crop water use, crop yields and evaluate best management practices under limited irrigation. The unit scientists will measure the "water production function" (crop per drop) for four crops (wheat, sunflower, corn, dry beans) grown in a rotation under both conventional tillage and minimum tillage. This work will be done on an intensively instrumented 17 acre research site east of Greeley with the goal of better understanding the crops' responses to deficit irrigation and how to best allocate and schedule limited water supplies. The unit will work closely with crop modelers in the ARS Agricultural Systems Unit to improve crop models so crop yields with limited water can be predicted. Results will be compared with results from related studies by CSU researchers and from research from Kansas, Nebraska, and Texas. With the help of CSU ag economists and extension staff, the unit hopes to summarize the results in a decision support system that growers can use to plan crops and schedule irrigations.



Dr. Dale Shaner

Weed response to water management in limited water systems will also be evaluated. Good weed management will be critical to maximizing returns with limited water. While crop responses are being measured, the WMRU weed scientists will be evaluating how weed populations and growth respond to the limited water and tillage conditions, and how weed management changes under dry soil conditions. We expect that dry soils and slower developing crop canopies will both effect weed growth and competition, and that limited irrigation will impact herbicide efficacy. These studies will lead to weed management recommendations under limited irrigation. The WMRU is composed of five lead scientists - three agricultural engineers and two weed scientists, a technical support staff of seven technicians, programmers and engineers. The group employs several CSU students to assist with their projects and maintains a cooperative research agreement with CSU to carry out joint studies. Their newly built offices and fabrication shop are located just south of CSU campus on Centre Drive.

The group's lead scientists are Tom Trout, an agricultural engineer and the new research leader (*see next page*), agricultural engineers Walter Bausch and Gerald Buchleiter, and weed scientists Lori Wiles and Dale Shaner.

Dr. Walter Bausch's current work has been in the development of techniques for remotely estimating the growth stage of the crop and for nitrogen management under center pivot systems based on estimating the real-time nitrogen status of the crop using passive and active sensors. His future plans are to quantify the degree of water stress imposed on the crop during various growth stages from plant and soil measurements to determine when to irrigate and how much water to apply for optimal application of limited water supplies using canopy temperature and canopy reflectance as plant based inputs.

Dr. Gerald Buchleiter's recent work has been using soil electrical conductivity measurements to identify and map soil variability and identify soil water characteristics, determining what crop production factors (water, nitrogen, weed, insects, etc.) cause yield variability in corn under center pivot irrigation systems, and in center pivot technology for variable rate fertilizer and chemical application. He will be involved in various aspects of design, installation and operation of the precision irrigation system for the water production function study, and will take the lead in data collection to establish the water balance and irrigation schedule.



Dr. Lori Wiles

Dr. Dale Shaner's recent work has been the use of apparent soil electrical conductivity maps as a basis for predicting variability in herbicide activity and degradation, on technology for identifying herbicide resistance in weeds, and on technology for variable rate herbicide application in center pivot systems based on soil variation. Dr. Shaner's research over the next five years will focus on two areas. 1) The effect of deficit irrigation and crop rotation on herbicide efficacy and dissipation and 2) Developing methods for mapping variability of

soil properties at the field level and using these maps for site-specific weed management to minimize herbicide use.

Dr. Lori Wiles' recent work has been in developing decision tools for weed management and strategies to reduce herbicide use with site-specific weed management. Her future research will focus on using knowledge of the weed population, spatial and community dynamics of water-efficient cropping practices to 1) identify weed problems that may prevent the long term use of new, water-efficient practices for crop production and develop strategies to eliminate these problems; 2) find opportunities to minimize herbicide use; and 3) develop tools to predict the risk of establishment and success of common, invasive and noxious weeds with specific practices.

Introducing WMRU's New Research Leader, Dr. Thomas Trout

WMRU's new research leader, Dr. Thomas (Tom) Trout brings expertise in irrigation system design and crop water use under a wide range of conditions to the unit. Dr. Trout received his B.S. in Mechanical Engineering from Case Western Reserve University and his M.S. and PhD in Agricultural Engineering from Colorado State University. After 3 years working in international technical assistance programs with CSU, US AID and the World Bank, Dr. Trout joined the ARS Northwest Irrigation and Soils Research Center in Kimberly, Idaho. During 13 years in Idaho, Dr. Trout developed and promoted automated surface irrigation systems (cablegation), quantified the effects of soil management on infiltration and the impacts of infiltration variability on surface irrigation efficiency and management, and described the mechanisms that cause soil erosion under surface irrigation.

In 1995, Dr. Trout became the Research Leader of the Water Management Research Unit at Fresno, California. At the California WMR Unit, he worked on irrigation management practices for horticultural crops including peaches,



Dr. Tom Trout

strawberries, lettuce, and peppers. Dr. Trout used weighing lysimeters, precision micro-irrigation systems, and infrared photography to develop water production functions and crop coefficients based on canopy size that apply to a wide range of horticultural crops. He also worked closely with the strawberry industry to evaluate their drip irrigation systems and develop improved irrigation design and management practices.

When Dr. Trout arrived in California in 1995, ARS and the California WMR Unit undertook a high priority program to find alternatives to soil fumigation with methyl bromide, which was being phased out under international treaty. He led a program that evaluated alternative fumigants, developed safe and effective application methods, and

demonstrated alternatives on grower fields. A success of the program was development and implementation of soil fumigant application through drip irrigation systems. This method is currently the primary alternative being used by the billion dollar strawberry industry in California. This effort, with Dr. Trout as team leader, has won several national awards.



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FACULTY PROFILE

Jeff Ballweber

Community Development Specialist

Department of Agriculture and Resource Economics



Mr. Jeff Ballweber joined the Colorado State University faculty in September 2006 as a Community Development Specialist in the Department of Agricultural and Resource Economics. His primary duties are to work with Colorado's rural communities to develop and implement viable long-term economic development initiatives that reflect local

values and preserve or enhance the communities' quality of life. Jeff does not have any current teaching responsibilities but is interested in developing a Water Law course in the Department.

Mr. Ballweber earned dual BS degrees in Political Science and Philosophy from Oregon State University in 1987. He earned his J.D. degree from the University of Oregon School of Law in December 1990. During law school, Jeff received a Dean John A. Knauss National Marine Policy Fellowship which allowed him to spend a year on U.S. Senator John Breaux's legislative staff. In that position, he focused on transboundary resource management and Endangered Species Act reauthorization issues.

Jeff comes to CSU from Mississippi State University where he had been the Associate Director, with stints as Acting Director, of the Mississippi Water Resources Research Institute (MWRRI) since September 1999. Jeff was also MSU's administrative contact with the Gulf of Mexico Cooperative Ecosystem Studies Unit and served on its Executive Board. On the academic side, Jeff had adjunct academic appointments as an Associate Research Professor in MSU's Departments of Agricultural Economics and Forestry. At MSU Mr. Ballweber's activities focused on using the MWRRI to

informally organize the expertise of the University's faculty, staff and resources around water quality and quantity needs. He would then work closely county and local governments, federal, state and local agencies and the private sector to build partnerships to utilize the University's expertise. As partnerships grew, Jeff's time was largely spent working with the individual partnerships to identify, secure and manage external funding. These partnerships developed a consensus on priority projects in the broad areas of: 1) rural economic development, watershed/river basin management, 3) water quality and source water protection, and, 4) low impact development/Smart Growth. Just recently, several of these partnerships have expanded to include water supply and alternative energy issues. Since 1999, Jeff was able to secure and manage more than \$5,000,000 in funding from federal, state and county agencies and the private sector implement plans developed by these partnerships.

Jeff has not been at CSU long enough to have any Colorado projects but he recognizes that Colorado offers a new set of water and broader economic development challenges. Much like in Mississippi, the Colorado Water Resources Research Institute has been a great starting point to get the pulse of Colorado's water issues. Surprisingly, there are some similarities between Colorado and Mississippi in the water world as both states are using watershed alliances or basin roundtables to develop broad local consensus to identify and prioritize water projects. In addition, there are many commonalities between rural agricultural communities in Mississippi and Colorado. Nationally, rural demographics, employment patterns, and private income sources are changing. The challenge is to identify and adapt development plans that will provide quality employment and training opportunities as well as the infrastructure (transportation, water/wastewater, communication, energy, etc) for sustainable economic development opportunities that benefit rural residents, but also protect or enhance their quality of life. At CSU, Jeff intends to apply his experience to help Colorado's communities face these challenges.

Jeff can be reached at: Jeff Ballweber, Department of Agricultural and Resource Economics, B308 Clark, Ft. Collins, CO 80523, 970/491-6946, jeff.ballweber@colostate.edu.

Colorado Water Workshop moves to May

2007 Workshop will focus on Colorado River Watershed issues from the Colorado and Green river headwaters in Colorado and Wyoming to the Delta in Mexico.

It's the same workshop in the same Gunnison location and with a new date. After 32 years of annual Colorado Water Workshop conferences in late July, 2007 will see a change with a move to May 22-24 in the College Union building. Workshop director Pete Lavigne notes that the move will make it easier for Western students and faculty to participate, and will bring the workshop's economic impact to Gunnison at a slow time of year when local hotels and restaurants can easily absorb the 200 plus visitors to town. "Late July has worked well for the workshop over many years but few Western students have been around to participate then and we see some additional benefits by moving to late May. Speakers for the Water Workshop from beyond the local area are more likely to be available in May as many are on vacation in July and Gunnison hotels are emptier in May and therefore cheaper," says Lavigne. "After getting feedback from over thirty formal and informal Workshop advisors and sponsors, we went with the vast majority who liked the idea of moving the annual gathering to May." Gunnison weather in late May is usually in the high 60s with beautiful dry weather. "According to the weather records, Gunnison is actually drier in May than in



July and should be great for golfing, bird watching, fishing and other outdoor activities that workshop participants like to plan for," says Lavigne.

There was unanimous feedback that the 2007 theme should focus on basin wide issues in the Colorado River watershed. "1992 was the last time the Workshop specifically took a basin wide approach to the Colorado River. We'll be discussing a variety of issues from the headwaters of the Colorado and

Green rivers in Colorado and Wyoming all the way to the delta in Mexico," says Lavigne. Already former Commissioner of the Bureau of Reclamation Dan Beard has committed to keynote the Workshop and other potential speakers are also volunteering. Lavigne adds, "George Sibley did a fantastic job of widening the Workshop's reach over the past five years and his great work is making it easy to attract top notch speakers for the plenary sessions and workshops. As the advisors work with

us on specific panels and topics over the next few months I'll be announcing those results as we go along. In the meantime we hope many folks from the region will write in the new dates and plan to attend."

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Sen. Jim Isgar, Chair, Senate Agriculture, Natural Resources, and Energy, Committee

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A Presentation by Floyd Ciruli
Panel reaction to follow

Over The River, Project for the Arkansas River, State of Colorado, A Work in Progress

Christo and Jeanne-Claude

The Platte River Recovery Program Agreement – The Trail Chosen

Perspectives from Colorado, Nebraska, and Wyoming

Peace in Our Time? An Overview of the Seven States Negotiations

How Climate Change May Affect Future Planning Decisions on the Colorado River

Jim Lochhead, Attorney and Eric Kuhn, Colorado River Water Conservation District

A Film Presentation: President John F. Kennedy on the Fryingpan-Arkansas Project The Never Ending Challenge to Prepare the Way for Future Generations

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RESEARCH AWARDS

Colorado State University, Fort Collins, Colorado Awards for October 2006 to December 2006*

Bledsoe, Brian: 1372: USDA-USFS-Rocky Mtn. Rsrch Station - CO: National Riparian Protocol Development: \$117,500

Colbert, Debora A: 1042: CCHE-Commission on Higher Education: Distance Education Course on Colorado Water Law: \$10,000

Collett, Jeffrey L Jr: 1375: DOI-NPS-National Park Service: ROMANS Study: Characterizing Pollutant Deposition to Rocky Mountain National Park: \$460,585

Cooper, David Jonathan: 1472: DOI-NPS-National Park Service: Developing Concepts for Stream Channel & Floodplain Restoration at Canyon de Chelly Monument, Arizona: \$105,000

Demott, Paul J: 1371: NSF - National Science Foundation: Ice Nuclei and Ice Initiation in Mid-Latitude Clouds in Springtime: Background and Dust-Affected: \$652,602

Demott, Paul J: 1371: NSF - National Science Foundation: Aerosol particle effects on warm and cold cloud formation: \$182,343

Duda, Joseph A: 5060: Colorado Office of Emergency Management: Colorado Watershed Mitigation and Flood Risk Reduction Project: \$1,713,468

Garcia, Luis: 1033: Various "Non-Profit" Sponsors: Developing a Decision Support System for the South Platte Basin: \$10,000

Garcia, Luis: 1372: DOI-Bureau of Reclamation: Multi-Temporal High-Resolution GIS-Based Spatial Evapotranspiration: \$3,278

Gates, Timothy K: 1372: Lower AR Valley Water Conservancy Dist: Monitoring and Modeling Toward Optimal Management of the Lower Arkansas River: \$30,000

Hansen, Neil: 1170: DOI-Bureau of Reclamation: Demonstrating Limited Irrigation Technology as an Approach to Sustain Irrigated Agriculture While Meeting Increasing: \$23,561

Jayasumana, Anura P: 1373: Colorado School of Mines: Wireless Sensor Network Based Subsurface Contaminant Plume Monitoring: \$15,730

Johnson, Brett Michael: 1474: DOI-Bureau of Reclamation: Chemically Fingerprinting Nonnative Fishes in Reservoirs (Project No. C18/19): \$20,557

Kummerow, Christian D: 1371: NASA - Natl Aeronautics & Space Admin: A Cooperative Climate Rainfall Data Center : \$245,548

Kummerow, Christian D: 1371: NASA - Natl Aeronautics & Space Admin.: A Physical Validation Approach for Precipitation: \$85,263

Liston, Glen E: 1375: NASA - Natl Aeronautics & Space Admin.: Parameterizing Subgrid Snow-Vegetation-Atmosphere Interactions in Earth-System Models: \$140,000

Loftis, Jim C: 1372: DOI-NPS-National Park Service: Status and Trends of Impaired, Threatened, & Outstanding National/State Resource Waters in the: \$345,066

Myrick, Christopher A: 1474: DOI-Bureau of Reclamation: A Literature & Laboratory Study of Appropriate Fish Loading & Hauling Conditions at the US Bureau of Reclamation: \$56,644

Prenni, Anthony J: 1371: NASA - Natl Aeronautics & Space Admin.: Laboratory & Field Measurements of Aerosol Particle Effects on Cloud Ice Formation in the Amazon Basin: \$126,667

Pruden-Bagchi, Amy: 1372: Golder Associates, Inc.: Microbial Characterization of the Peerless Jenny King Passive Treatment System: \$40,000

Ramirez, Jorge A: 1372: USDA-USFS-Rocky Mtn. Rsrch Station - CO: Vulnerability of the United States Water Supply System to Shortage: \$7,500

Roesner, Larry A: 1372: EPA - Environmental Protection Agency: SWMM Runoff Manual: \$24,997

Sanders, Thomas G: 1372: DOI-NPS-National Park Service: Preservation, Protection, & Management of Water Aquatic Resources of Units of the National Park System: \$126,600

Sanders, Thomas G: 1372: DOI-NPS-National Park Service: Preservation, Protection, & Management of Water Aquatic Resources of Units of the National Park System: \$446,700

Shaw, Robert B: 1490: USDA-USFS-Rocky Mtn. Rsrch Station - CO: Aquatic/Fisheries Technical Support for Fort Leonard Wood, Missouri: \$88,200

Shaw, Robert B: 1490: USDA-USFS-Rocky Mtn. Rsrch Station - CO: Clean Air, Dust Monitoring, and Safe Drinking Water Compliance Study, US Army Garrison, Hawaii: \$59,301

Shaw, Robert B: 1490: USDA-USFS-Rocky Mtn. Rsrch Station - CO: Mitigation Wetland Monitoring and Clean Water Act Section 404 Support for Fort Drum, New York: \$34,650

Theobald, David M: 1499: USDA-USFS-Forest Research: Western Riparian Threats Assessment: \$40,000

Thornton, Christopher I: 1372: FEMA-Federal Emergency Management Agency: Improvement of Regression Equations for Analysis of Embankment Dam Breaching: \$163,513

Wohl, Ellen E: 1482: USDA-USFS-Rocky Mtn. Rsrch Station - CO: National Riparian Protocol Development: \$117,500

Yang, Chih Ted: 1372: DOD-ARMY-Corps of Engineers: Lewis & Clark Reservoir Sedimentation Study: \$214,645

*Research awards from institutions of higher education in Colorado other than Colorado State University are provided by self-report of the Principal Investigator. If you have water related research awards to report, send them to cwri.colostate.edu

CALENDAR

Dec. 8	National Groundwater Association Expo. Las Vegas, NV. For more information go to http://www.ngwa.org/expo2006/main.cfm
Dec. 13-15	Colorado River Water Users Association 61st Annual Conference. Las Vegas, NV. For more information visit http://www.crwua.com/
2007	2007
Jan. 11-12	5th Annual National Salinity Conference. San Diego, CA. For more information go to http://wrrri.nmsu.edu/conf/confsymp.html
Jan. 22-23	American Water Resources Association Third National Water Resources Policy Dialogue. Arlington, VA. For more information, go to http://www.awra.org/meetings/DC2007/index.html .
Jan. 25-26	Colorado Water Congress 49 th Annual Convention. Denver, CO. For more information go to: www.cowatercongress.org , or phone 303/837-0812, or email macravey@cowatercongress.org .
Jan. 27	Water Resources Archive Water Tables 2007. Fort Collins, CO. For more information please visit http://lib.colostate.edu/develop/events/watertables07/index.html
Jan. 28-Feb. 1	USDA-CSREES National Water Conference: Research, Extension and Education for Water Quality and Quantity. Savannah, GA. For more information go to http://www.soil.ncsu.edu/swetc/waterconf/2007/home07.htm
Feb. 1	Big Thompson Watershed Forum presents: Our Watershed's Vital Signs 9th Annual Meeting & Symposium. Fort Collins, CO. For more information and to register, visit www.btwatershed.org or call (970)613-6166

CALENDAR - CONTINUED

March 19-21	AGU Hydrology Days 2007. Fort Collins, CO. For more information and to register please visit http://HydrologyDays.ColoState.edu/
May 22-24	Colorado Water Workshop: A Watershed Wide Look at Colorado River Controversies. Gunnison, CO. For more information please contact Peter Lavigne (Director Colorado Water Workshop) at plavigne@western.edu or pete@igc.org . Contact by phone: 970-641-2579
June 6-9	USCID Second Conference on SCADA and Related Technologies for Irrigation System Modernization. Denver, CO. For more information visit http://www.uscid.org/
June 24-26	2007 UCOWR/NIWR Conference: Hazards in Water Resources. Boise, ID. For more information visit http://www.ucowr.siu.edu .
June 25-27	SWRA Summer Specialty Conference: Emerging Contaminants of Concern in the Environment: Issues, Investigations, and Solutions, Vail, CO. For more information go to http://www.awra.org/meetings/Vail2007/index.html
Sep. 30 to Oct. 5	Fourth International Conference on Irrigation and Drainage: Role of Irrigation and Drainage in a Sustainable Future. Sacramento, CA. for more information go to http://www.uscid.org/

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